PROADAPTA
Adaptação à Mudança do Clima

MINISTÉRIO DA INFRAESTRUTURA

SERVIÇOS DE CONSULTORIA:

Contratação de serviços de consultoria para o levantamento de impactos e riscos climáticos sobre a infraestrutura federal de transporte terrestres (rodoviário e ferroviário) existente e projetada

PRODUTO 6 - MEDIDAS DE ADAPTAÇÃO

Setembro de 2022

Consultoria: Associação GITEC/COPPE

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AbE	Adaptação baseada em Ecossistemas
AR5	*IPCC Fifth Assessment Report* (em português, Quinto Relatório de Avaliação do IPCC)
AR6	*IPCC Sixth Assessment Report* (em português, Sexto Relatório de Avaliação do IPCC)
BID	Banco Interamericano de Desenvolvimento
BIM	*Building Information Modeling*
BIRD	Banco Internacional para Reconstrução e Desenvolvimento
CBI	*Climate Bond Initiative*
CEMADEN	Centro Nacional de Monitoramento e Alertas de Desastres Naturais
CENAD	Centro Nacional de Gerenciamento de Riscos e Desastres
CGEE	Centro de Gestão e Estudos Estratégicos
DER/DF	Departamento de Estradas de Rodagem do Distrito Federal
DNIT	Departamento Nacional de Infraestrutura de Transportes
FI	Fator de Impacto
FWD	*Falling Weight Deflectometer*
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit*
ICF	*International Climate Finance*
IDA	Índice de Desempenho Ambiental
IGG	Índice de Gravidade Global
IIED	*International Institute for Environment and Development*
INPE	Instituto Nacional de Pesquisas Espaciais
IoT	*Internet of Things*
IRI	*International Roughness Index*

IPCC	*Intergovernmental Panel on Climate Change* (em português, Painel Intergovernamental sobre Mudanças Climáticas)
IUCN	*International Union for Conservation of Nature's*
KPI	*Key Performance Indicators*
MCTI	Ministério da Ciência, Tecnologia e Inovações
MInfra	Ministério da Infraestrutura
MRV	Mensuração, Reporte e Verificação
MaaS	*Mobility as a Service*
OAE	Obras de Arte Especiais
OICS	Observatório de Inovação para Cidades Sustentáveis
PBMC	Painel Brasileiro de Mudanças Climáticas
PROADAPTA	Projeto Apoio ao Brasil na Implantação da Agenda Nacional de Adaptação à Mudança do Clima
S2iD	Sistema Integrado de Informações sobre Desastres
SAM	Sistema de Administração da Manutenção
SbN	Soluções baseadas na Natureza
SGO	Sistema de Gestão de Obras de Artes Especiais
TdR	Termo de Referência
TIC	Tecnologia de Informação e Comunicação
UNEP-WCMC	*United Nation Environmental Program - World Conservation Monitoring Centre*
UKSIP	*UK Sustainable Infrastructure Program*
VMA	Velocidade Máxima Autorizada

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- **Anexo II. Rede de conexão entre palavras-chave**
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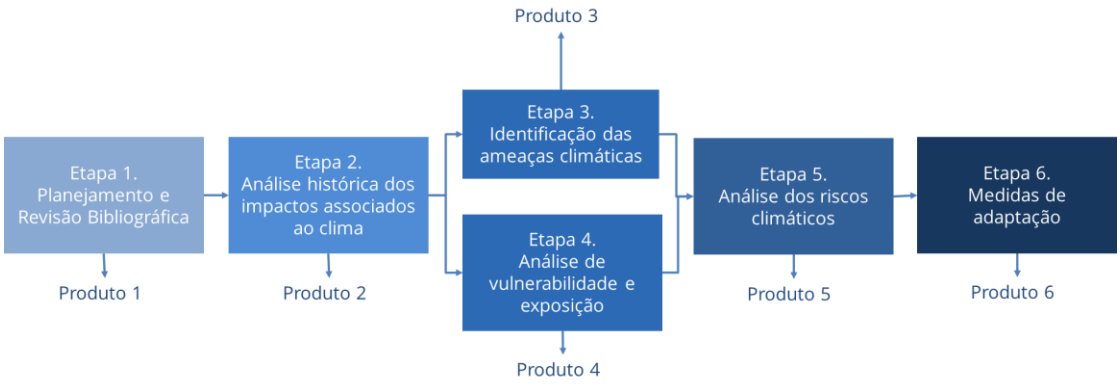
1. Introdução

O **Produto 6 - Medidas de adaptação** - consiste na etapa final do estudo "Levantamento de impactos e riscos climáticos sobre a infraestrutura federal de transporte terrestre (rodoviário e ferroviário) existente e projetada" (ou "Estudo AdaptaVias"), que tem como objetivo fornecer informações que sirvam como subsídio para o desenvolvimento de estratégias de adaptação à mudança do clima para o setor, no âmbito do Memorando de Entendimento celebrado entre o Ministério da Infraestrutura (MInfra) e a *Deutsche Gesellschaft fur Internationale Zusammenarbeit* (GIZ) GmbH no Brasil, que conta com o apoio do Ministério da Ciência, Tecnologia e Inovações (MCTI) e do Instituto Nacional de Pesquisas Espaciais (INPE), e é executado pela parceria formada entre a GITEC Brasil, GITEC-IGIP e o Programa de Engenharia de Transportes da COPPE/UFRJ, no Projeto "Apoio ao Brasil na Implantação da Agenda Nacional de Adaptação à Mudança do Clima - PROADAPTA".

A metodologia de desenvolvimento do Estudo AdaptaVias consistiu em seis etapas e para cada uma delas foram definidas atividades correspondentes, de acordo com as especificações apresentadas no Termo de Referência - TdR, e uma meta foi associada a cada etapa. As metas consistem na entrega dos produtos esperados para cada etapa, conforme apresentado na Figura 1.

Figura 1 - Fluxo metodológico das etapas e produtos associados.



Fonte: Elaboração própria (2022).

Mais especificamente na Etapa 6, são elencadas medidas de adaptação necessárias para reduzir os danos e prejuízos dos impactos (biofísicos ou diretos) da mudança do clima na infraestrutura de transporte terrestre, tendo como eixos centrais os principais impactos (biofísicos ou diretos) na infraestrutura, sendo analisados: (i) inundação, erosão, deslizamento, queimada e impactos diretos de altas temperaturas para a infraestrutura rodoviária; e (ii) erosão, deslizamento e impactos diretos de altas temperaturas para a infraestrutura ferroviária. Salienta-se que as medidas de adaptação apresentadas neste estudo não pretendem vincular-se a nenhum empreendimento específico e tampouco avaliar o mérito de quaisquer ações em andamento ou existentes.

Esta etapa almeja responder às seguintes questões norteadoras: (i) A partir de experiências nacionais e internacionais já documentadas, quais medidas de adaptação são recomendadas para a realidade brasileira, considerando as diversas fases do ciclo de vida dos ativos de infraestrutura de transporte terrestre? (ii) Como e quais dados são coletados atualmente e o que precisa ser aperfeiçoado nesse processo de coleta? e (iii) Quais são as orientações para empreendedores quanto à análise de risco climático nas infraestruturas de transportes terrestres no país?

2. Abordagem metodológica

Especificamente para a Etapa 6 - Medidas de Adaptação -, buscou-se desenvolver uma revisão bibliográfica sistemática e compreensiva, em âmbito nacional e internacional, sobre medidas de adaptação à mudança do clima para a infraestrutura de transporte terrestre - rodoviário e ferroviário (Produto 6). Destaca-se ainda que são elencadas tanto medidas não estruturais, ou também chamadas de *soft adaptation*, quanto medidas estruturais, ou também chamadas de *hard adaptation*. As medidas de adaptação incluem medidas para reduzir e/ou prevenir a exposição de componentes e da infraestrutura de transporte terrestre aos impactos da mudança do clima e gerenciar riscos residuais de modo a manter a operacionalidade/continuidade das atividades do sistema.

Atividades da **Etapa 6:**

6.1. Consolidação e detalhamento de revisão bibliográfica sobre medidas de adaptação à mudança do clima para a infraestrutura de transporte terrestre;

6.2. Levantamento de medidas de adaptação por tipo de impacto potencial;

6.3. Elaboração de diretrizes sobre as ameaças climáticas e medidas de adaptação identificadas;

6.4. Reunião virtual para apresentação e debate do Produto 6;

6.5. Entrega do Produto 6.

Vale ressaltar que o escopo deste trabalho não contempla a priorização das indicações das medidas de adaptação e nem estimativas de custos para a implementação de tais medidas, visto que o objetivo presente se trata de uma abordagem mais ampla sobre a temática de forma a apoiar uma tomada de decisão.

3. Protocolo de Revisão Bibliográfica Sistemática - Desenvolvimento do Repositório de Pesquisa

Com o crescente aumento (intensidade e frequência) das ameaças e dos impactos biofísicos decorrentes da mudança do clima, a necessidade de estudos sobre o tema é cada vez mais urgente (PICKETTS *et al.*, 2016; QUINN *et al.*, 2018; WANG *et al*, 2020; HÄNSEL *et al.*, 2022; ABREU *et al.*, 2022), se tornando uma agenda importante para os planejadores em todos os níveis do governo e da sociedade (SCHWEIKERT, 2015). A infraestrutura de transporte é particularmente vulnerável aos impactos de eventos climáticos extremos, pois é projetada para longas vidas operacionais, e as condições episódicas e sazonais contribuem para a deterioração, ocorrência de incidentes e consequente interrupção (PICKETTS *et al.*, 2016).

Portanto, esforços, ainda em fase de crescimento (WANG, 2019; 2020), têm sido empregados para identificar os impactos na infraestrutura de transporte terrestre, bem como determinar as melhores medidas de adaptação a eles, em diferentes localizações geográficas e regiões (HÄNSEL *et al.*, 2022). Entretanto, torna-se necessário realizar uma pesquisa rigorosa sobre os estudos para encontrar as

lições apreendidas e explorar os desafios de pesquisa proeminentes para mudar o foco da pesquisa para os tópicos emergentes mais relevantes (PICKETTS *et al.*, 2016; WANG *et al*, 2020).

Nesse sentido, este estudo realiza uma revisão abrangente sobre o tema adaptação climática, identificação de medidas de adaptação nos sistemas de transporte terrestres, com base em buscas diretas nas bases de dados do *Web of Science* e *Scopus* e buscas documentais em relatórios técnicos de instituições e iniciativas nacionais (por exemplo, o Painel Brasileiro de Mudanças Climáticas - PBMC e o Projeto AdaptaBrasil) e internacionais (por exemplo, o *Intergovernmental Panel on Climate Change* - IPCC, o *National Research Council* e o *World Bank Group*). Cabe destacar que esta pesquisa é complementar e está alinhada à revisão da literatura desenvolvida na Etapa 1 do Projeto AdaptaVias - Produto 1: Plano de Trabalho e Revisão Bibliográfica -, que consistiu no levantamento de dados e estudos existentes acerca dos impactos e riscos da mudança do clima na infraestrutura de transportes e na elaboração do repositório de pesquisa.

3.1 Rodoviário

O repositório de pesquisa sobre a adaptação da infraestrutura rodoviária aos impactos da mudança do clima englobou estudos obtidos pelas buscas diretas e documental, fazendo uso de palavras-chave relacionadas à mudança do clima como *'climate change'* e *'adaptation'* e palavras-chave referentes ao transporte rodoviário como *'road infrastructure'*, '*highway infrastructure'* e *'pavement'*. Cabe ressaltar que, assim como recomendado por WANG *et al.* (2020), a escolha das palavras-chave e suas combinações passou por um processo de *brainstorming*[1], que envolveu os pesquisadores da Equipe COPPE/UFRJ.

Dessa forma, com a exclusão dos estudos duplicados, foi realizada a aplicação dos critérios de inclusão (tais como preferência aos estudos mais atuais, publicados nos últimos 10 anos, enquadramento com o objetivo proposto e prestígio da fonte[2]) e qualificação (tais como os argumentos são expostos claramente e sem viés subjetivo? Há inovação técnica ou contribuição para o estado da arte? Busca averiguar os impactos da mudança do clima na infraestrutura rodoviária e não o inverso?)

Durante as buscas diretas e aplicação dos critérios de inclusão e qualificação foram obtidos 268 estudos do *Web of Science* e 288 estudos do *Scopu*s. Desses, foram retirados da base de dados 190 duplicados e outros 10 com a implementação dos filtros de qualidade. Dessa forma, o repositório final para o transporte rodoviário consta com 356 estudos. Além disso, foram obtidos mais 8 estudos por meio da busca documental. Com o repositório de pesquisa completo, de acordo com o exposto no ANEXO I - Repositórios de Pesquisa, é possível realizar algumas análises bibliométricas, conforme apresentado a seguir.

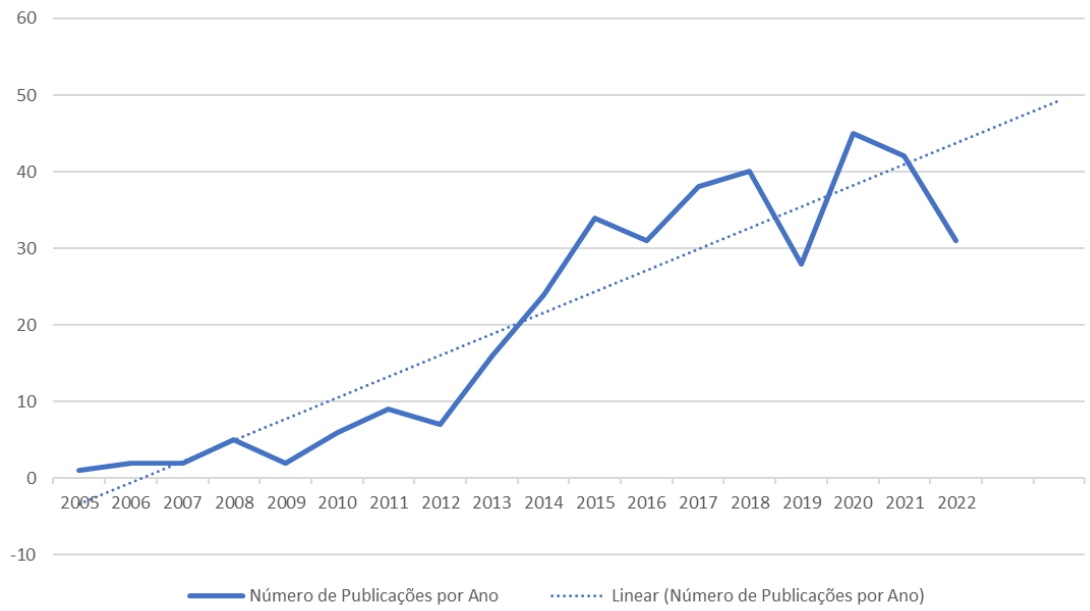
[1] O *brainstorming* ou tempestade de ideias, mais que uma técnica de dinâmica de grupo, é uma atividade desenvolvida para explorar a potencialidade criativa de um indivíduo ou de um grupo.

[2] Foram considerados artigos publicados em grandes periódicos científicos (que preferencialmente apresentam FI), estudos publicados em grandes congressos internacionais e relatórios técnicos de instituições e organismos renomados sobre a mudança climática e a infraestrutura de transporte.

A **pesquisa bibliométrica** busca realizar uma análise exploratória dos dados relacionados à temática em questão, mensurando a contribuição do conhecimento científico derivado das publicações e fornecendo embasamento para a elaboração e implementação de políticas públicas e novas pesquisas.

Nesse sentido, por meio da Figura 2, é possível identificar o crescimento das publicações sobre a temática ao longo dos anos. Nela, nota-se que o ano com maior número de publicações é 2020 (com 42 publicações - aproximadamente 13% do total), embora 2022, mesmo estando com apenas 7 meses completos de duração, já se encontra entre os anos com maiores números de estudos com 31 (aproximadamente 9% do total). Um destaque deve ser dado ainda ao fato de que a partir de 2014, com a publicação do Quinto Relatório de Avaliação (do inglês, *Fifth Assessment Report* - AR5) do IPCC, o IPCC (2014), o número de estudos sobre a temática cresceu significativamente, resultando em 88% da base de dados corresponde a estudos publicados a partir de 2014.

Figura 2 - Crescimento de publicações sobre temas combinados de adaptação e de infraestrutura rodoviária ao longo dos anos.



Fonte: Elaboração própria (2022).

Outro ponto que merece destaque é a identificação dos periódicos nos quais os estudos foram publicados. Isso porque quanto maior for a quantidade de estudos publicados em grandes periódicos internacionais (com elevado Fator de Impacto[3] - FI), que utilizam o processo de *blind review*, maior

[3] O Fator de Impacto avalia a importância e a reputação de periódicos científicos em suas respectivas áreas, consistindo em uma medida que reflete o número médio de citações de artigos científicos publicados em determinado periódico. Quanto maior o fator de impacto, mais bem classificada a revista é. Ou seja, o fator de impacto é apenas um cálculo que permite classificar as revistas em um ranking.

será a relevância da base de dados. Dessa forma, a Tabela 1 apresenta os periódicos com maiores quantitativos de publicações, com respectivos FI relativo ao ano de 2021 e o FI médio de 5 anos.

Tabela 1 - Periódicos com maior quantitativo de publicações sobre o tema combinado de adaptação e de infraestrutura rodoviária e respectivos Fatores de Impacto.

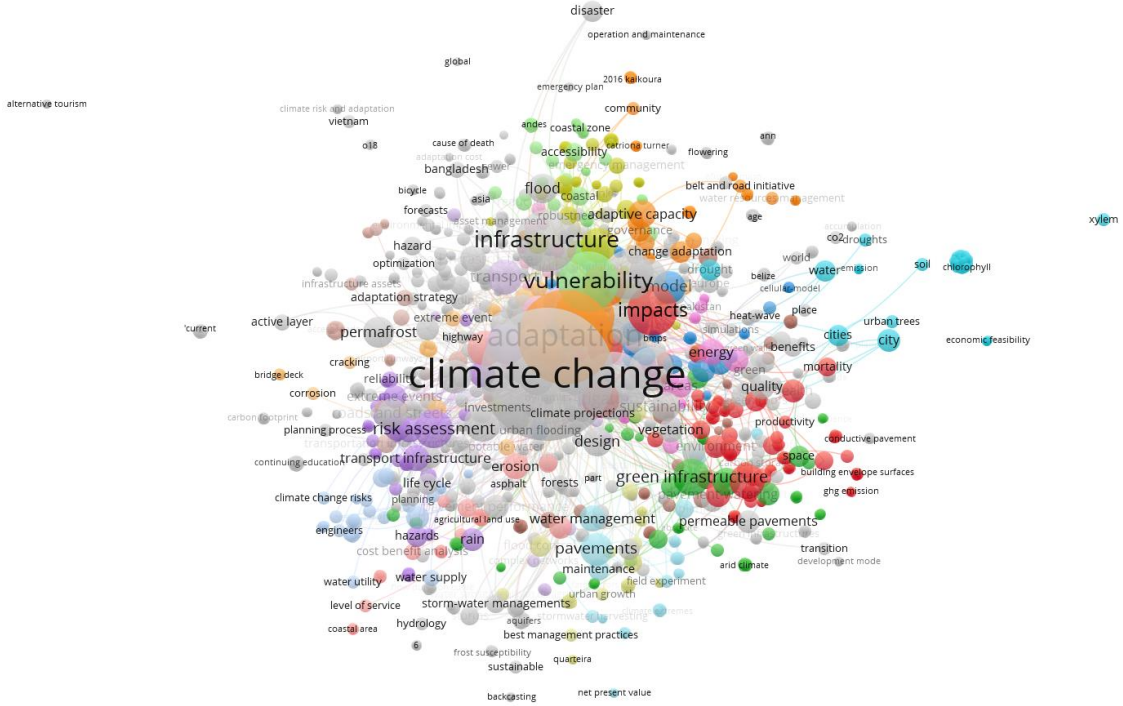
Periódico	Número de Publicações	FI (2021)	FI (Média em 5 anos)
Sustainability	17	3,889	4,089
Journal of Infrastructure Systems	11	3,462	3,095
Climatic Change	8	5,174	6,058
Transportation Research Record	8	2,019	2,005
Urban Climate	6	6,663	6,979
International Journal of Disaster Risk Reduction	6	4,842	5,213
Transportation Research Part D-Transport and Environment	5	7,041	7,624
Transport Policy	5	6,173	6,228
Urban Forestry & Urban Greening	5	5,766	6,463
Water	5	3,530	3,628
Natural Hazards	5	3,158	3,685

Fonte: Elaboração própria (2022).

Com a Tabela 1, nota-se que os periódicos que mais publicam sobre o assunto são o *Sustainability*, com aproximadamente 5% das publicações e o *Journal of Infrastructure Systems* com aproximadamente 3%; ambos com FI maior que 3,4 - que é uma pontuação alta em comparação a outros importantes periódicos internacionais. Cabe destacar a presença de renomados periódicos, tais como o *Transportation Research Part D - Transport And Environment* e o *Urban Climate*, que apresentam respectivamente FIs em 2021 iguais a 7,041 e 6,663. Além disso, destaca-se que na base de dados, ao todo, foram encontradas 239 fontes de publicação dos estudos (dentre periódicos, congressos, livros, dentre outros), o que mostra o grande interesse sobre a temática nos mais diversos periódicos, livros e congressos.

Pode-se ainda avaliar as principais palavras-chave encontradas nos estudos incluídos no repositório de pesquisa, identificadas na rede de interconexão entre palavras-chave mostrada na Figura 3, desenvolvida com o auxílio do Software VOSviewer, que constrói e visualiza redes bibliométricas.

Figura 3 - Rede de interconexão entre as principais palavras-chave sobre adaptação na infraestrutura rodoviária.



Fonte: Elaboração própria (2022).

A rede representada na Figura 3 é composta por 1.978 itens, 55 *clusters* e 23.877 links/conexões, da qual é possível identificar as palavras-chave mais utilizadas (de acordo com o tamanho da esfera sob sua representação) e as interconexões entre eles (de acordo com as conexões entre as esferas).

Nesse sentido, as palavras-chave mais recorrentes foram *'climate change'* (com 197 ocorrências), *'adaptation'* (com 101 ocorrências)', *'climate change adaptation'* (com 52 ocorrências'), *'infrastructure''* (com 43 ocorrências) e *'vulnerability'* (com 41 ocorrências). Cabe destacar outras palavras-chave, que embora menos recorrentes, também são de grande relevância para temática como aquelas relacionadas ao impacto biofísico sob investigação como '*floods'*, *'sea-level rise'* e *'erosion'* e aquelas relacionadas ao gerenciamento de risco como *'risk assessment'*, *'climate change risk'* e *'planning process'*.

Além disso, destaca-se a presença de medidas de adaptação já anunciadas nas próprias palavras-chave como *'green infrastructure'*, *'water management'*, *'permeable pavements'*, *'climate projections'*, *'governance'*, *'nature-based solutions'*, *'flexible pavement'* e *'computer simulation'*. Cabe salientar que, embora tenham sido apenas mencionadas, todas essas medidas de adaptação serão discutidas ao longo deste Produto.

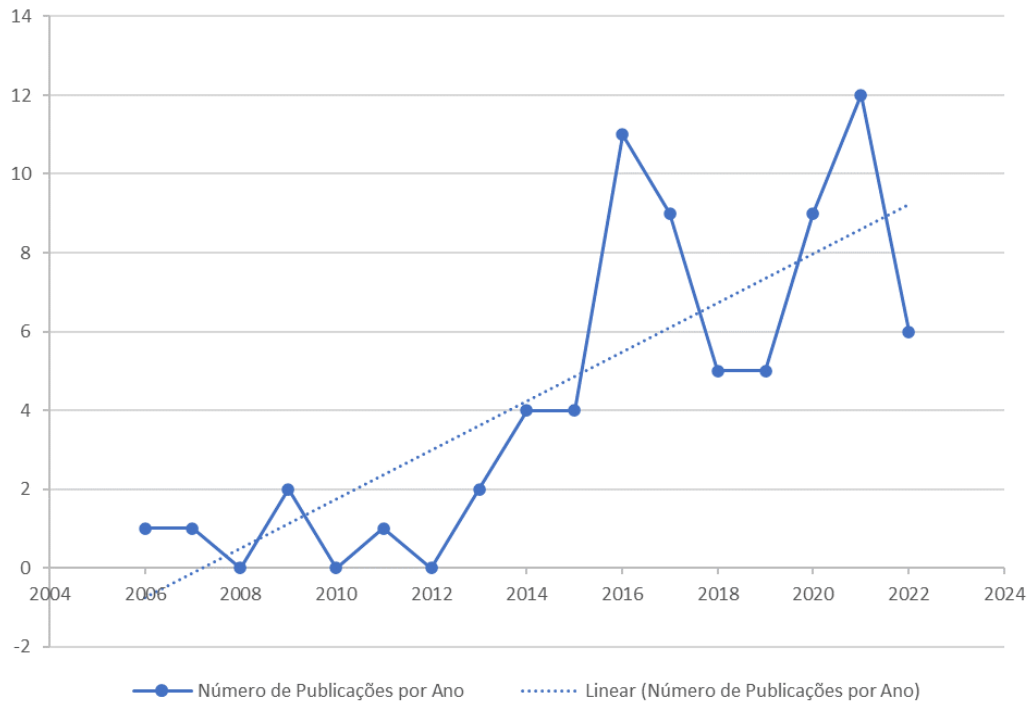
3.2 Ferroviário

Para criação do repositório de pesquisa sobre adaptação da infraestrutura ferroviária frente aos impactos da mudança do clima, foram realizadas buscas diretas utilizando uma combinação entre palavras-chave, assim como ocorrido no contexto da infraestrutura rodoviária. Nesse sentido, buscou-se combinar palavras-chave diretamente relacionadas à mudança do clima como '*climate change*' e *'adaptation*' e palavras-chave relacionadas à infraestrutura sob análise como '*railway infrastructure*' e '*railroad infrastructure*'.

Dessa forma, com a exclusão dos estudos duplicados e aplicação dos critérios de inclusão (tais como, preferência aos estudos mais atuais, publicados nos últimos 10 anos, enquadramento com o objetivo proposto e prestígio da fonte) e qualificação (tais como, os argumentos são expostos claramente e sem viés subjetivo? Há inovação técnica ou contribuição para o estado da arte? Busca averiguar os impactos da mudança do clima na infraestrutura ferroviária e não o inverso?) foram obtidos 61 estudos por meio das buscas diretas nas bases de dados do *Web of Science* e *Scopus*. Pelas buscas documentais, foram obtidos ainda mais 9 relatórios de importantes instituições. Dessa forma, o repositório final consiste em 70 estudos sobre adaptação no contexto da infraestrutura ferroviária.

Assim como realizado na Subseção 3.1, são feitas algumas análises bibliométricas a seguir. Quanto ao crescimento das publicações sobre a adaptação na infraestrutura ferroviária frente aos impactos da mudança do clima, a Figura 4 indica que o maior número de publicações foi identificado no ano de 2021, que corresponde a 17% do total de publicações sobre o assunto. Além disso, cabe destacar que, assim como identificado na análise sobre o transporte rodoviário, o número de publicações cresceu bastante a partir da publicação do AR5 - IPCC (2014) - representando 90% das publicações a partir de 2014.

Figura 4 - Crescimento de publicações sobre *temas combinados de* adaptação e infraestrutura ferroviária ao longo dos anos.



Fonte: Elaboração própria (2022).

Analisando a relevância dos estudos em função dos periódicos, a Tabela 2 mostra a predominância na publicação do assunto pelo *Climatic Change*, com 04 publicações, correspondendo a aproximadamente 6% das publicações e o *Transportation Research Part D - Transport and Environment*, com 3 publicações, aproximadamente 4%. Ambos são conceituados *journals* com FI superior a 5,1. Cabe ainda destacar a presença do *Science of The Total Environment*, que apresenta um FI superior a 10. Ao todo foram identificadas 52 fontes de publicação.

Tabela 2 - Publicações sobre adaptação e infraestrutura ferroviária por periódicos.

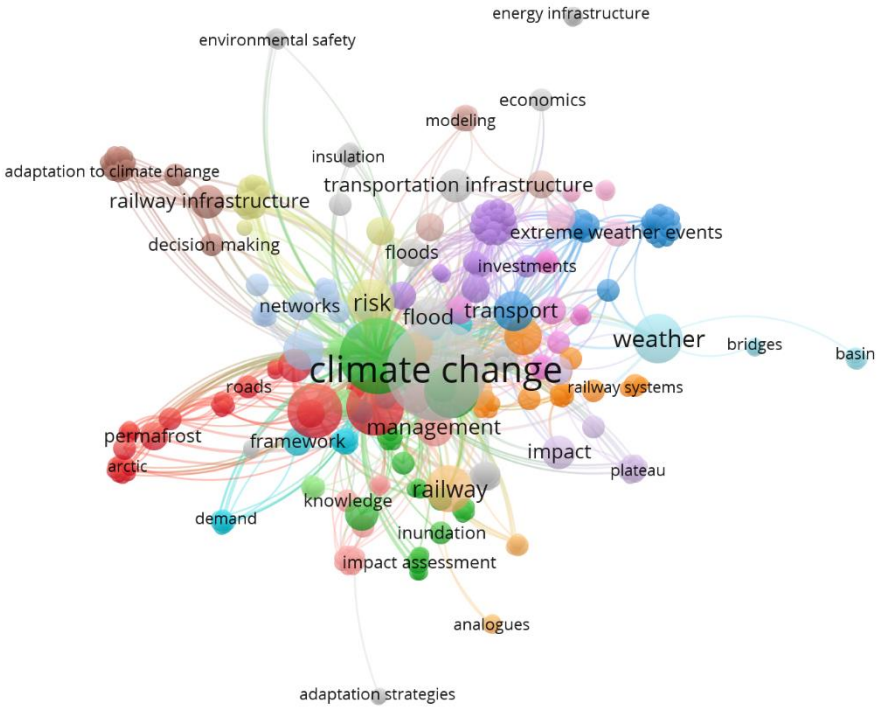
Periódico	Número de Publicações	FI (2021)	FI (Média em 5 anos)
Climatic Change	4	5,174	6,058
Transportation Research Part D-Transport and Environment	3	7,041	7,624
Science of The Total Environment	2	10,753	10,237
Journal of Transport Geography	2	5,899	6,524
Meteorological Applications	2	2,451	2,639

Proceedings of The Institution of Civil Engineers-Engineering Sustainability	2	1,368	1,521
European Journal of Transport and Infrastructure Research	2	1,244	2,109

Fonte: Elaboração própria (2022).

Cabe ainda destacar a rede de interligação entre as palavras-chave apresentada na Figura 5 composta por 389 itens, 24 *clusters* e 4.047 links/conexões. Essa estratégia permite aos pesquisadores encontrar mais facilmente estudos diretamente relacionados ao assunto investigado, bem como identificar novos rumos de pesquisa, determinando os fatores, dimensões-chave e áreas principais (ABREU, SANTOS & MONTEIRO, 2022). Cabe destacar que foi desenvolvido ANEXO 2 - Rede de conexão entre palavras-chave – com a inclusão das Figuras 3 e 5 em alta resolução.

Figura 5 - Rede de interconexão entre as principais palavras-chave sobre adaptação na infraestrutura ferroviária.



Fonte: Elaboração própria (2022).

Com a Figura 5, nota-se que, similar a rede de interligação sobre a infraestrutura rodoviária, as palavras-chave mais recorrentes foram *'climate change'* (com 36 ocorrências), *'adaptation'* (com 21 ocorrências), *'vulnerability'* (com 12 ocorrências), *'infrastructure'* (com 11 ocorrências) e *'resilience'* (também com 11 ocorrências). Cabe ainda a presença de outras palavras-chave importantes como

'adaptive management', *'assessment approaches'*, *'methodological frameworks'*, *'network security'* e *'architectural design'*.

4. Conjuntos de medidas de adaptação

A adaptação pode ser definida como: "processo de ajuste em sistemas naturais ou humanos em resposta a estímulos climáticos reais ou esperados e seus efeitos, que moderam ou evitam danos ou exploram oportunidades benéficas" (IPCC, 2007; 2014). A adaptação desempenha um papel fundamental na redução da exposição e vulnerabilidade à mudança do clima (IPCC, 2022a). A pesquisa de adaptação à mudança do clima tem sido um campo em crescimento, principalmente após a publicação do AR5 do IPCC (ABREU, SANTOS & MONTEIRO, 2022), pois cientistas e profissionais agora reconhecem que, mesmo com a mitigação, o planeta experimentará certos níveis inevitáveis de mudança do clima (IPCC, 2022a).

As medidas de adaptação podem ser tanto de natureza política, educacional e social, ou seja, adaptações não estruturais (do inglês, *soft adaptation*), quanto adaptações estruturais (do inglês, *hard adaptation*) (PALIN *et al.*, 2021; ABREU, SANTOS e MONTEIRO, 2022), devendo estar ligadas às práticas atuais e futuras de redução de riscos e iniciativas de gestão para aumentar a resiliência do transporte e reduzir os impactos de eventos climáticos extremos (SANTOS, RIBEIRO e ABREU, 2020). Além disso, essas alternativas e soluções de adaptação devem ser compatíveis e de forma combinadas com as estratégias de mitigação (ou seja, precisam ter sinergia) para evitar o aumento drástico das emissões de Gases de Efeito Estufa (GEE) (WANG *et al.*, 2020).

O AR6 (IPCC, 2022a; b) destaca claramente a necessidade de implementação de medidas estruturais e não estruturais que acarretem impactos positivos na adaptação e mitigação à mudança do clima em apoio à promoção do desenvolvimento sustentável em todas as nações, principalmente nos países em desenvolvimento que apresentam maiores restrições orçamentárias.

Como exemplo, pode ser mencionada a expansão urbana que interfere indiretamente nos processos climáticos, aumentando as emissões de GEE e a vulnerabilidade das cidades, o que prejudica o potencial de adaptação para ajustar sistemas e a sociedade para enfrentar os impactos da mudança do clima (IPCC, 2022b). Assim, uma variedade de formas de transportes de alta capacidade e rapidez (trens, metrôs*, Bus rapid transit*, dentre outros.) podem ser utilizadas como elementos estruturantes para o crescimento urbano, acarretando a mitigação das emissões e reduzindo os impactos da mudança do clima em novas infraestruturas, principalmente em áreas mais vulneráveis (Newman *et al*. 2017).

4.1 Soluções baseadas na Natureza

Soluções baseadas na Natureza (SbN, ou *Nature-based Solutions* - NbS, em inglês), um termo de ampla definição que, assim como diversos outros na área da sustentabilidade, tratam de conceitos já conhecidos porém com outra abordagem, consistem em "ações para proteger, gerenciar de forma sustentável e restaurar ecossistemas naturais ou modificados, que abordam os desafios da sociedade

de forma eficaz e adaptativa, proporcionando simultaneamente benefícios para o bem-estar humano e a biodiversidade" (CEBDS, 2021).

As SbN são uma abordagem da engenharia que busca trabalhar com a natureza, protegendo a biodiversidade e assegurando o fluxo de serviços que apoiam o bem-estar humano. O Sexto Relatório de Avaliação do IPCC (IPCC, 2022a) reforça que SbN são cruciais para apoiar no enfrentamento da mudança do clima, e afirma que essas soluções "fornecem benefícios de adaptação e mitigação para a mudança do clima, além de contribuir para outros objetivos de desenvolvimento sustentável".

As SbN funcionam bem em contextos rurais e são mais eficazes quando combinadas com as opções tradicionais de infraestrutura. As chamadas soluções híbridas (que integram a infraestrutura verde junto à infraestrutura cinza, por exemplo) podem apresentar menor custo inicial, implementação mais rápida, melhor sustentabilidade a longo prazo e menor custo de manutenção. As comunidades locais devem fazer parte da solução para projetar e implementar a SbN no setor rodoviário e ferroviário (FRAGA, 2020).

Contudo, nem toda infraestrutura sustentável ou cujo funcionamento envolve processos naturais é uma SbN. Sistemas naturais podem realmente ajudar a proteger os investimentos em infraestrutura cinza diretamente relacionada à Adaptação baseada em Ecossistemas (AbE) ou *Ecosystem-based Adaptation* (EbA), em inglês, que pode ser definida como o uso da biodiversidade e dos serviços ecossistêmicos, como parte de uma estratégia geral de adaptação, para ajudar as pessoas a se adaptarem aos efeitos adversos da mudança do clima (CONVENTION OF BIOLOGICAL DIVERSITY, 2009).

Uma AbE eficaz reduz uma série de riscos de mudança do clima para pessoas, biodiversidade e serviços ecossistêmicos com múltiplos co-benefícios (alta confiança[4]). A adaptação baseada no ecossistema é vulnerável aos impactos da mudança do clima, com a sua eficácia diminuindo com o prosseguimento do aquecimento global (alta confiança). O esverdeamento urbano usando árvores e outras vegetações pode proporcionar resfriamento local (confiança muita alta) (IPCC, 2022a).

Ainda, de acordo com o IPCC (2022a) sistemas fluviais naturais, áreas úmidas e ecossistemas florestais a montante reduzem o risco de inundações, armazenando e retardando o fluxo de água, na maioria das circunstâncias (alta confiança). As zonas úmidas costeiras protegem contra a erosão costeira e inundações associadas a tempestades e ao aumento do nível do mar, onde há espaço suficiente e habitats adequados até que as taxas de elevação do nível do mar excedam a capacidade adaptativa natural de construir sedimentos (confiança muito alta).

A adaptação baseada em ecossistemas — um subconjunto de abordagens baseadas na natureza para ajudar as pessoas a se adaptarem às mudanças climáticas — é uma estratégia cada vez mais utilizada. Segundo estudo realizado pelo IIED, juntamente com a União Internacional para Conservação da Natureza (*International Union for Conservation of Nature* - IUCN, sigla em Inglês) e o Centro de

[4] Cada conclusão do IPCC (2022a) é baseada na avaliação de evidências e acordos. O nível de confiança é expresso utilizando cinco qualificadores: muito baixo, baixo, médio, alto e muito alto.

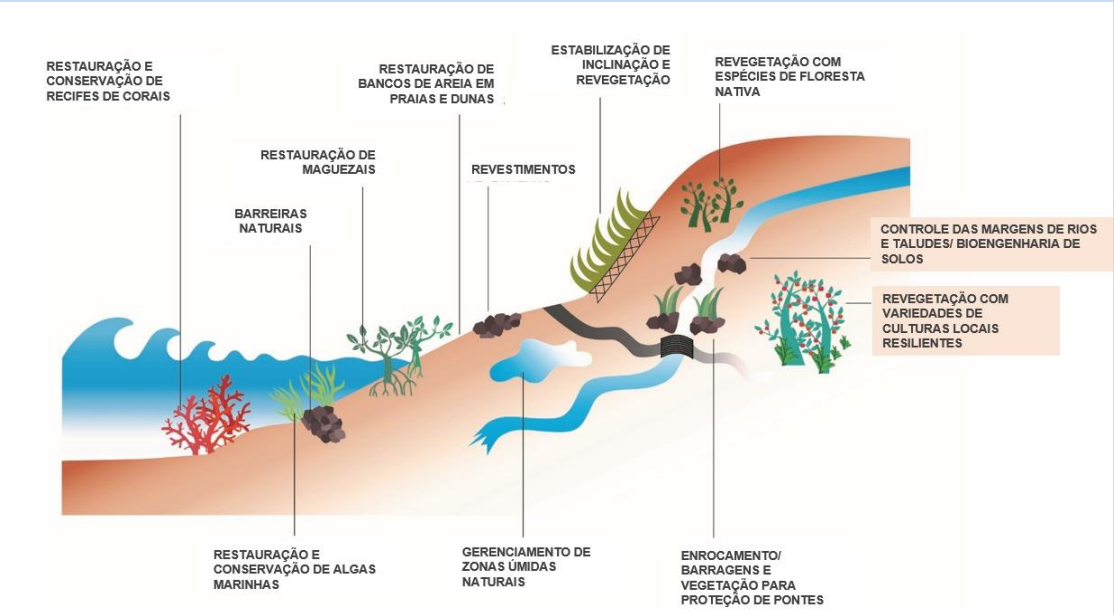
Monitoramento e Conservação Mundial (World Conservation Monitoring Centre) do Programa das Nações Unidas para o Meio Ambiente (UNEP-WCMC), existem evidências de 13 iniciativas em 12 países que mostram que a AbE pode fornecer benefícios importantes, de longo alcance e de longo prazo relacionados à adaptação, ao meio ambiente e às questões sociais (IIED, 2019).

Box 1 - Soluções baseadas na Natureza (SbN) e Adaptação baseada em Ecossistemas (AbE).

Soluções baseadas na natureza, conforme exemplo exposto na Figura 6, são soluções inspiradas e apoiadas pela natureza que proporcionam simultaneamente benefícios ambientais, sociais e econômicos. Um exemplo de Soluções baseadas na Natureza (SbN), — Adaptação baseada em Ecossistemas (AbE) — pode gerar retornos sociais e econômicos e fornecer múltiplos benefícios, incluindo melhoria da saúde, proteção da biodiversidade, segurança alimentar e oportunidades alternativas de subsistência. As SbN são parte de uma gama de abordagens para adaptação que têm a natureza como elemento central. O ponto fundamental em ações ou medidas de AbE é a utilização de ecossistemas e os benefícios que estes trazem para o bem-estar humano como base para a adaptação à mudança do clima. Outro ponto é que a AbE é uma abordagem antropogênica, ou seja, o foco são os problemas socioeconômicos como ponto de partida, e as atividades humanas para sua solução, considerando os ecossistemas e seus serviços como parte de um plano ou planejamento para resolver tais problemas. As ações relacionadas à AbE têm como objetivo reduzir a vulnerabilidade das pessoas à mudança do clima e aumentar a resiliência através da recuperação, do uso sustentável e da conservação dos ecossistemas.

Cabe destacar que a AbE reduz a sensibilidade biofísica do sistema estudado e influencia menos na sensibilidade da própria infraestrutura. A abordagem pressupõe que ecossistemas bem gerenciados podem atuar como infraestrutura natural e amortecedora, reduzindo a exposição física a muitas ameaças e diminuindo a sensibilidade do sistema. Mas, além de oferecer uma oportunidade para fortalecer a infraestrutura verde e a resiliência humana contra os impactos de risco, o gerenciamento de ecossistemas também gera uma série de outros benefícios sociais, econômicos e ambientais para várias partes interessadas (FUNDAÇÃO GRUPO BOTICÁRIO & ICLEI, 2015).

Figura 6 - Soluções Baseadas na Natureza e Adaptação baseada nos ecossistemas.



Fonte: Adaptada de World Bank (2021).

O Brasil está avançando nos estudos e na agenda de implementação de projetos de SbN. O Observatório de Inovação para Cidades Sustentáveis (OICS) do Centro de Gestão e Estudos Estratégicos (CGEE) lançou em 2022 o primeiro Catálogo Brasileiro de Soluções baseadas na Natureza (OICS, [s.d]).

Cabe ainda destacar que muitas SbN podem representar esforços de adaptação/mitigação (IPCC, 2022a), porque por meio de medidas como "Instalação de proteção suave que inclui barreiras naturais de sedimentação e florestas, além de zonas úmidas que criam uma zona de amortecimento" podem acarretar diminuição dos impactos de inundações na infraestrutura rodoviária, como também mitigação das emissões de GEE - florestas podem remover o carbono da atmosfera e armazená-lo.

A Gestão de Riscos de Desastres deve ser incorporada ao planejamento dos transportes terrestres, por autoridades rodoviárias e ferroviárias. É necessário integrar intervenções de adaptação como SbN com foco em como proporcionar maior resiliência em projetos existentes e futuros. A gestão de políticas que integram essas soluções precisa adotar uma abordagem mais holística e coordenar com diversos atores, incluindo setores como gestão da água, agências rodoviárias e ferroviárias, especialistas ambientais e engenheiros, responsáveis por manutenção, e populações locais.

Os impactos da mudança do clima devem ser considerados em todas as fases do planejamento e projeto da infraestrutura de transporte, redefinindo assim a mudança do clima de uma tensão 'anormal' para uma tensão 'normal' que é prontamente incorporada nos processos de planejamento atuais e futuros (SCHWEIKERT, 2015). Nesse sentido, devido à incerteza de alto nível em relação à futura mudança do clima, o planejamento da adaptação é encorajado a ser robusto (WANG *et al.*, 2020). Além disso, devem ser implementadas medidas de manutenção e monitoramento das condições da infraestrutura de transporte, bem como aplicadas ações corretivas, quando necessárias, para aumentar a resiliência e a robustez dessas infraestruturas (ANDERSSON-SKÖLD *et al.*, 2021). Cabe destacar que a resiliência descreve não apenas a capacidade de manter a função, identidade e estrutura essenciais, mas também a capacidade de transformação (IPCC, 2022a).

Além disso, de maneira a otimizar todo o processo (aumentar a relação custo-efetividade), podem ser implementadas medidas de adaptação que também podem ajudar a reduzir as emissões de Gases de Efeito Estufa (GEE). Nesse sentido, tomadores de decisão de todo o mundo têm examinado oportunidades para esforços combinados de adaptação e mitigação (IPCC, 2022a; b).

4.2. Medidas de adaptação não estruturais

Os impactos da mudança do clima estão adicionando problemas potencialmente agravantes aos desafios existentes, trazendo tensões não planejadas a redes que já estão se degradando; mesmo sem considerações sobre a mudança do clima, a questão da qualidade, quantidade, planejamento, financiamento, operações e manutenção da infraestrutura é um desafio contínuo para os planejadores locais, estaduais e nacionais (SCHWEIKERT, 2015; VAL *et al.*, 2019).

Portanto, apesar de um crescente apelo para incorporar uma perspectiva mais holística e de longo prazo no planejamento de infraestrutura, devido, por exemplo, a limitações na modelagem, informação e disponibilidade de dados, a maioria dos projetos não consegue integrar uma série de fatores críticos do ciclo de vida das infraestruturas, incluindo abastecimento de água e energia, gestão de esgoto, sistemas de comunicação e transportes (KWIATKOWSKI *et al.*, 2013).

Dessa forma, diversos artigos científicos, relatórios técnicos de importantes instituições, e iniciativas pública e privada tem se empenhado em identificar quais são as medidas de adaptação com potencial para tornar a infraestrutura de transporte terrestre (rodoviário e ferroviário) mais resiliente aos impactos da mudança do clima. Nesse contexto, as medidas de adaptação designadas pelo Estudo AdaptaVias de não-estruturais ou de não-engenharia, englobam políticas, alocações de uso do solo, educação e envolvimento social (ABREU, SANTOS e MONTEIRO, 2022), conforme lista apresentada no Quadro 1.

Cabe destacar que se optou por unificar as medidas de adaptação não estruturais do transporte rodoviário (que, conforme já mencionado, é mais trabalhado na literatura científica) e do ferroviário porque acredita-se que quase a totalidade delas podem ser implementadas nos dois casos, sendo ainda muitas delas aplicadas a outros modos de transporte.

Quadro 1 - Medidas de Adaptação não-estruturais para o setor de transporte terrestre.

Medidas de Adaptação	**Fonte**
Incorporação de cláusulas de adaptação ao investimento nacional em infraestrutura de transporte	DTTAS (2019); PALIN *et al.* (2021)
Mudanças nas normas rodoviárias e ferroviárias e nas políticas de gestão de ativos (de forma a promover a adaptação)	PALIN *et al.* (2021); ANDERSSON-SKÖLD *et al.* (2021)
Desenvolvimento de um Plano de Contingência Integrado, incorporando o sistema de transporte como um todo	CENTRO CLIMA (2016); PALIN *et al.* (2021); HÄNSEL *et al.* (2022)
Promoção de maior envolvimento do setor de transportes nas questões de adaptação à mudança do clima, através de capacitação e disseminação de informações	MMA (2015)
Fortalecimento das estruturas organizacionais e a coordenação horizontal e vertical	CENTRO CLIMA (2016)
Estabelecimento de mecanismos de financiamento contínuo para apoiar a estrutura de planejamento, coordenação, avaliação e monitoramento da adaptação com a ajuda do ponto focal institucional	CENTRO CLIMA (2016)

Medidas de Adaptação	**Fonte**
Elaboração de estudos e pesquisas sobre a relação da mudança do clima com a vulnerabilidade da infraestrutura de transportes, visando subsidiar as políticas públicas, o planejamento e a identificação de soluções para o setor	MMA (2015); PALIN *et al.* (2021)
Reforço, centralidade e transparência à informação sobre o histórico de monitoramento e manutenção das infraestruturas de transporte	CENTRO CLIMA (2016)
Análise de incentivos fiscais ou fundos flexíveis de adaptação	CENTRO CLIMA (2016)
Rápida recuperação - isto é, o gerente de infraestrutura precisa ter capacidade disponível para fornecer uma resposta oportuna e eficaz para reestabelecer a infraestrutura e, assim, os serviços. Isto pode incluir intervenções temporárias, tais como barreiras de inundação portáteis para controlar e limitar os danos à infraestrutura e acelerar a recuperação	PALIN *et al.* (2021)
Avaliação da possibilidade de existência de co-benefícios e sinergias entre mitigação e adaptação relacionadas às diferentes alternativas aplicadas ao setor de transportes (por exemplo, a promoção do modo ferroviário é mais favorável tanto para a adaptação, quanto para a mitigação) (**)	MMA (2015); ABREU, SANTOS e MONTEIRO (2022)
Proibição do desenvolvimento (construção ou expansão da infraestrutura) em áreas de vulnerabilidade ambiental, reconhecendo o custo inerente de construção em áreas propensas aos riscos (*)	CENTRO CLIMA (2015); VAJJARAPU, VERMA, e HEMANTHINI (2018); NAZARNIA *et al.* (2020); SUTP (2021)
Realização de uma revisão intermediária dos planos estatutários de adaptação da infraestrutura crítica com possíveis contribuições de atores relevantes	DTTAS (2019)
Melhoria da gestão de risco, identificando infraestruturas críticas (*hotspots*)	ZIMMERMAN e FARIS (2010); CENTRO CLIMA (2015); MMA (2015); STAMOS; MITSAKIS; GRAU (2015); FRASER, BERNATCHEZ e DUGAS (2017); WANG *et al.* (2018); PALIN *et al.* (2021); ANDERSSON-SKÖLD *et al.* (2021); HÄNSEL *et al.* (2022)
Avaliação dos materiais utilizados, identificando se eles estão nos padrões para suportar o aumento na frequência dos eventos de precipitação intensa e altas temperaturas	CENTRO CLIMA (2015); ABREU, SANTOS e MONTEIRO (2022)

Medidas de Adaptação	**Fonte**
considerando os possíveis cenários climáticos de curto, médio e longo prazo	
Incentivo à utilização de novas tecnologias, como sistemas de drenagem sustentáveis, que reduzirá os riscos de inundações existentes e futuros (*)	URS (2010); PALIN *et al.* (2021)
Participação, engajamento e apoio das partes interessadas - incentivar o envolvimento das partes interessadas com as necessidades de adaptação ao clima e construção de resiliência	BOLLINGER *et al.*, (2014); CENTRO CLIMA (2016); DTTAS (2019); SUTP (2021); GARMABAKI *et al.* (2021); PALIN *et al.* (2021); ANDERSSON-SKÖLD *et al.* (2021)
Criação de abordagens de adaptação dinâmicas, evitando a predominância de soluções que se prendem a caminhos únicos ou cursos de ação irreversíveis	ZIMMERMAN e FARIS (2010); SUTP (2021)
Divulgação de Relatório de Progresso sobre a Implementação de Medidas de Adaptação de Transporte para representantes ou defensores da acessibilidade e demais setores interessados	FRASER, BERNATCHEZ e DUGAS (2017); DTTAS (2019)
Aumento da consciência pública e a capacidade de agir em situações de perigo	ZIMMERMAN e FARIS (2010)
Disseminar mapas de impacto de distribuição geoespacial para as partes interessadas em transporte	DTTAS (2019)
Fortalecimento das respostas de adaptação setorial, garantindo que a resiliência climática seja considerada nas orientações de avaliação	CENTRO CLIMA (2016); DTTAS (2019)
Estabelecimento de parcerias público-privadas para a implementação da adaptação e resiliência	CENTRO CLIMA (2016)
Integração efetiva dos transportes com outros setores no processo de planejamento e desenvolvimento por meio, por exemplo, da Avaliação Ambiental Estratégica (**)	DTTAS (2019)
Revisão da eficácia dos procedimentos atuais de coleta de dados quantitativos para os impactos de eventos climáticos extremos e mudança do clima de longo prazo, com o objetivo de desenvolver um mecanismo de relatório intersetorial	DTTAS (2019); ANDERSSON-SKÖLD *et al.* (2021)

Medidas de Adaptação	**Fonte**
Garantia da compreensão setorial de informações climáticas atualizadas, incluindo um resumo de observação de resultados de modelagem climática de longo prazo	DTTAS (2019)
Revisão periódica dos mapas de risco climático	ADB (2012); CHAPMAN (2014); QUINN *et al.* (2018); WANG *et al.* (2018); PALIN *et al.* (2021)
Inspeção mais frequente e aprimorada dos locais afetados	URS (2010); SUTP (2021)
Desenvolvimento de indicadores de monitoramento apropriados para avaliar a eficácia das medidas de adaptação	DTTAS (2019); PALIN *et al.* (2021)
Planejamento do uso da terra pautado no desenvolvimento sustentável, incluindo o Desenvolvimento Orientado ao Transporte Sustentável (DOTS) (*)	CHAPMAN (2014); FRASER, BERNATCHEZ e DUGAS (2017); NAZARNIA *et al.* (2020); ABREU, SANTOS e MONTEIRO (2022)
Melhoria do planejamento espacial integrado em relação aos alinhamentos de estradas e ferrovias para garantir que os ecossistemas críticos adjacentes, que servem como amortecedores contra inundações, erosões, aumentos de temperaturas, dentre outros., sejam mantidos e protegidos (Ex.: Adaptação baseada em ecossistemas) (*) (**)	ADB (2012); KOETSE e RIETVELD (2012); PALIN *et al.* (2021)
Melhoria na capacidade de previsão do tempo e implementação de sistemas de alerta precoce	CENTRO CLIMA (2015); SUTP (2021); PALIN *et al.* (2021)
Incorporação da sistematização das informações históricas de danos causados por eventos climáticos, especificando o tipo de evento e impacto biofísico decorrente. Além disso, devem ser considerados os impactos econômicos e o desempenho da infraestrutura	CENTRO CLIMA (2016); ARMSTRONG, PRESTON e HOOD (2016); FRASER, BERNATCHEZ e DUGAS (2017); ANDERSSON-SKÖLD *et al.* (2021); HÄNSEL *et al.* (2022)
Identificação de necessidades de treinamento sobre avaliação de danos, seleção de respostas, análise de custo-benefício e elaboração de planos e projeto	CENTRO CLIMA (2016); ARMSTRONG, PRESTON e HOOD (2016)
Sistematização de informação sobre o comportamento das infraestruturas estratégicas de transporte em situações climáticas adversas, centralizando-as numa base de dados única	CENTRO CLIMA (2016); FRASER, BERNATCHEZ e DUGAS (2017)
Avaliação das condições futuras com o objetivo de projetar e priorizar as medidas de adaptação que não tenham efeitos contraproducentes, considerando a complementação das metodologias com ferramentas mais orientadas para o futuro	QUINN *et al.* (2018)

Medidas de Adaptação	**Fonte**
Análise sistemática da redução de riscos combinada com os custos associados à implementação das medidas de adaptação	WANG *et al.* (2018)
Aumento da capacidade de resposta do setor de transportes frente aos eventos climáticos extremos por meio de planos, protocolos de ação e medidas preventivas	MMA (2015); PALIN *et al.* (2021)
Definição de funções na geração e identificação de dados necessários, especificando instrumentos e coleta de dados e armazenando e mantendo em bancos de dados	CENTRO CLIMA (2016); FRASER, BERNATCHEZ e DUGAS (2017)
Aprimoramento da produção e disponibilização de informações sobre eventos extremos relacionados ao sistema de transporte	MMA (2015); PALIN *et al.* (2021)
Contribuição na divulgação de dados entre academia, grupos de pesquisa, governos nacionais e internacionais	CENTRO CLIMA (2016); FRASER, BERNATCHEZ e DUGAS (2017)
Realização de um amplo estudo sobre o padrão histórico de desgaste da infraestrutura, identificando riscos para a integridade estrutural e funcional decorrentes da ocorrência e intensificação de eventos climáticos extremos	CENTRO CLIMA (2016); ARMSTRONG, PRESTON e HOOD (2016)
Desenvolvimento de técnicas de modelagem e simulação para representar e analisar os complexos conjuntos de interações desencadeadas por ameaças climáticas	BOLLINGER *et al.* (2014); ARMSTRONG, PRESTON e HOOD (2016)
Elaboração de Protocolo de Gestão de Recuperação, Reabilitação e Reconstrução de infraestrutura (Ex. novo código de obras)	CENTRO CLIMA (2016)
Priorização de obras corretivas para os locais avaliados como de maior risco de falha ou interrupção do serviço	URS (2010)
Aumento da resiliência na fase de renovação de ativos	URS (2010); SUTP (2021)
Aprimoramento da capacidade adaptativa de maneiras expansíveis, modificáveis e amplamente diversas	ZIMMERMAN e FARIS (2010)
Criar regulamentação de restrição de carga nas rodovias, melhorar o sistema de pesagem e monitoramento do peso	CENTRO CLIMA (2015)
Encorajamento do transporte de carga pesada a viajar no período noturno quando a temperatura ambiente é menor, afetando menos o asfalto	CENTRO CLIMA (2015)

Medidas de Adaptação	**Fonte**
Projeto e investimento em novos ativos com capacidade de "restauração rápida"	STAMOS; MITSAKIS e GRAU (2015)
Consulta e coordenação de autoridades rodoviárias, subcontratados, fornecedores e principais interessados para ajustar as estratégias de adaptação	STAMOS; MITSAKIS e GRAU (2015)
Integração de diferentes tipos de bancos de dados de monitoramento de ativos, havendo de preferência uma certa padronização entre eles	KAUFMAN *et al.* (2012); STAMOS; MITSAKIS e GRAU (2015); FRASER, BERNATCHEZ e DUGAS (2017)
Planejamento e preparação de emergências com brigada de incêndio e demais serviços de emergência; praticar planos de emergência para eventos climáticos severos	KAUFMAN *et al.* (2012); STAMOS; MITSAKIS e GRAU (2015)
Incentivo à logística reversa para que os resíduos não atuem como barreiras às drenagens naturais, que acabam influenciando no fluxo de água, provocando alagamentos em vias de transporte	FUNDAÇÃO GRUPO BOTICÁRIO & ICLEI (2014)
Pesquisa de novas técnicas e materiais adequados ao desgaste reduzido, de modo a incorporá-lo em cartilhas de instrução e normas técnicas de construção	CENTRO CLIMA (2016); CALDAS *et al.* (2021)
Instituição de regulamentação de redução da velocidade máxima	CENTRO CLIMA (2015)
Incentivo às novas tecnologias de pneus que causem menos atrito ao pavimento	CENTRO CLIMA (2015)
Análise dos potenciais níveis futuros de temperatura e a resistência do pavimento ao uso.	CENTRO CLIMA (2016)

Nota: (*) Refere-se à Soluções baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação

Fonte: Elaboração própria (2022).

Destaca-se que a adaptação regulamentar e/ou baseada em políticas ("soft") que contribui para a melhoria da gestão, comunicação e resposta a eventos extremos dentro e entre organizações é extremamente valiosa e é um passo em direção à adaptação "transformacional". Além disso, as medidas de adaptação não estruturais também podem ser "menos regressivas" do que as intervenções duras, ou mesmo "sem regressão" - podendo oferecer um equilíbrio positivo de custo-benefício, independentemente da mudança do clima que for realizada (PALIN *et al.*, 2021).

4.3. Medidas de adaptação estruturais

A variabilidade atual do clima representa um desafio para a infraestrutura e as operações do setor de transporte (WANG *et al.*, 2019). A infraestrutura que mantém a função sob estresse climático de longo prazo ou de eventos intensos, pode afetar a capacidade dos sistemas de transporte de resistir, responder e se recuperar desses eventos (SCHWEIKERT, 2015). Nesse contexto, as próximas subseções (Subseção 4.3.1 e 4.3.2) buscam identificar medidas de adaptação estruturais que podem ser implementadas para aumentar a resiliência do transporte rodoviário e ferroviário. Destaca-se que para o transporte rodoviário são estudadas medidas para cinco impactos distintos (sendo eles, inundação, erosão, deslizamento, queimada e impactos diretos devido às altas temperaturas) e para o transporte ferroviário identificam-se estratégias para três impactos (sendo eles, erosão, deslizamento e impactos diretos devido às altas temperaturas).

4.3.1. Rodoviário

O setor de transporte rodoviário é um dos que mais sofre com os impactos da mudança do clima em sua infraestrutura e operação, sendo necessária uma resposta urgente dos tomadores de decisão para aumentar sua resiliência. Nesse sentido, esta seção serve a esse propósito ao elencar medidas de adaptação que possam ser adotadas para reduzir os impactos de inundações, erosões, deslizamentos, queimadas e impactos diretos por altas temperaturas na infraestrutura rodoviária, com foco em medidas de adaptação duras, ou seja, estruturais, também chamadas no estudo AdaptaVias de medidas de engenharia.

4.3.1.1. Inundação

Os eventos de inundação tornaram-se um impacto biofísico frequente nos últimos anos em decorrência principalmente da ocorrência de episódios de precipitação intensa, constituindo um dos desastres naturais mais graves e potencialmente devastadores, causando não apenas grandes perturbações físicas nos recursos hídricos, mas também perdas significativas de vidas e danos à infraestrutura. Para o setor de transporte rodoviário, essa realidade é indiscutível, pois eventos severos de inundação tendem a danificar a infraestrutura de transporte e reduzir a conectividade da rede, aumentando os custos de reparo, manutenção e construção (ABREU *et al.*, 2022). Desta forma, apresentam-se no Quadro 2 algumas medidas de adaptação estruturais para a infraestrutura rodoviária.

Quadro 2 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura rodoviária quanto aos impactos de inundação.

Medidas de Adaptação	**Fonte**
Utilização de novas misturas asfálticas - pavimento permeável - que auxiliam na drenagem mais rápida de água parada	MATTHEWS (2011); STAMOS; MITSAKIS e GRAU (2015)

Medidas de Adaptação	**Fonte**
Construção de infraestrutura redundante[5]	STAMOS; MITSAKIS e GRAU (2015); VAJJARAPU, VERMA, e HEMANTHINI (2018); SUTP (2021)
Adaptação dos padrões de construção para os novos eventos climáticos	CENTRO CLIMA (2015)
Instalação de tecnologia de desaguamento *WellPoint* para uso permanente - aumento da capacidade de desaguamento	NAZARNIA *et al.* (2020); ANDERSSON-SKÖLD *et al.* (2021)
Instalação de proteção rígida que fornece uma barricada contra a entrada de água	ADB (2012); KOETSE e RIETVELD (2012); CENTRO CLIMA (2015; NAZARNIA *et al.* (2020); ANDERSSON-SKÖLD *et al.* (2021)
Instalação de proteção suave que inclui barreiras naturais de sedimentação e florestas, além de zonas úmidas que criam uma zona de amortecimento (*) (**)	DTTAS (2019); NAZARNIA *et al.* (2020); ANDERSSON-SKÖLD *et al.* (2021)
Realização de plantio de vegetação ao longo das vias para diminuir a exposição das rodovias à inundação (*) (**)	BOLLINGER *et al.* (2014); STAMOS; MITSAKIS e GRAU (2015); CENTRO CLIMA (2015); DTTAS (2019); ANDERSSON-SKÖLD *et al.* (2021)
Modificação dos padrões de drenagem (*) (**)	BOLLINGER *et al.* (2014)
Alteração da composição do subsolo (*) (**)	BOLLINGER *et al.* (2014)
Elevação e proteção da sinalização e outros equipamentos elétricos	SUTP (2021)
Aumento da redundância em sistemas elétricos	SUTP (2021)
Melhoria na manutenção de Obras de Arte Correntes, por exemplo, de drenos e bueiros	CHAPMAN (2014); CENTRO CLIMA (2015); STAMOS; MITSAKIS e GRAU (2015);

[5] A infraestrutura redundante busca incluir capacidade adicional ou alternativa para permitir que os serviços continuem em operação mesmo que o ativo de infraestrutura seja incapaz de operar.

Medidas de Adaptação	**Fonte**
	ANDERSSON-SKÖLD *et al.* (2021)
Aumento da limpeza e a manutenção das estradas e rodovias e seus arredores	CENTRO CLIMA (2015)
Melhoria da gestão nas planícies de inundação (*) (**)	CENTRO CLIMA (2015)
Melhoria das condições de monitoramento do subleito, especialmente após grandes chuvas	CENTRO CLIMA (2015)
Aumento da capacidade do sistema de drenagem de águas pluviais (*)	ZIMMERMAN e FARIS (2010); ADB (2012); CENTRO CLIMA (2015); NAZARNIA *et al.* (2020)
Aumento do número de estações ou da capacidade de bombeamento nas rodovias	NAZARNIA *et al.* (2020); CENTRO CLIMA (2015); SUTP (2021); ANDERSSON-SKÖLD *et al.* (2021)
Bombeamento adicional em túneis	NATIONAL RESEARCH COUNCIL (2008); STAMOS; MITSAKIS e GRAU (2015); ANDERSSON-SKÖLD *et al.* (2021)
Aumento da altura das pontes para permitir o transporte em níveis de água mais altos	KOETSE e RIETVELD (2012)
Substituição da superfície da estrada impermeável por material permeável em áreas vulneráveis (*)	VAJJARAPU, VERMA e HEMANTHINI (2018)
Atualização do revestimento de túnel para evitar a infiltração de águas subterrâneas	SUTP (2021)
Redesenho, realocação, ou até mesmo abandono de estradas críticas localizadas em zonas de inundação	ADB (2012), LÖWE *et al.* (2017); NAZARNIA *et al.* (2020)
Elevação da infraestrutura rodoviária	STAMOS; MITSAKIS e GRAU (2015); SUTP (2021)
Instalação de drenagem melhorada nas interseções	GERMAN DEVELOPMENT COOPERATION (2009);

Medidas de Adaptação	Fonte
	STAMOS; MITSAKIS e GRAU (2015)
Instalação de reforço das barreiras e diques existentes	NATIONAL RESEARCH COUNCIL (2008); STAMOS; MITSAKIS e GRAU (2015)
Melhoria nas defesas contra inundações em casos de elevação do nível do mar	NATIONAL RESEARCH COUNCIL (2008); CHAPMAN (2014); STAMOS, MITSAKIS e GRAU (2015)
Utilização de barreiras móveis para evitar que a água entre em túneis e sistemas de trânsito subterrâneo	SUTP (2021)
Criação de acomodações que dizem respeito à redução da gravidade dos danos, como elevação e modificação de infraestruturas para reduzir o impacto das inundações	NAZARNIA *et al.* (2020)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.1.2. Erosão

O aumento da precipitação, bem como a frequência e magnitude das inundações, acelera a erosão, - que produz a desagregação dos materiais, já influenciados pelos processos de intemperismo químico e/ou físico - de estradas, rodovias e pontes e as torna mais vulneráveis as falhas (ALMEIDA e MOSTAFAVI, 2016). Nesse sentido, embora sejam menos investigadas na literatura que as estratégias para redução dos impactos de inundações (ABREU, SANTOS e MONTEIRO, 2022), torna-se fundamental determinar medidas de adaptação que podem ser implementadas para melhorar a resiliência da infraestrutura rodoviária às erosões, conforme apresentado no Quadro 3.

Cabe destacar que muitas dessas medidas podem ser implementadas tanto para reduzir as erosões, quanto às inundações, uma vez que problemas de drenagem estão diretamente relacionados a esses dois impactos biofísicos. Além disso, a erosão amplia a probabilidade de deslizamentos, que será discutido na Subseção 4.3.1.3, e depende de vários fatores adicionais (por exemplo, altura e inclinação do talude, características de resistência das camadas do solo, nível do lençol freático, pressão da água dos poros e carga) (ANDERSSON-SKÖLD *et al.*, 2014).

Quadro 3 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura rodoviária quanto aos impactos de erosão.

Estratégias de Adaptação	**Fonte**
Utilização de materiais de melhor qualidade e resistentes à erosão	CENTRO CLIMA (2015)
Realização de plantio de vegetação ao longo das vias para diminuir a exposição das rodovias à erosão (*) (**)	CENTRO CLIMA (2015)
Instalação mais frequente de proteção dura contra erosão (cascalho e pedra, blocos de concreto, gabiões e estacas de aço ou madeira)	ANDERSSON-SKÖLD *et al.* (2021)
Instalação de proteção suave contra erosão (grama, capim, árvores e arbustos, esteiras de coco ou geotêxtil com vegetação, planta morta material) (*) (**)	ANDERSSON-SKÖLD *et al.* (2021)
Prevenção combinada da erosão (revestimentos com vegetação, blocos de concreto com vegetação, estacas de madeira com vegetação, toras, paredes de toras ou madeira morta, dentre outros) (*) (**)	ANDERSSON-SKÖLD *et al.* (2021)
Desenvolvimento de túneis de drenagem embaixo de grandes estradas para facilitar a drenagem de forma mais rápida	CENTRO CLIMA (2015)
Desenvolvimento e implementação de métodos aprimorados de detecção de erosão do subleito	SUTP (2021)
Inspeção mais frequente e aprimorada dos locais afetados	SUTP (2021); ANDERSSON-SKÖLD *et al.* (2021)
Manutenção/recuperação de áreas de mangues que atuam como dissipadores de energia em regiões costeiras, mantendo a linha de costa (*) (**)	FUNDAÇÃO GRUPO BOTICÁRIO e ICLEI (2014)
Realização de monitoramento e manutenção regulares de estradas e rodovias	CENTRO CLIMA (2015)
Monitoramento da condição do solo das estradas existentes (*) (**)	CENTRO CLIMA (2015)

Estratégias de Adaptação	**Fonte**
Melhoria da infraestrutura de drenagem (bueiros) para ser capaz de lidar com os eventos intensos de precipitação	CENTRO CLIMA (2015)
Aumento da limpeza e a manutenção das estradas e seus arredores	CENTRO CLIMA (2015)
Ajuste da frequência de inspeção e manutenção devido aos riscos	CENTRO CLIMA (2016)
Ajuste na frequência de manutenção e limpeza periódica da rede de drenagem próxima a rodovias e vias estruturantes	CENTRO CLIMA (2016)
Implementação de medidas de controle de erosão nas margens de rodovias	SUTP (2021)
Melhoria das fundações	CENTRO CLIMA (2015)
Aumento na frequência de correção de sulcos/afundamentos no pavimento (*mill out ruts*)	CENTRO CLIMA (2015)
Para erosão induzida por ondas, construção de novas barreiras ou melhoria de quebra-mares e paredões existentes	SUTP (2021)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.1.3. Deslizamento

Os deslizamentos de solo e rocha são outros problemas que a infraestrutura rodoviária enfrenta para manter sua operação. Este impacto biofísico, intensificado por precipitação intensa, é capaz de causar interrupções parciais ou totais de estradas e rodovias, quanto acarretar danos menos intensivos (queda de árvores, por exemplo) ou mais críticos (como ruptura do corpo estradal). Nesse sentido, o Quadro 4 apresenta medidas de adaptação que podem ser implementadas para reduzir os impactos de deslizamentos, que envolvem tanto estratégias para melhorar a drenagem das rodovias, como estratégias para estabilizar encostas.

Quadro 4 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura rodoviária quanto aos impactos de deslizamento.

Estratégias de Adaptação	**Fonte**
Recuperação/conservação de encostas próximas a rodovias (*) (**)	FUNDAÇÃO GRUPO BOTICÁRIO e ICLEI (2014)
Instalação de paredes de retenção modernas, que são estruturas embutidas flexíveis que mobilizam a força do solo para proporcionar estabilidade	PALIN *et al.* (2021)
Realização de plantio de vegetação ao longo das vias para diminuir a exposição das rodovias ao deslizamento de solo e rocha (*) (**)	CENTRO CLIMA (2015)
Desenvolvimento de túneis de drenagem embaixo de grandes estradas e rodovias para facilitar a drenagem de forma mais rápida	CENTRO CLIMA (2015)
Melhoria da infraestrutura de drenagem (bueiros) para ser capaz de lidar com os eventos intensos de chuvas	CENTRO CLIMA (2015)
Aumento na manutenção frequente da infraestrutura de drenagem	SUTP (2021)
Aumento da limpeza e a manutenção das estradas e seus arredores	CENTRO CLIMA (2015)
Ajuste da frequência de inspeção e manutenção devido aos riscos	CENTRO CLIMA (2016)
Manutenção e limpeza periódica da rede de drenagem próxima a rodovias e estações ferroviárias, estações de metrô e vias estruturantes	CENTRO CLIMA (2016)
Estabilização de encostas usando estruturas de suporte físico (por exemplo, vários tipos de muros de contenção) e reforço vegetativo (*) (**)	SUTP (2021); ANDERSSON-SKÖLD *et al.* (2021)
Redução das encostas íngremes para um ângulo mais seguro e raso	SUTP (2021)

Estratégias de Adaptação	Fonte
Remoção da camada superficial do aterro com risco de deslizamento (*)	ANDERSSON-SKÖLD *et al.* (2021)
Redução ou restrição da pressão dos poros do solo	ANDERSSON-SKÖLD *et al.* (2021)
Melhoria na drenagem do declive e do subsolo	SUTP (2021)
Introdução de agentes ligantes hidráulicos no material de terraplenagem	SUTP (2021)
Aumento da implantação de medidas de proteção contra deslizamentos de encostas nas proximidades do corpo estradal e plataforma ferroviária	NATIONAL RESEARCH COUNCIL (2008); STAMOS; MITSAKIS e; GRAU (2015)
Reforço das barreiras e diques existentes	NATIONAL RESEARCH COUNCIL (2008); STAMOS; MITSAKIS e GRAU (2015)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.1.4. Queimadas

Outro impacto biofísico cada vez mais recorrente nas rodovias são as queimadas/incêndios, que embora sejam majoritariamente associados às ações antrópicas (lançamento de pontas de cigarro, lançamento de balões e incêndios criminosos, por exemplo), podem também estar atreladas à mudança do clima, devido às altas temperaturas e condições de seca (aumento da temperatura causa evaporação, e quanto mais seco o ambiente mais rápido o fogo se espalha) (ANDERSSON-SKÖLD *et al.*, 2021).

As queimadas não só provocam prejuízo ambiental e risco de acidentes, como também apresentam impacto significativo na infraestrutura rodoviária. Estes impactos podem acarretar mudança da paisagem, alteração física e química do solo e perda da vegetação local que intensificam outros impactos como erosões e deslizamentos, além da perda sem precedentes da biodiversidade nas áreas atingidas. Nesse sentido, embora sejam pouco investigadas na literatura (ABREU, SANTOS e MONTEIRO, 2022), são necessárias medidas de adaptação, que envolvam principalmente a utilização de materiais resistentes ao calor (UNEP, 2021), de acordo com o Quadro 5.

Quadro 5 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura rodoviária quanto aos impactos de queimada.

Estratégias de Adaptação	**Fonte**
Desenvolvimento de projeto de novas misturas asfálticas resistentes ao calor	NATIONAL RESEARCH COUNCIL (2008); GERMAN DEVELOPMENT COOPERATION (2009); STAMOS; MITSAKIS e GRAU (2015); CALDAS *et al.* (2021); UNEP (2021)
Instalação de juntas de ponte mais resistentes ao calor	SCHWARTZ (2010); STAMOS; MITSAKIS; GRAU (2015)
Aplicação de regimes de inspeção e manutenção aprimorados	SUTP (2021); ANDERSSON-SKÖLD *et al.* (2021)
Ajuste da frequência de inspeção e manutenção devido aos riscos	CENTRO CLIMA (2016)
Aumento na frequência da correção dos sulcos/afundamentos no pavimento (*mill out ruts*)	CENTRO CLIMA (2015)
Substituição mais frequente do concreto por asfalto de alta resistência quando houver necessidade (trincamentos/ rupturas/ *blows out*)	CENTRO CLIMA (2015)
Restauração da capacidade de suporte das camadas da sub-base e base da estrada, principalmente após a ocorrência de eventos extremos	ANDERSSON-SKÖLD *et al.* (2021)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.1.5. Impactos diretos devido às altas temperaturas

Os impactos diretos das altas temperaturas na infraestrutura rodoviária também precisam ser destacados como um dos principais problemas intensificados pela mudança do clima. Isso porque as ondas de calor podem causar mudanças na infraestrutura rodoviária, ocasionando migração de asfalto líquido ou exsudação[6] (do inglês, *bleeding*) e desmoronamento (perda de pedras) na

[6] Quando a temperatura está elevada, o asfalto se dilata e os ligantes, devido a dificuldade de ocupar espaços vazios ou por estarem em excesso, migram para a superfície do pavimento.

superfície das estradas e rodovias (LAWSON e SENADHEERA, 2009; ANDERSSON-SKÖLD *et al.*, 2021). Dessa forma, apresentam-se algumas medidas de adaptação no Quadro 6 para minimização desses impactos.

Quadro 6 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura rodoviária quanto aos impactos diretos de altas temperaturas.

Estratégias de Adaptação	**Fonte**
Uso de materiais mais resistentes ao calor, tais como: (i) ligantes mais resistentes e ambientalmente seguros; (ii) pavimento com percentagens mais elevadas de enchimento; (iii) pavimento do tipo *cheap seal*; (iv) utilização de diferentes materiais para aumentar a refletância do pavimento, diminuindo sua temperatura; e (v) requisitos mais elevados para os tipos de agregados, visando aumentar o atrito interno.	CENTRO CLIMA (2015); SUTP (2021); ABREU, SANTOS e MONTEIRO (2022)
Construção de infraestrutura redundante	SUTP (2021)
Realização de obras de construção em dias mais frios – agendar as obras para estações do ano mais propícias	CENTRO CLIMA (2015)
Desenvolvimento de projetos de novas misturas asfálticas resistentes ao calor	NATIONAL RESEARCH COUNCIL (2008); GERMAN DEVELOPMENT COOPERATION (2009); STAMOS; MITSAKIS e GRAU (2015)
Juntas de ponte mais resistentes ao calor	SCHWARTZ (2010); STAMOS; MITSAKIS e GRAU (2015)
Ajuste das rotinas de monitoramento e manutenção regulares de estradas e rodovias	CENTRO CLIMA (2015)
Monitoramento digital que avise quando as juntas de pontes se tornarem muito densas ou a necessidade de substituir os materiais por outros mais resistentes ao calor	ANDERSSON-SKÖLD *et al.* (2021)
Ajuste das rotinas de monitoramento e manutenção regulares de equipamentos elétricos	SUTP (2021)
Realização de monitoramento da condição do solo das estradas e rodovias existentes	CENTRO CLIMA (2015)

Estratégias de Adaptação	Fonte
Realização de plantio de vegetação ao longo das vias para diminuir a exposição das rodovias ao calor (*) (**)	GERMAN DEVELOPMENT COOPERATION (2009); CENTRO CLIMA (2015); SUTP (2021)
Ajuste da frequência de inspeção e manutenção devido aos riscos	CENTRO CLIMA (2016)
Ajuste da frequência de correção dos sulcos/afundamentos no pavimento (*mill out ruts*)	CENTRO CLIMA (2015)
Adicionamento de agregado de diferentes tamanhos de grão no asfalto em caso de exsudação para reduzir o escorregamento	LAWSON e SENADHEERA (2009); ANDERSSON-SKÖLD *et al.* (2021)
Aumento do resfriamento do asfalto com água em dias quentes	LAWSON e SENADHEERA (2009); ANDERSSON-SKÖLD *et al.* (2021)
Substituição do revestimento asfáltico danificado por outro revestimento composto por materiais mais resistentes ao calor	LAWSON e SENADHEERA (2009); ANDERSSON-SKÖLD *et al.* (2021)
Substituição de equipamentos elétricos existentes por equipamentos que possam suportar temperaturas mais altas	SUTP (2021)
Intervenções de reforço com materiais com maior resistência ao calor e capacidade de suporte	CENTRO CLIMA (2015)
Substituição mais frequente do concreto por asfalto de alta resistência quando houver necessidade (trincamentos/ rupturas/ *blows out*)	CENTRO CLIMA (2015)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.2. Ferroviário

O transporte ferroviário é vulnerável às ameaças climáticas como precipitação intensa e altas temperaturas e a seus impactos biofísicos atrelados como erosão e deslizamento, existindo

consequências extremas para a sua infraestrutura (trilhos, pontes, túneis, sistemas de drenagem, terraplenagem, dentre outros) e o nível aceitável de serviços para manter operações seguras (Wang *et al.*, 2018). Portanto, existe a necessidade de implementar medidas de adaptação eficazes e eficientes, conforme descritas nas próximas subseções, para controlar ou reduzir os impactos da mudança do clima como erosão do leito dos trilhos, entupimento do sistema de drenagem, flambagem de trilhos, ruptura de fundações de pontes, dentre outros, que resultam em custos altos (ANDERSSON-SKÖLD *et al.*, 2021; GARMABAKI *et al.*, 2021).

4.3.2.1. Erosão

A erosão, que, conforme já indicado anteriormente, tem relação direta com a alta precipitação e episódios de inundação, também é um dos impactos biofísicos que mais acarretam danos na infraestrutura ferroviária, podendo causar desguarnecimento de lastro, problemas na estabilidade das pontes ferroviárias, obstrução de sistemas de drenagem, colapso de estruturas, dentre outros impactos significativos (WANG *et al.*, 2018). Dessa forma, o Quadro 7 apresenta sugestões de medidas de adaptação que possam subsidiar os tomadores de decisão.

Quadro 7 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura ferroviária quanto aos impactos de erosão.

Estratégias de Adaptação	**Fonte**
Cobertura vegetal e estruturas radiculares para proteger contra a erosão do solo (*) (**)	DAVIES; FRANDSEN e HOCKRIDGE (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)
Proporcionar redundância dentro do sistema (*)	PALIN *et al.* (2021)
Instalação mais frequente de proteção dura contra erosão (cascalho e pedra, blocos de concreto, gabiões e estacas de aço ou madeira)	ANDERSSON-SKÖLD *et al.* (2021)
Instalação de proteção suave contra erosão (grama, capim, arbustos e árvores, esteiras de coco ou geotêxtil com vegetação, planta morta material) (*)(**)	ANDERSSON-SKÖLD *et al.* (2021)
Prevenção combinada da erosão (revestimentos com vegetação, blocos de concreto com vegetação, estacas de madeira com vegetação, toras, paredes de toras ou madeira morta, dentre outros) (*)(**)	ANDERSSON-SKÖLD *et al.* (2021)
Realização de monitoramento e manutenção regulares da via e do leito da via	KOETSE e RIETVELD (2012); GARMABAKI et al (2021)

Estratégias de Adaptação	Fonte
Uso de musgo e líquens para controle de erosão (*)(**)	WEI; YU e CHEN (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)
Estabilização biotécnica (*) para aprimorar estruturas de engenharia cinza (**)	PIERSON; WOOD e DRIEDGER (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.2.2. Deslizamento

Deslizamentos de solo e rochas, figuram como um dos impactos biofísicos mais relevantes nas ferrovias, são principalmente desencadeados por eventos de precipitação intensos em curto intervalo de tempo e/ou em dias consecutivos de chuva (WANG *et al.*, 2018). Esses impactos biofísicos podem causar uma série de danos em elementos da infraestrutura ferroviária, como, entre outros, instabilidade de encostas, obstrução do sistema de drenagem, flambagem de trilhos ou até o colapso da plataforma. Dessa forma, é importante destacar as medidas de adaptação como as listadas no Quadro 8.

Quadro 8 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura ferroviária quanto aos impactos de deslizamento.

Estratégias de Adaptação	Fonte
Instalação de paredes de retenção modernas, que são estruturas embutidas flexíveis que mobilizam a força do solo para proporcionar estabilidade	PALIN *et al.* (2021)
Reengenharia de taludes para modificar seu grau de inclinação, melhorar a drenagem ou proporcionar estabilização	SMETHURST *et al.*, (2017); PALIN *et al.* (2021)
Gerenciamento da vegetação para melhorar a estabilidade da inclinação dos taludes (*)(**)	PALIN *et al.* (2021)
Plantio de “florestas de proteção” (*)(**)	DOLL *et al.* (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)
Inclusão de redundância dentro do sistema	PALIN *et al.* (2021)

Estratégias de Adaptação	Fonte
Manutenção e melhoria das zonas úmidas naturais (*)(**)	SUTHERLAND *et al.* (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)
Adequação do monitoramento e manutenção regulares da via e do leito da via	KOETSE e RIETVELD (2012); SMETHURST *et al.*, (2017); GARMABAKI *et al* (2021)
Detecção de eventos por monitoramento local de taludes com sensores	PALIN *et al.* (2021)
Aumento das atividades de estabilização de taludes, incluindo a instalação de paredes de gabiões, pregos de solo e estacas-prancha	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022); ANDERSSON-SKÖLD *et al.* (2021)
Melhoramento de drenagem, aparafusamento/ancoramento de rochas, redirecionamento	PALIN *et al.* (2021)
Adequação da instalação de drenos de contraforte em taludes e reforma de drenos de crista	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022)
Estabilização biotécnica (*) para aprimorar estruturas de engenharia cinza (**)	PIERSON; WOOD e DRIEDGER (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

4.3.2.3. Impactos diretos devido às altas temperaturas

Além dos impactos tratados anteriormente, as ondas de calor afetam as ferrovias e suas estruturas de apoio (ANDERSSON-SKÖLD *et al.*, 2021). O calor extremo provoca a expansão da linha férrea de aço, levando a um risco de flambagem do trilho (empenamento), causando não apenas restrições de velocidade (em um contexto mais ameno), mas, até mesmo, comprometendo o uso da via, causando uma interrupção generalizada (PALIN *et al.*, 2021). O Quadro 9 apresenta possíveis medidas de adaptação de forma a subsidiar a tomada de decisão.

Quadro 9 - Medidas de Adaptação estruturais para aumentar a resiliência da infraestrutura ferroviária quanto aos impactos diretos devido às altas temperaturas.

Estratégias de Adaptação	**Fonte**
Alteração do procedimento de instalação do trilho para aumentar o limite de temperatura para a expansão térmica	MARTEAUX (2016); NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022)
Compra, instalação e manutenção dos sensores de temperatura da ferrovia e infraestrutura de software relacionada	NEUMANN *et al.* (2021)
Instalação de proteção contra sol para desviar o calor (plantio de árvores ou outras formas de cobertura, pintura de trilhos, dentre outros)	NETWORK RAIL (2020b); BLACKWOOD; RENAUD e GILLESPIE (2022)
Manejo da vegetação ao longo do corredor ferroviário, incluindo seleção de vegetação adequada (*) (**)	LINDGREN; JONSSON e CARLSSON-KANYAMA (2009); DOLL *et al.* (2014); BLACKWOOD; RENAUD e GILLESPIE (2022)
Proporcionar redundância dentro do sistema	PALIN *et al.* (2021)
Realização de pinturas dos trilhos de branco em áreas de alto risco conhecido de expansão térmica sob luz solar direta	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022); PALIN *et al.* (2021)
Nos trilhos, uso preferencial de juntas com talas, para evitar tensão residual e internas geradas pela dilatação, e manutenção preventiva do lastro para garantir a rigidez e bom funcionamento da via	PALIN *et al.* (2013; 2021); ANDERSSON-SKÖLD *et al.* (2021)
Monitoramento digital que avise quando as juntas de pontes se tornarem muito densas ou a necessidade de substituir os materiais por outros mais resistentes ao calor.	ANDERSSON-SKÖLD *et al.* (2021)
Invólucro do equipamento elétrico com revestimento duplo para auxiliar o resfriamento	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022)
Substituição de trilho articulado por trilho soldado continuamente	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022)

Estratégias de Adaptação	Fonte
Ajuste na frequência de substituição de trilhos para reparar defeitos de alinhamento lateral na zona de flambagem e realinhamento de trilhos em zonas adjacentes	NEUMANN *et al.* (2021)
Substituição de pontes por materiais resistentes ao calor com menores coeficientes de expansão térmica	NETWORK RAIL (2020a); BLACKWOOD; RENAUD e GILLESPIE (2022)
Remoção controlada de vegetação para evitar incêndios florestais	BAUDUCEAU (2015); BLACKWOOD; RENAUD e GILLESPIE (2022)

Nota: (*) Refere-se à Soluções Baseadas na Natureza e (**) refere-se aos esforços de adaptação/mitigação.

Fonte: Elaboração própria (2022).

5. Casos de sucesso e as principais limitações e lições aprendidas no contexto das infraestruturas federais de transporte terrestre brasileiras

Esta seção tem o propósito de apresentar alguns exemplos de projetos e iniciativas implementadas no Brasil com foco na adaptação do setor de transporte terrestre. Além disso, são apresentadas algumas estratégias que podem ser implementadas para aprimorar essas ações, tornando a infraestrutura de transporte brasileira mais resiliente aos impactos da mudança do clima.

5.1 O uso da tecnologia (TICs) na gestão da manutenção de rodovias - DER/DF (medida não estrutural)

O Departamento de Estradas de Rodagem do Distrito Federal (DER/DF) é responsável por controlar mais de 1,9 mil quilômetros de estradas e garantir a segurança de todos que trafegam nesses trechos. Um dos maiores desafios do DER/DF na gestão da malha rodoviária é fazer a manutenção rodoviária eficiente: planejar e executar as ações necessárias para assegurar a qualidade e o conforto nessas estradas.

O sistema escolhido foi o Sistema de Administração da Manutenção (SAM), plataforma modular utilizada para tornar a gestão da manutenção rodoviária eficiente, com mais de 45 mil elementos vistoriados. A plataforma modular para gestão de infraestrutura de transportes e obras comporta todos os processos necessários à conservação rodoviária, oferecendo separação clara de todos os passos e procedimentos e promovendo uma gestão ágil e eficiente. O sistema permite planejar e acompanhar a execução das manutenções de forma eficiente, otimizando tempo e recursos. Isso porque gerencia todas as etapas do processo de manutenção, sendo elas:

- Elaboração do inventário dos elementos que geram a conservação;

- Análise e consolidação das informações específicas de cada elemento rodoviário, definindo as prioridades e custos unitários dos serviços;
- Estabelecimento de quantidade anual de serviços, que permite uma previsão orçamentária precisa e eficiente;
- Elaboração da programação anual e mensal dos serviços;
- Acompanhamento da execução.

Além da versão desktop, o sistema também é *mobile* e permite que o levantamento seja feito em campo, pelos fiscais, via smartphone com cadastro georreferenciado de maneira off-line, sem a necessidade de conexão com internet. Os profissionais utilizam o App para inserir imagens, dados e a geolocalização de todos os elementos que necessitam de manutenção, conservação e/ou recuperação. Como resultados, ao todo 940 km de rodovias pavimentadas foram inventariadas; mais de 45 mil elementos vistoriados e cadastrados e mais de 14 mil ordens de serviço expedidas (SOFTPLAN, 2022).

5.2 Estratégia de Adaptação à Mudança do clima - o caso da cidade do Rio de Janeiro (medida não estrutural)

A estratégia de adaptação elaborada para a cidade do Rio de Janeiro, apesar de não ser um exemplo de caso relacionado à infraestrutura federal de transporte terrestre, pode apoiar como uma referência para subsidiar a elaboração de um plano de adaptação para o setor de transportes, por exemplo.

Com base na Visão e nos Princípios, a Estratégia de Adaptação foi estruturada em seis Eixos Estratégicos. O primeiro Eixo trata do fortalecimento da capacidade de instituições e pessoas, sendo a base para a construção do caminho de adaptação. Os demais eixos consideram especificidades dos Sistemas de Interesse e Infraestruturas estratégicas. Aos Eixos Estratégicos foram associadas linhas de ação, as quais estão vinculadas iniciativas e respectivas atividades, conforme apresentado na Figura 6.

Figura 6 - Estratégia de adaptação da cidade do Rio de Janeiro.

Fonte: Centro Clima (2016).

Para cada atividade, foram indicados os correspondentes perigos climáticos e o direcionamento das ações, assim como a prioridade e atores envolvidos. Os perigos climáticos são identificados, neste estudo, como passíveis de causar perdas e danos ao ambiente construído, à saúde da população e aos ativos ambientais; o direcionamento da ação indica o local em que cada iniciativa deverá ser implementada; a prioridade busca orientar o tomador de decisão na seleção e sequenciamento das iniciativas; os atores envolvidos trata de instituições e stakeholders que deverão estar, prioritariamente, engajados no processo de implementação das iniciativas e, por seguinte, na elaboração do Plano de Adaptação (CENTRO CLIMA, 2016).

5.3 Projeto de Lei Nº 4129/2021, que estabelece diretrizes para formulação de planos de adaptação à mudança do clima (medida não estrutural)

Entre as áreas prioritárias estão agricultura, biodiversidade, indústria, energia, recursos hídricos, populações vulneráveis, segurança alimentar e saúde. O setor de transportes não aparece como um setor prioritário, contudo deveria ser considerado dada a relevância do mesmo e pela alta vulnerabilidade frente à mudança do clima.

Pelo projeto de lei, os planos de adaptação à mudança do clima deverão adotar diretrizes como: gestão e redução do risco climático; estabelecimento de instrumentos financeiros e socioambientais para adaptação da sociedade e do meio ambiente e previsão de medidas para enfrentamento dos desastres naturais mais recorrentes. Os planos devem prever também a integração entre as estratégias de mitigação e adaptação nos âmbitos local, regional e nacional, em alinhamento com os compromissos assumidos pelo Brasil no Acordo de Paris, que prevê a redução das emissões de gases de efeito estufa (AGÊNCIA CÂMARA DE NOTÍCIAS, 2021).

5.4 Plano de Adaptação de Rodovias Federais a Desastres Naturais e Desastres Naturais Recorrentes (PARF) do DNIT

O Plano de Adaptação de Rodovias Federais a Desastres Naturais e Desastres Naturais Recorrentes (PARF, 2017) resulta de um Plano de Trabalho, objeto do Termo de Execução Descentralizada (TED Nº 935/2014) assinado com a Universidade Federal de Santa Catarina (UFSC), visando a apoiar a elaboração e o monitoramento do Plano Nacional de Manutenção Rodoviária, em especial à Meta 02.B “Plano de Adaptação de Rodovias Federais a Desastres Naturais e Desastres Naturais Recorrentes” (PARF, 2017). O PARF tem como objetivo principal aumentar a resiliência da malha rodoviária do Departamento Nacional de Infraestrutura de Transportes (DNIT), visando assegurar condições permanentes de trafegabilidade, segurança e conforto aos usuários.

O PARF tem como objetivos específicos:

· Reduzir riscos à estabilidade da infraestrutura e à segurança dos usuários, considerando a incidência e a recorrência de eventos extremos.

· Otimizar o relacionamento, tanto interno quanto externo, com outras entidades, a fim de aumentar o desempenho na prevenção e na resposta às situações de emergência.

· Intensificar a manutenção das rodovias, com o intuito de reduzir situações que possam gerar interdições de tráfego em períodos de chuvas e evitar a geração de passivos ambientais.
· Capacitar o corpo técnico do DNIT, visando aumentar a eficiência de resposta e na prevenção às situações de emergência.

Dentre os componentes do PARF, tem-se o Atlas do Plano de Adaptação de Rodovias Federais, que reúne mapas temáticos sobre desastres naturais e ocorrências emergenciais na malha rodoviária federal. Tais mapas permitem visualizar informações espacialmente e correlacioná-las, fornecendo uma importante ferramenta para atuação do DNIT, órgão gestor e executor das rodovias federais, dentre outras vias, possibilitando assim a execução de ações voltadas à redução do risco de desastres naturais e de ocorrências emergenciais que possibilitem a segurança, o conforto e a economia das operações viárias.

Os mapas do Atlas subsidiam a avaliação de cenários para a tomada de decisões, entre eles, vale ressaltar: "Desastres naturais, ocorrências e obras emergenciais na malha do DNIT (2011-2014)" e "Trechos rodoviários prioritários para adaptação 2017". Diversas ações propostas para o alcance dos objetivos do PARF derivam de tais mapas e da proposição de intervenções; portanto, o PARF possibilita a definição dos trechos prioritários para adaptação, aprofundando o conhecimento acerca da criticidade relacionada, avaliando a vulnerabilidade e propondo ações de intervenção sobre a malha viária, contribuindo assim para o aumento da resiliência da infraestrutura rodoviária frente à mudança do clima.

5.5. Estudo do MInfra junto ao BID: Projeto BID Rodoviário - Infraestrutura de Transporte e Logística Sustentáveis

O Ministério de Infraestrutura (MInfra) firmou com o Banco Interamericano de Desenvolvimento (BID) a Cooperação Técnica "Infraestrutura de Transporte e Logística Sustentáveis (BR-T1478)" (CGPlan/DPI/SFPP, 2022), não-reembolsável, no valor de US $ 1,6 milhão (BID, 2022). Essa cooperação tem como objetivo "apoiar os esforços do Governo brasileiro no desenvolvimento de infraestrutura de transporte sustentável, por meio de melhorias nos modos de transporte de longa distância, logística e serviços de infraestrutura de baixo carbono" (CGPlan/DPI/SFPP, 2022). Tais ações serão possíveis a partir da atualização do PNL 2035 (Plano Nacional de Logística 2035) e do desenvolvimento dos Planos Gerais de Ações Públicas ou de Parcerias, no contexto do Planejamento Integrado de Transportes (BID, 2022).

Para que essa cooperação se concretizasse, o BID buscou financiamento do Programa Infraestrutura Sustentável do Reino Unido (*UK Sustainable Infrastructure Program* – UKSIP) (BID, 2022; PELEGI, 2021). O UKSIP é um programa subsidiado pelo governo do Reino Unido destinado ao financiamento do desenvolvimento de infraestruturas de baixo carbono em países da América Latina (Brasil, Peru, Colômbia e México), catalisando recursos privados para investimentos críticos, buscando o atendimento desses países aos objetivos do Acordo de Paris (DIPLOMACIA BUSINESS, 2022; PELEGI, 2021).

A parceria com o BID/UKSIP engloba avaliações de viabilidade de logística e transportes sustentáveis até a adoção de critérios de gestão e mitigação de risco climático (MENZEL, 2021). Na primeira etapa desta parceria, serão traçados objetivos, metas e indicadores para o plano de

parcerias do modo rodoviário (MENZEL, 2021). Dados do Global Infrastructure Hub indicam a necessidade de investimentos na ordem de aproximadamente US $ 1,2 trilhão até 2040 para suprir a demanda da infraestrutura rodoviária do país (MENZEL, 2021).

No âmbito dessa parceria, o MInfra desenvolveu um plano estratégico e sustentável de infraestrutura de transporte e logística, cujo objetivo é apoiar melhorias no Programa de Concessões Rodoviárias do Governo (PROCROFE). Tal plano levará em conta "ferramentas de gestão que facilitem a definição de diretrizes, objetivos e metas mensuráveis, além de metas de desempenho, conferindo assim uma maior transparência para a execução e monitoramento do programa de concessões e a implantação de um sistema de gestão de risco" (CGPlan/DPI/SFPP, 2022).

5.6. Exemplos de casos focados em financiamento para adaptação à mudança do clima

O financiamento climático é um dos meios de implementação da agenda de mitigação e adaptação da mudança do clima, segundo a Convenção-Quadro das Nações Unidas de Mudança do Clima (ADAPTACLIMA, [s.d]). Esse financiamento provém de mercados de capitais e reservas governamentais, podendo ser adquirido por intermédio de canais multilaterais (instituições criadas por grupos de países, incluindo bancos internacionais e de desenvolvimento, agências e divisões das ONU, do Banco Mundial e do BID), bilaterais (organizações fundadas em um único país, como bancos e agências de desenvolvimento), nacionais, regionais e privados (INSTITUTO ETHOS e WWF BRASIL, 2017).

De acordo com um levantamento feito pelo Instituto Ethos e WWF-Brasil (2017), existem 28 fundos internacionais para investir em projetos e estudos voltados à adaptação à mudança do clima no Brasil e 20 fundos nacionais. Uma dessas fontes nacionais de financiamento é o Fundo Nacional Sobre Mudança do Clima, também chamado de Fundo Clima, um fundo de natureza contábil, vinculado ao Ministério do Meio Ambiente, criado através da Lei nº 12.114/2009 (BRASIL, 2009), que tem como objetivo apoiar projetos ou estudos e financiar empreendimentos voltados à mitigação das mudanças do clima e à adaptação à mudança do clima e aos seus efeitos. O § 4º do artigo 5º desta lei (BRASIL, 2009) traz em seus incisos um rol de atividades às quais os recursos do FNMC podem ser destinados, a saber:

> "I - educação, capacitação, treinamento e mobilização na área de mudanças climáticas;
> II - Ciência do Clima, Análise de Impactos e Vulnerabilidade;
> III - adaptação da sociedade e dos ecossistemas aos impactos das mudanças climáticas; projetos de redução de emissões de gases de efeito estufa - GEE;
> IV - projetos de redução de emissões de carbono pelo desmatamento e degradação florestal, com prioridade a áreas naturais ameaçadas de destruição e relevantes para estratégias de conservação da biodiversidade;
> V - desenvolvimento e difusão de tecnologia para a mitigação de emissões de gases do efeito estufa;
> VI - formulação de políticas públicas para solução dos problemas relacionados à emissão e mitigação de emissões de GEE;
> VII - pesquisa e criação de sistemas e metodologias de projeto e inventários que contribuam para a redução das emissões líquidas de gases

> de efeito estufa e para a redução das emissões de desmatamento e alteração de uso do solo;
> VIII - desenvolvimento de produtos e serviços que contribuam para a dinâmica de conservação ambiental e estabilização da concentração de gases de efeito estufa;
> IX - apoio às cadeias produtivas sustentáveis; pagamentos por serviços ambientais às comunidades e aos indivíduos cujas atividades comprovadamente contribuam para a estocagem de carbono, atrelada a outros serviços ambientais;
> X - sistemas agroflorestais que contribuam para redução de desmatamento e absorção de carbono por sumidouros e para geração de renda; recuperação de áreas degradadas e restauração florestal, priorizando áreas de Reserva Legal e Áreas de Preservação Permanente e as áreas prioritárias para a geração e garantia da qualidade dos serviços ambientais" (BRASIL, 2009).

O FNMC trata-se de um dos principais instrumentos da Política Nacional sobre Mudança do Clima.

No escopo do Fundo Clima, foi criado o Programa Fundo Clima, que destina parte dos recursos reembolsáveis do fundo para apoiar a implantação de empreendimentos, a aquisição de máquinas e equipamentos, e o desenvolvimento tecnológico relacionado à redução da emissão de gases de efeito estufa (GEEs) e à adaptação à mudança do clima e aos seus efeitos. Esse programa possui 9 (nove) subprogramas, a saber: mobilidade urbana; cidades sustentáveis e mudança do clima; máquinas e equipamentos eficientes; energias renováveis; resíduos sólidos; carvão vegetal; florestas nativas; gestão e serviços de carbono; e projetos inovadores. Dentre tais subprogramas, os três primeiros elencados podem ser mecanismos de financiamento de projetos voltados para adaptações do setor de transportes à mudança do clima. De acordo com informações existentes na página do BNDES sobre o Programa (BNDES, [s.d]), o valor máximo do financiamento pago por beneficiário é de R$ 80 milhões a cada 12 meses. Contudo, notícias veiculadas na imprensa em abril de 2022 (CLIMAINFO, 2022) apontam que o Fundo Clima tem sofrido sucessivos cortes orçamentários, de tal modo que ele não realiza chamamentos públicos de projetos desde 2018.

Apesar da diversidade de fundos existentes para investimentos em projetos de adaptação no Brasil, não são claramente identificáveis os *Key Performance Indicators* (KPIs) ligados a esses fundos. Entre os identificáveis, tem-se KPIs definidos pelo UK International Climate Finance (ICF), por exemplo, que visam a apoiar o monitoramento, a avaliação e a aprendizagem do fundo, como:

- KPI 1 (CLIMATE CHANGE COMPASS, 2018) – Mede o alcance dos programas de adaptação à mudança do clima da UK ICF. Conta o número de pessoas apoiadas por programas da ICF de preparação e adaptação aos efeitos da mudança do clima, incluindo mudanças de longo prazo nos padrões climáticos (p. ex., variabilidade climática), bem como aumento da frequência e gravidade de eventos climáticos extremos;
- KPI 4 (CLIMATE CHANGE COMPASS, 2019) – Número de pessoas cuja resiliência melhorou como resultado do ICF;
- KPI 11 (OECD DAC, 2016) - Volume de financiamento público mobilizado para o clima para propósitos de mudança como resultado do financiamento do ICF; dentre outros.

Uma publicação recente do Duke Nicholas Institute (2022) apresenta uma abordagem para o desenvolvimento de KPIs para adaptação à mudança do clima e resiliência, com base nas ferramentas atualmente disponíveis e referenciadas. Apesar de ter sido criado visando apoiar o planejamento de agências norte-americanas à adaptação climática, sua abordagem é amplamente aplicável.

Além disso, outros convênios já foram firmados anteriormente buscando apoiar a mudança da infraestrutura do modal de transportes brasileiro rumo a uma maior sustentabilidade no setor, como a do presente Estudo (AdaptaVias) e com a *Climate Bond Initiative* (CBI) para qualificar o portfólio de transportes a potencial financiamento via títulos verdes (*green bonds*), que tornou concessões ferroviárias (Ferrogrão, Ferrovia de Integração Oeste-Leste (Fiol) e Ferrovia de Integração Centro-Oeste (FICO)) aptas à emissão de títulos verdes. (MENZEL, 2021; PELEGI, 2021).

5.7. Casos sobre integração de dados e novas tecnologias como BIM e Digital Twin

Alguns exemplos de integração de dados e novas tecnologias envolvem a transformação digital, principalmente no setor de infraestrutura de transportes. Entre tais inovações, tem-se o BIM - do inglês, *Building Information Modeling*, ou "Modelagem da Informação da Construção".

O BIM corresponde a um conjunto de processos e tecnologias que possibilita a geração e a gestão de representações digitais de características físicas e operacionais de construção (GANUT *et al.*, 2021; SIENGE, [s.d.]). Assim, permite a projeção, o planejamento, a construção e o acompanhamento de uma edificação ou instalação (GANUT *et al.*, 2021). Os modelos criados são arquivos de computador (softwares) que podem ser extraídos, trocados ou colocados em rede para apoiar a tomada de decisão em relação a um ativo construído (GANUT *et al.*, 2021; SIENGE, [s.d.]).

Entre os benefícios e as funcionalidades do uso do BIM, podem ser ressaltados: permite a visualização 3D do que está sendo projetado; ensaio da construção no computador; extração automática das quantidades de projeto; realização de simulação e ensaios virtuais; identificação automática de interferências (geométricas e funcionais); geração de documentos mais consistentes e mais íntegros; complemento do uso de outras tecnologias (GANUT *et al.*, 2021; DER-MG [2021 ou 2022]). Tais benefícios podem ser percebidos em todas as fases da construção, desde a etapa de anteprojeto à construção (DER-MG [2021 ou 2022]).

Especificamente em projetos rodoviários, o BIM apoia as análises para escolha do melhor tipo de empreendimento; possibilita, por exemplo, a criação de estudos preliminares de alternativas de traçado de rodovias em projetos de implantação, fornecendo informações sobre a topografia do local e movimentações de terra, e seus reflexos em termos de volume de solo e soluções de contenção, bem como, a identificação de locais que garantem paradas seguras, considerando curvaturas e obstruções visuais, como barreiras, vegetação, entre outros, garantindo a segurança viária (GANUT *et al.*, 2021). Além disso, possibilita que as informações acerca do projeto sejam coordenadas e confiáveis, à medida que os dados são colocados no software e as informações são atualizadas em tempo real, possibilitando a visualização do impacto provocado por quaisquer modificações durante as etapas do projeto. Isso facilita a avaliação das possibilidades existentes acerca do desenho da rodovia, otimizando os quantitativos, o sequenciamento e o planejamento de toda a obra.

No Brasil, o Programa de Concessões de Rodovias Federais, criado pela Portaria Ministerial nº 10/93, passou por diversas modificações desde a sua criação. A mais recente se refere à determinação do uso do BIM na execução direta ou indireta de obras e serviços de engenharia de obras públicas federais, inclusive em rodovias, por meio do Decreto nº 10.306/2020 (GANUT *et al.*, 2021). Assim, o BIM será aplicado na elaboração, revisão e compatibilização de modelos de

arquitetura e engenharia, na geração de documentos e na extração de quantitativos vinculadas a diversos ministérios, como o Minfra (GANUT *et al.*, 2021).

A implementação do BIM no DNIT será realizada em ciclos, sendo que o primeiro projeto-piloto, denominado de Programa Proarte (Programa de Manutenção e Reabilitação de Estruturas), foi iniciado em 2016 e tem como objetivo a reabilitação e a manutenção de aproximadamente 8000 pontes e viadutos distribuídos na malha rodoviária federal sob responsabilidade daquele departamento (GANUT *et al.*, 2021).

Além do BIM, o *Digital Twins* é outra ferramenta digital que poderia ser utilizada para a integração de dados na área de infraestrutura de transportes. Trata-se de uma tecnologia disruptiva que simula virtualmente as condições reais de um produto para extrair informações que permitam uma visão em tempo real da evolução do item "copiado" (CANDIDO, 2021). É um banco de dados de um determinado objeto físico que, uma vez analisado, permitiria melhorar processos e apoiar tomadas de decisões da gestão (CANDIDO, 2021). Entre as vantagens, tem-se a redução de custos, garantia da segurança de processos em que haja riscos, melhoria da eficiência de produtos e criação de novas oportunidades (CANDIDO, 2021).

A seguir, são apresentadas algumas diretrizes que podem subsidiar a elaboração e implementação de um plano de adaptação setorial: Plano de Adaptação do Transporte Rodoviário e Ferroviário frente à mudança do clima. A recomendação é que o Plano de Adaptação forneça não somente diretrizes mais genéricas, mas que possam apresentar os possíveis caminhos e ferramentas de gestão e governança para a adoção de medidas identificadas e apresentadas neste estudo.

6. Diretrizes sobre opções de medidas de adaptação por tipo de ameaça e impacto

Esta seção tem como objetivo implementar a busca bibliográfica realizada na Seção 3 de modo a indicar diretrizes que podem ser aplicadas pelos tomadores de decisão para tornar a infraestrutura de transporte terrestre mais resiliente aos impactos e, consequentemente, com minimização de danos e prejuízos acarretados pela mudança do clima.

6.1 Diretrizes gerais para um plano de adaptação

A falta de dados confiáveis e padronizados sobre os impactos das mudanças do clima, bem como a análise de custo-benefício representam um desafio significativo para os planejadores de transporte, o que também resulta no fracasso das estratégias de adaptação no setor (KOETSE e RIETVELD 2012). Devido às altas incertezas relacionadas ao clima futuro, as medidas de adaptação devem ser robustas para efetivamente aumentar a resiliência do setor de transporte (WANG *et al.*, 2018).

Medidas de adaptação e mitigação podem ser buscadas conjunta e ativamente, sempre que possível, de forma a responder às ameaças climáticas atuais e futuras (UNEP, 2021). A recomendação é que um Plano de Adaptação considere medidas associadas: estratégias de mitigação-adaptação ou adaptação-mitigação, a depender do objetivo principal, refletindo a sinergia tão necessária. Assim, os cobenefícios a serem alcançados podem dar uma maior robustez a um plano, como facilitar o

acesso a financiamento, promover uma maior eficiência na adoção de medidas e na contabilização destas, envolvimento de mais atores e partes interessadas, tornando todo o ciclo, desde a elaboração até a execução e monitoramento, mais colaborativo.

O Estudo AdaptaVias está alinhado com as Diretrizes de Sustentabilidade do Ministério da Infraestrutura, em especial à Diretriz 2, de promover a inserção das questões relacionadas à mudança do clima na infraestrutura de transportes, contextualizados aos princípios de: "II. Conciliação da infraestrutura de transportes com a conservação do meio ambiente;" e "V - Adaptação dos sistemas de transportes à mudança do clima".

Com relação às medidas de adaptação em transportes, algumas experiências foram identificadas: realocação de estradas e vias, mudanças nos projetos e substituição e adequação de estruturas, como pontes, estradas e pavimentos, de forma a suportar os possíveis efeitos que as condições meteorológicas e a mudança do clima poderão acarretar para o setor (SANTOS, 2014).

Desta forma, o **Produto 6 - Medidas de adaptação**, conforme já mencionado, propõe um conjunto de medidas, com base na revisão da literatura, que podem ser consideradas num plano de adaptação para o setor de transportes terrestres: rodoviário e ferroviário. A seguir é apresentada uma proposta de estrutura para um plano de adaptação dividido em 6 eixos.

Box 2 - Proposta de estrutura com divisão de eixos para um Plano de Adaptação dos setores de transportes rodoviário e ferroviário.

Plano de Adaptação do setor de transportes terrestres: rodoviário e ferroviário

Proposta de Eixos:

1. **Governança -** instituição(ões) responsável(eis) pela adoção das ações - quem coordena o Plano? Quem fiscaliza? Criação de um comitê específico?
2. **Informação, educação, sensibilização e capacitação** - Envolvimento de atores - criação de capacidades, treinamentos especializados e contínuos a empresas, governos, educação das populações que vivem em área de risco;
3. **Recursos financeiros -** identificação, acesso a financiamento e previsão de recursos para as ações necessárias, com a sinalização de metas de curto, médio e longo prazo; instituições responsáveis;
4. **Avaliação de Risco Climático -** Identificação dos impactos (Estudo AdaptaVias) - Indicadores de Risco Climático (Ver a Plataforma AdaptaBrasil); **Áreas críticas (hotspots[7]);** atualização e avaliação periódica dos riscos;
5. **Medidas propostas** - classificação e agrupamento das medidas por categorias (Planejamento, Implantação - construção, ampliação, dentre outros; Operação & Manutenção e Monitoramento - conforme o Estudo AdaptaVias) e priorização de medidas;

[7] Os "hotspots", ou áreas críticas são áreas que necessitam de maior atenção. No estudo foram consideradas as áreas com o risco variando de muito alto e alto, que necessitam ser priorizadas em termos da urgência na adoção de medidas que visem reduzir o risco e aumentar a resiliência.

6. **Mensuração, Reporte e Verificação (MRV)** - Como serão reportadas as ações? Como se dará a verificação quanto ao cumprimento (se por terceira parte)? (necessidade de transparência).

Fonte: Elaboração própria com base em Santos (2014).

Destaca-se que as questões a serem consideradas nos eixos propostos dependem de qual é o agente ou em que escala e nível de governança está sendo elaborado o Plano. Por exemplo, se o Plano está no nível do MInfra deve-se considerar diferentes aspectos daqueles que seriam necessários para elaboração de Plano de Adaptação de uma concessionária. Ao mesmo tempo, deve-se observar que as ações e exemplos apresentados nos diferentes eixos estão mais voltados ao nível de projeto e operação de infraestruturas.

A adaptação à mudança do clima pode ser entendida como uma série de respostas aos impactos atuais e potenciais da mudança do clima, com objetivo de minimizar possíveis danos e aproveitar as oportunidades potenciais. Estas respostas podem assumir diversas formas, desde infraestrutura, de engenharia, até a de adaptação por ecossistemas (SANTOS, 2014).

A adaptação no setor de transportes ainda está em seus estágios iniciais e os esforços precisam ser rapidamente ampliados para lidar com os impactos de um clima cada vez mais intenso. O IPCC geralmente avalia o risco 'adicional' devido aos impactos ou respostas à mudança do clima, não o risco total para um sistema que pode estar relacionado à exploração de recursos, poluição, fragmentação de habitat, dentre outros. O Capítulo 16 do AR6 WGII sintetiza os impactos observados da mudança do clima, as respostas relacionadas à adaptação, os limites da adaptação e os principais riscos identificados em todos os setores e regiões (IPCC, 2022a).

O Eixo 1 - Governança - Este estudo apresenta uma série de intervenções de adaptação para responder às ameaças climáticas identificadas, como precipitação intensa e altas temperaturas, para a infraestrutura rodoviária e ferroviária e diferentes configurações, onde governos e formuladores de políticas podem promover e ampliar essas ações integrando em políticas e regulamentações para o setor. Também reflete sobre as possíveis medidas de infraestrutura considerando a abordagem baseada na Solução baseada na Natureza para Adaptação.

A governança é de suma importância, ela deve unir esforços de cooperação. O Sistema de governança é muitas vezes a entidade responsável e legítima para gerenciar os impactos das mudanças do clima (MEASHAM *et al.*, 2011; SANTOS, 2014), e as instituições têm três papéis críticos: 1) respostas estruturadas para os impactos locais; 2) a mediação entre as respostas individuais e coletivas para a vulnerabilidade; e 3) governança para prover recursos para facilitar a adaptação. A boa governança deve garantir uma coordenação adequada entre todos os agentes envolvidos.

Integrar a avaliação de risco e a análise de custo-benefício num processo de tomada de decisão dinâmica, a fim de incorporar a resiliência em investimentos urbanos e de infraestrutura de transporte requer: (a) ferramentas técnicas para realizar a avaliação de risco e análise custo-benefício; (b) os arranjos institucionais para incorporar essas análises no processo de tomada de

decisão; (c) a vontade política de adotar instrumentos institucionais de avaliação de riscos; e (d) a capacidade de todas as partes interessadas para ser capaz de acessar e utilizar informações e ferramentas de risco de forma eficaz (JHA *et al.*, 2013; SANTOS, 2014).

Um ponto que merece destaque consiste na revisão de normas (não só dos normativos executivos, mas também de novos materiais e normativos operacionais) relacionados ao transporte terrestre, principalmente daquelas que apresentam oportunidades ou "pontos de entrada" para a consideração da mudança do clima e cenários futuros. Nesse sentido, aconselha-se que sejam observados:

1. Drenagem: Tratando sobre os dispositivos de drenagem, sugere-se revisão do Manual de hidrologia básica para estruturas de drenagem (DNIT, 2005): deve-se rever os parâmetros iniciais, como Tempo de Recorrência; além disso, tratando dos métodos de dimensionamento de estruturas para escoamento de águas pluviais e fluviais, como os especificados no Manual de drenagem de Rodovias (DNIT, 2006a) e no Manual de Pavimentação (DNIT, 2006b), é interessante que se façam as revisões dos coeficientes, parâmetros e modelos utilizados, com vistas nos patamares atuais dos eventos climáticos aderentes à temática; por fim, é interessante que documentos que apresentem soluções tidas como recorrentes, como o Álbum de Projetos-Tipo de dispositivos de drenagem (DNIT, 2010), também sejam revisitados;
2. Pavimento: sobre o método de dimensionamento para pavimento flexível do DNER (DNIT, 2006b), especificamente no que diz respeito ao Fator climático Regional, é interessante que os coeficientes sejam revisitados para estarem alinhados com as mudanças climáticas. A mesma sugestão pode ser aplicada ao método Medina, e aos parâmetros de clima utilizados no software de gestão de pavimentos HDM-4;
3. Obras-de-Arte Especiais: é interessante que sejam referenciados os impactos dos eventos extremos nos critérios avaliados, como: parâmetros hidrológicos para sistema de drenagem; capacidade de resistência térmica para juntas de dilatação; critérios de sobrecarga, como carga de vento e efeitos de ressonância.

Além disso, as ISOs - *International Organization for Standardization*, ou seja, Organização Internacional de Padronização, tais como a ISO 14091:2021, que apresenta diretrizes sobre vulnerabilidade, impactos e avaliação de riscos no âmbito da Adaptação à mudança do clima (ISO, 2021), devem ser levadas em consideração. Deve-se ainda incentivar a utilização em larga escala de modelos tais como o *Highway Development and Management Model* (HDM-4), que analisa as condições da rede de rodovias para apoiar a tomada de decisões relacionadas principalmente à gestão da conservação e à reabilitação de pavimentos de redes viárias (DNIT, [s.d]).

Especificamente para o transporte ferroviário, aconselha-se estar atento às normas da AREMA quanto às atualizações sobre a temática de mudança do clima, buscando adequar as recomendações para a realidade do Brasil.

O **Eixo 2 - Informação, educação, sensibilização e capacitação** - é importante melhorar continuamente a comunicação sobre o risco, implementar sistemas de alerta precoce, contingência de emergência, evacuação e planejamento de recuperação. Os investimentos em sistemas de alerta precoce estão entre as medidas mais custo-efetivas que qualquer país pode realizar. A informação passa a ser considerada como recurso estratégico nas tomadas de decisões, onde a agregação de valor a partir do acesso, tratamento, utilização e disseminação da informação é a chave para o sucesso (SANTOS, 2014).

A informação é considerada como o ingrediente básico do qual dependem os processos de decisão e a gestão moderna exige que a tomada de decisão seja feita com o máximo de informação. É criticamente importante para a resposta frente a uma emergência e para a recuperação rápida de uma infraestrutura ou ativo, comunidade e sua economia, um planejamento e uso do solo baseado no risco, com a identificação das áreas críticas, como também as áreas mais seguras para priorizar investimentos imediatos em desenvolvimento urbano e projetos de infraestrutura (JHA *et al.*, 2013; SANTOS, 2014).

Os sistemas inteligentes de informação ampliam a rapidez e a eficiência na obtenção e disseminação da informação, sendo estratégica uma ampla participação da sociedade seja, muitas vezes reportando um incidente, bem como atuando como agente disseminador da informação. Em se tratando da mudança do clima e eventos climáticos extremos, a informação sobre o risco é fundamental para lidar com situações de emergência e para o planejamento em caso de desastres. Considerando que o risco nunca pode ser totalmente eliminado, a resposta de emergência e o planejamento de recuperação são caminhos para reduzir os impactos, facilitando o processo de reconstrução e recuperação após um desastre. De acordo com Santos (2014) apud Measham *et al.* (2011), a falta de informação útil, confiável e relevante sobre a natureza do risco climático para o qual devemos nos adaptar vem a ser uma barreira fundamental para o planejamento da mudança do clima.

Com relação ao **Eixo 3 - Recursos financeiros** - Algumas iniciativas têm sido desenvolvidas com vistas em facilitar a obtenção de recursos financeiros para atuar em resiliência em cidades, como exemplo, a criação de alianças entre grandes organizações internacionais com o propósito de criar uma maior resiliência urbana com desenvolvimento social, econômico e ambiental. É importante que exista um orçamento para medidas de adaptação dos setores aos possíveis riscos e impactos das mudanças do clima, bem como recurso que possibilite ao governo nacional e subnacional atuar em construção de capacidades e, no caso de desastres, nas medidas de emergência.

Identificar as ferramentas quantitativas consistentes para avaliar os investimentos públicos, a fim de tomar decisões orçamentárias e de investimento, e integrar métodos baseados no risco em abordagens de custo-benefício, torna possível considerar os prováveis impactos da mudança do clima e de desastres pela quantificação das consequências econômicas desses eventos. Entre essas ferramentas estão: - Avaliação de risco; - Ordenamento do território com base no risco; - A gestão dos ecossistemas urbanos; - Requalificação urbana; - Comunidade e participação das partes

interessadas; - Sistemas de gestão de desastres; - Coleta de dados, análise e aplicação; e - Financiamento para a redução do risco e abordagens de transferência.

Medidas de adaptação e mitigação necessitam de forte articulação e dependem de outros níveis de governança (SANTOS, 2014). Tanto do ponto de vista do financiamento, como também da formulação, essas políticas deverão ser apoiadas pelos níveis nacionais e subnacionais. As principais instituições de financiamento externo são: o Banco Interamericano de Desenvolvimento – BID e o Banco Internacional para Reconstrução e Desenvolvimento – BIRD.

É importante conhecer as iniciativas de financiamento existentes e aproveitar as oportunidades para captar recursos disponíveis. Muitas vezes estes recursos existem e não são utilizados, seja por falta de conhecimento, ou por falta de capacidades de instituições para submeterem propostas de projetos. Recursos financeiros constituem um elemento importante para o planejamento e financiamento das medidas de adaptação para atuar em resiliência. É importante ter a definição clara do custo detalhado de cada linha de ação e etapa de um plano de ação, a origem da fonte de recurso (de preferência do orçamento permanente do governo, seja local ou nacional), e deve existir uma estrutura de governança robusta para atuar de forma eficiente, sempre pautada na transparência.

Eixo 4 - Avaliação de Risco Climático - Identificação das Ameaças climáticas - no estudo AdaptaVias foram identificadas lacunas em termos da disponibilidade de dados de indicadores sobre ameaça, exposição e vulnerabilidade (sensibilidade e capacidade adaptativa), que poderiam representar melhor o risco climático para rodovias e ferrovias. Conforme descrito na atividade 4.3, a equipe de consultoria identificou possíveis indicadores, a partir da disponibilidade do dado em formato adequado e georreferenciado. Nesse sentido, sugere-se a adoção de uma base de dados aberta georreferenciada sobre risco de impactos da mudança do clima e de desastres para a infraestrutura de transportes terrestres (rodoviário e ferroviário).

No modo rodoviário, sugere-se considerar a disponibilidade de dados de:

1. Informações padronizadas, tanto para vias concessionadas, quanto para vias não concessionadas, sobre FWD (*Falling Weight Deflectometer*), IGG (Índice de Gravidade Global), IRI (*International Roughness Index*), que buscam avaliar a condição estrutural de pavimentos;
2. Intervenções no trecho rodoviário, assim como planos de manutenção contendo informações sobre os trechos historicamente mais críticos;
3. Monitoramento e localização de Obras de Arte Especiais - OAE (pontes e viadutos), com idade do ativo, altura e vão livre, patologias apontadas na avaliação estrutural e grau/nota estrutural. Sugere-se que seja avaliado junto ao Departamento Nacional de Infraestrutura de Transportes - DNIT a viabilidade de tornar público o acesso aos dados do Sistema de Gestão de Obras de Artes Especiais - SGO (https://www.gov.br/dnit/pt-br/servicos/sistemas-gerenciais/sgo);
4. Monitoramento e localização dos dispositivos de drenagem (bueiros, caixas de passagem, descidas d'água, dentre outros.) com idade do ativo, patologias apontadas na avaliação estrutural e grau/nota estrutural.

No modo ferroviário, sugere-se considerar a disponibilidade de dados de:

1. Intervenções no trecho, assim como planos de manutenção contendo informações sobre os trechos historicamente mais críticos;
2. Dados de monitoramento de via permanente, como geometria, os quais também são indicadores de sensibilidade e exposição;
3. Dados de monitoramento de OAE (pontes e viadutos), que possuam a idade do ativo, vão livre, altura, tipo de estrutura, patologias apontadas na avaliação estrutural, os quais também são indicadores de sensibilidade e exposição. Sugere-se que seja avaliado junto ao DNIT a viabilidade de tornar público o acesso aos dados do SGO (https://www.gov.br/dnit/pt-br/servicos/sistemas-gerenciais/sgo);
4. Dados de operação e caracterização da infraestrutura ferroviária - de Rampa máxima (%) e Raio de curva (metros) que podem demonstrar áreas com maior sensibilidade à mudança do clima; e
5. Velocidade Máxima Autorizada - VMA, assumindo que a diminuição histórica do VMA pode ser inferida como problemas na infraestrutura, levando ao aumento da sensibilidade.

As bases para os modos terrestres devem considerar indicadores importantes que foram identificados no estudo, e estes devem atender aos critérios: estarem num mesmo formato (padrão), georreferenciados e que tenham abrangência nacional, de forma a possibilitar a construção de uma série histórica para que no futuro sejam incorporados na avaliação de risco climático.

Áreas críticas - a identificação de áreas críticas ou *hotspots* é fundamental para definir uma escala de priorização, guiar o montante de financiamento necessário, equipe envolvida e serviços e escopo a serem contratados. As áreas críticas (Risco muito alto e alto), conforme já mencionado, necessitam de um tratamento diferenciado, por serem prioritárias, devendo estar numa alta escala de priorização. O planejamento; implantação - construção, ampliação, dentre outros; operação e manutenção; e monitoramento devem ter uma periodicidade diferenciada, remetendo ao grau de urgência e cuidado necessário.

Eixo 5 - Medidas propostas - as medidas identificadas foram apresentadas na Seção 4 deste relatório, classificadas como medidas não-estruturais, ou de não-engenharia, e medidas estruturais, ou de engenharia, por tipo de ameaça climática.

O **Eixo 6 - Mensuração, Reporte e Verificação** - monitorar, quantificar e acompanhar a evolução remete à necessidade de atualizar periodicamente a Avaliação de Risco Climático realizada. Deve registrar e reportar o progresso publicamente para informar e dar transparência ao processo.

Além disso, monitorar e controlar as ações implementadas, bem como estabelecer um planejamento para as iniciativas de curto, médio e longo prazo também devem ser consideradas num plano. Recomenda-se também monitorar o progresso da implementação dos investimentos, definir indicadores de monitoramento, estabelecer um processo de revisão para acompanhar a implementação do investimento.

6.2. Diretrizes sobre as medidas de adaptação por tipo de ameaça e impacto

Nessa seção, são apresentadas algumas diretrizes sobre as medidas de adaptação identificadas a partir da revisão da literatura, apresentada na Seção 4, para o setor de transporte terrestre (rodoviário e ferroviário). Nesse sentido, em alinhamento com o comitê gestor, acordou-se em desenvolver o ANEXO 3 - Medidas de Adaptação -, que subdivide as medidas de adaptação em diversas categorias.

Dessa forma, além de separar cada medida de adaptação por tipo de ameaça e impacto, tipo de medida (estrutural ou não estrutural), se é uma SbN e se consiste em um esforço de adaptação/mitigação, conforme já discutido na Seção 4, o ANEXO 3 categoriza as medidas por:

- Etapas do ciclo do ativo, sendo elas: (I) Planejamento; (II) Implantação - construção, ampliação, dentre outros; (III) Operação & Manutenção; e (IV) Monitoramento.
- Níveis da medida, sendo eles: (I) Estratégico; (II) Tático; e (III) Operacional.

Além disso, sugere-se a categorização dessas medidas de adaptação por diretrizes e linhas de ação do MInfra.

Com o preenchimento da planilha, foi possível quantificar as medidas de adaptação por categoria, conforme descrito a seguir. Primeiramente, notou-se que **ao todo foram apresentadas 179 medidas,** das quais 56 podem ser utilizadas por ambos os modos, 90 para o modo rodoviário e 33 para o modo ferroviário. Além disso, dividindo essas medidas por tipo, nota-se que foram encontradas **58 medidas não estruturais**, sendo que 54 servem para ambos os modos e 4 apenas para o rodoviário, e **121 medidas estruturais**, sendo 86 para o modo rodoviário, 33 para o modo ferroviário e duas para ambos os modos.

Separando as medidas por tipo de impacto, foram identificadas **28 medidas para inundação, 28 para erosão, 28 para deslizamento, 34 para impactos diretos devido às altas temperaturas e apenas 7 para queimadas**, que é um impacto biofísico pouco trabalhado na literatura. Cabe ainda destacar que outras 126 medidas, ou seja, as medidas não estruturais servem para todos os impactos.

Em relação às etapas do ciclo do ativo, foram contabilizadas: **(i) 67 medidas sobre planejamento; (ii) 46 sobre implantação; (iii) 55 sobre Operação & Manutenção; e (iv) 11 sobre Monitoramento**. Já em relação ao nível do planejamento, foram elencadas: **(i) 42 medidas estratégicas; (ii) 64 medidas táticas; e (iii) 73 medidas operacionais**.

Destaca-se que as medidas apresentadas neste estudo são representativas e atuais, englobando, conforme já destacado, ações inovadoras que podem ser aplicadas por tomadores de decisão para aumentar a resiliência do transporte terrestre, inclusive incluindo conceitos de SbN e esforços de adaptação/mitigação, tão salientados no IPCC (2022a; b). Destaca-se ainda que esta pesquisa não é exaustiva, podendo ter ficado de fora das considerações outras medidas igualmente importantes.

Entretanto, acredita-se que a planilha desenvolvida no ANEXO 3 pode ser constantemente atualizada, inclusive podendo ser incluídas outras categorizações.

7. Conclusões

O Produto 6 identificou e categorizou as medidas de adaptação, tanto não estruturais, quanto estruturais, a partir da revisão da literatura, para permitir uma tomada de decisão mais assertiva contra os impactos da mudança do clima da infraestrutura de transporte terrestre, em alinhamento ao atendimento às perguntas norteadoras, que são respondidas na presente seção.

Respostas às Perguntas Norteadoras:

PN 6.1. "A partir de experiências nacionais e internacionais já documentadas, quais medidas de adaptação são recomendadas para a realidade brasileira, considerando as diversas fases do ciclo de vida dos ativos de infraestrutura de transporte terrestre?";

As medidas de adaptação são apresentadas na Seção 4 deste relatório - Produto 6, por tipo de impacto, para o setor rodoviário e ferroviário. Estão divididas em adaptação não estrutural, do inglês "*soft adaptation",* e adaptação estrutural, do Inglês "*Hard adaptation*". Com base na revisão bibliográfica foi possível identificar **58 medidas não estruturais**, ou seja, de adaptação não estruturais para o setor de transporte terrestre, apresentadas na Seção 4.1. Optou-se por unificar as medidas de adaptação não estruturais do transporte rodoviário e do ferroviário porque acredita-se que quase a totalidade delas (apenas 4 não) podem ser implementadas nos dois casos, sendo ainda muitas delas aplicadas a outros modos de transporte.

Para o setor rodoviário foram contabilizadas **86 medidas estruturais**, apresentadas na Seção 4.2.1, e envolvem obras de engenharia para adaptar um ativo da infraestrutura, correção e/ ou prevenção de desastres, manutenção e monitoramento e ações corretivas. Para o setor ferroviário, foram identificadas **33 medidas estruturais,** conforme apresentado na Seção 4.2.2.

Cabe ainda destacar que, dando uma atenção especial as fases do ciclo de vida dos ativos, foram identificadas 67 medidas sobre planejamento, 46 sobre implantação, 55 sobre Operação & Manutenção e 11 sobre Monitoramento. Já em relação ao nível do planejamento, foram elencadas: 42 medidas estratégicas, 64 medidas táticas e 73 medidas operacionais.

Limitações: A ausência de dados específicos sobre a infraestrutura, ano de construção/idade do ativo, ou acesso a relatórios de manutenção, correções, dificulta uma análise para possível recomendação de medidas. Outra lacuna é a não existência da data de ocorrência dos eventos/impactos, F que possibilitaria elaborar uma série histórica, a realização de análises mais robustas sobre os impactos associados à mudança do clima e à infraestrutura de transportes terrestres, e assim propor medidas de adaptação.

Contudo, torna-se difícil recomendar medidas específicas, considerando a dimensão do território nacional, a diversidade da infraestrutura e seus ativos, principalmente a rodoviária. Cabe destacar que a ausência de informação sobre a idade do ativo, por exemplo, ou a situação de sistemas de drenagem, dificulta qualquer recomendação mais específica (Ver Produto 2 – Quadros 6 e 7). Seria necessário um diagnóstico por trecho/km de rodovia ou ferrovia, por exemplo, ou por Obras de

Artes Especiais (OAE), que somente poderão ser realizados durante inspeções e manutenções periódicas.

PN 6.2. "Como e quais dados são coletados atualmente e o que precisa ser aperfeiçoado nesse processo de coleta?".

Como o tema é relativamente novo, a disponibilidade de dados é a principal lacuna existente e uma das principais barreiras a serem superadas. Não existem dados disponíveis numa base única e, conforme já relatado em etapas anteriores do estudo AdaptaVias (Etapa 2), quando disponíveis, estes estão pulverizados, fora de padrão e não georreferenciados. Foram considerados no estudo a disponibilidade de dados, fonte da referência, formato, tipo de dado, qualidade, relevância, horizonte temporal e alinhamento dos dados com o método de análise. Os dados disponibilizados por órgãos e entidades relevantes do setor de transporte terrestre rodoviário e ferroviário, que puderam ser consolidados, foram incorporados na base de dados (Produto 2 - Quadro de Consolidação das Bases de Dados - Anexo II), em que são apresentadas as informações sobre o conteúdo de cada base e as observações pertinentes ao estudo).

Limitações: Ausência da data de ocorrência dos eventos/impactos, o que possibilitaria elaborar uma série histórica, a realização de análises mais robustas sobre os impactos associados ao clima na infraestrutura de transportes terrestres rodoviário e ferroviário, e assim indicar quais medidas de adaptação levantadas na literatura melhor se aplicariam. Outra dificuldade vivenciada foi a identificação de que em um mesmo registro continham diversos impactos em rodovias e ferrovias. Contudo, visando superar essa dificuldade, a equipe executora do projeto empregou esforços para estruturar, padronizar termos e subdividir registros, preservando os dados originais de forma fidedigna. A ausência de dados para os campos mais importantes - sinal climático, impacto biofísico e impacto na infraestrutura - foi outro desafio do estudo. Mesmo diante de dados sem informações sobre a data de ocorrência dos eventos no transporte rodoviário e ferroviário, foi possível identificar os principais danos, com apoio dos questionários disponibilizados no início da Etapa 2.

Recomendações: No modo rodoviário, sugere-se considerar a disponibilidade de dados de informações padronizadas, tanto para vias concessionadas, quanto para vias não concessionadas, sobre FWD , IGG e IRI, que buscam avaliar a condição estrutural de pavimentos; intervenções no trecho rodoviário assim como planos de manutenção contendo informações sobre os trechos historicamente mais críticos; monitoramento e localização de OAE (pontes e viadutos), com idade do ativo, altura e vão livre, patologias apontadas na avaliação estrutural e grau/nota estrutural. Sugere-se que seja avaliado junto ao DNIT a viabilidade de tornar público o acesso aos dados do SGO; monitoramento e localização dos dispositivos de drenagem (bueiros, caixas de passagem, descidas d'água, dentre outros.) com idade do ativo, patologias apontadas na avaliação estrutural e grau/nota estrutural.

No modo ferroviário, sugere-se considerar a disponibilidade de dados de intervenções no trecho, assim como planos de manutenção contendo informações sobre os trechos historicamente mais críticos; dados de monitoramento de via permanente, como geometria os quais também são

indicadores de sensibilidade e exposição; dados de monitoramento de OAE (pontes e viadutos), que possuam a idade do ativo, vão livre, altura, tipo de estrutura, patologias apontadas na avaliação estrutural, os quais também são indicadores de sensibilidade e exposição. Sugere-se que seja avaliado junto ao DNIT a viabilidade de tornar público o acesso aos dados do Sistema de Gestão de Obras de Artes Especiais - SGO; dados de operação e caracterização da infraestrutura ferroviária - de Rampa máxima (%) e Raio de curva (metros) que podem demonstrar áreas com maior sensibilidade à mudança do clima; e velocidade máxima autorizada, assumindo que a diminuição histórica do VMA pode ser inferida como problemas na infraestrutura, levando ao aumento da sensibilidade.

A base poderia estar integrada com o Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN) e ao Centro Nacional de Gerenciamento de Riscos e Desastres (CENAD), em especial aos dados de monitoramento e emissão de alertas de desastres naturais, unidade de pesquisa vinculada ao Ministério da Ciência, Tecnologia e Inovações (MCTI) e o Sistema Integrado de Informações sobre Desastres (S2iD), plataforma do Sistema Nacional e Proteção e Defesa Civil, com o objetivo de qualificar e dar transparência à gestão de riscos e desastres no Brasil, por meio da informatização de processos e disponibilização de informações sistematizadas.

Foram propostos indicadores de capacidade adaptativa (Produto 4 – Quadros 4 e 5) para os modos rodoviário e ferroviário, e foi sugerido que o Índice de Desempenho Ambiental (IDA) seja revisado de modo a incorporar uma dimensão “Risco climático” ou “Adaptação à mudança do clima” e que sejam considerados outros indicadores mais específicos relacionados à mudança do clima, incluindo governança climática, disponibilidade de dados e acesso à informação, recursos tecnológicos e financeiros e infraestrutura. Também seria recomendável que a participação das instituições/empresas fosse obrigatória.

PN 6.3. “Quais são as orientações para empreendedores quanto à análise de risco climático nas infraestruturas de transportes terrestres no país?”

A análise de risco climático é um passo importante para o diagnóstico, ou seja, a identificação das áreas mais críticas e sensíveis e que merecem uma atenção prioritária, também chamadas de *hotspots*, essas áreas possuem um alto risco frente às ameaças climáticas. É fundamental adquirir conhecimento sobre as ameaças, os possíveis impactos da mudança do clima sobre os ativos que compõem a infraestrutura federal de transporte terrestre (rodovias e ferrovias), de modo a induzir uma reflexão acerca das medidas necessárias à incorporação de medidas de controle e resposta nas várias fases do ciclo de vida desses ativos. Avaliações de risco climático são úteis para aferir a necessidade e urgência de medidas de adaptação, planejar ações e fornecer os recursos necessários. As medidas de adaptação envolvem construir edificações e infraestruturas mais seguras e sustentáveis, restaurar os ecossistemas danificados, que são consideradas medidas promissoras de adaptação baseada em ecossistemas, planos de manutenção periódicos, ações corretivas, entre outras medidas. Os empreendedores precisam conhecer o problema, que a mudança do clima é evidente e que gera impactos sem precedentes. O custo de não incorporar a análise de risco e uma estratégia de adaptação para os empreendimentos de transportes terrestres

será muito maior no futuro. Ignorar o problema e não agir no presente custará muito mais no futuro, com risco de perdas de vida, econômicas e ambientais.

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PRODUTO 6 - MEDIDAS DE ADAPTAÇÃO. Anexo I. Repositório de Pesquisa

BASE COMPLEMENTAR

Document Title	Authors	Language	Document Type	Publication Year	Link
Adaptação às Mudanças do Clima: Infraestrutura de Transporte. PRODUTO 5 - IDENTIFICAÇÃO E CLASSIFICAÇÃO DAS ESTRATÉGIAS ADAPTATIVAS. 2	CENTRO CLIMA/COPPE/UFRJ	Portuguese	Report	2015	http://www.centroclima.coppe.ufrj.br/images/documentos/TransportesProduto_5.pdf
Climate Change Adaptation Strategy for the City of Rio de Janeiro.	CENTRO CLIMA/COPPE/UFRJ	English	Report	2016	http://www.centroclima.coppe.ufrj.br/images/Noticias/documentos/plano_de_adaptacao-ENG-FINAL.pdf
Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change.	CONVENTION OF BIOLOGICAL DIVERSITY.	English	Report	2009	https://www.cbd.int/doc/publications/cbd-ts-41-en.pdf
Oportunidades para políticas públicas em mudanças climáticas.	FUNDAÇÃO GRUPO BOTICÁRIO & ICLEI. ADAPTAÇÃO BASEADA EM ECOSSISTEMAS.	Portuguese	Report	2014	https://e-lib.iclei.org/wp-content/uploads/2018/10/Adapata%C3%A7%C3%A3o_baseada_em_ecossistemas.pdf
Oportunidades para políticas públicas em mudanças climáticas.	FUNDAÇÃO GRUPO BOTICÁRIO & ICLEI. ADAPTAÇÃO BASEADA EM ECOSSISTEMAS.	Portuguese	Report	2015	https://www.fundacaogrupoboticario.org.br/pt/Biblioteca/AbE_2015.pdf
Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Change.	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE	English	Report	2007	https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf
Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE	English	Report	2014	https://www.ipcc.ch/report/ar5/wg2/
Climate Change 2022. Impacts, Vulnerability and Adaptation. Summary for Policymakers.	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE	English	Report	2022	https://www.ipcc.ch/report/ar6/wg2/
Plano Nacional de Adaptação à Mudança do Clima. Grupo Executivo do Comitê Interministerial de Mudança do Clima – GEx-CIM.	MINISTÉRIO DO MEIO AMBIENTE	Portuguese	Report	2015	https://www.mds.gov.br/webarquivos/arquivo/seguranca_alimentar/caisan/Publicacao/Caisan_Nacional/PlanoNacionaldeAdaptacaoaMudancadoClima_Junho2015.pdf
Potential impacts of climate change on US transportation: Special report 290.	NATIONAL RESEARCH COUNCIL	English	Report	2008	https://nap.nationalacademies.org/catalog/12179/potential-impacts-of-climate-change-on-us-transportation-special-report
Anglia 2019 –2024 Route Weather Resilience and Climate Change Adaptation Plan.	NETWORK RAIL	English	Report	2020	https://www.networkrail.co.uk/wp-content/uploads/2016/11/Anglia-Route-WRCCA-Plan.pdf
London North East and East Midlands Route CP6 Weather Resilience and Climate Change Adaptation Plans 2019-2024.	NETWORK RAIL	English	Report	2020	https://www.networkrail.co.uk/wp-content/uploads/2020/10/LNE-and-EM-Route-WRCCA-Plan-CP6.pdf
A importância do setor de transporte para o aumento de resiliência das cidades frente à mudança climática: uma proposta de plano de ação para o Rio de Janeiro.	SANTOS, Andréa Souza.	Portuguese	Thesis	2014	https://www.pet.coppe.ufrj.br/index.php/pt/producao-academica/teses/2014/143-a-importancia-do-setor-de-transporte-para-o-aumento-de-resiliencia-das-cidades-frente-a-mudanca-climatica-uma-proposta-de-plano-de-acao-para-a-cidade-do-rio-de-janeiro
A Sustainability Framework To Prioritize Proactive Climate Change Adaptation Investments For Impacts On Road Infrastructure Using A Data-Driven Approach.	SCHWEIKERT, Amy Elizabeth.	English	Thesis	2015	https://www.semanticscholar.org/paper/A-Sustainability-Framework-To-Prioritize-Proactive-Schweikert/f01cf894c0830848341a1b07256503df32835923
Impactos, vulnerabilidades e adaptação às mudanças climáticas. Contribuição do Grupo de Trabalho 2 do Painel Brasileiro de Mudanças Climáticas ao Primeiro Relatório da Avaliação Nacional sobre Mudanças Climáticas	PAINEL BRASILEIRO DE MUDANÇAS CLIMÁTICAS	Portuguese	Report	2014	http://www.pbmc.coppe.ufrj.br/documentos/GT2_sumario_portugues_v2.pdf
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Financiamento climático para adaptação no Brasil. Mapeamento de fundos nacionais e internacionais.	INSTITUTO ETHOS & WWF	Portuguese	Report	2017	https://www3.ethos.org.br/wp-content/uploads/2017/09/Publicaca%C3%A7%C3%A3o_Financiamento_Clim%C3%A1tico_compressed.pdf
Nature-based solutions to climate change adaptation.	IIED	English	Report	2019	https://pubs.iied.org/17725iied

Calibração e Aferição Do Modelo Hdm-4 Para As Condições Da Rede De Rodovias Do Brasil.	DEPARTAMENTO NACIONAL DE INFRAESTRUTURA DE TRANSPORTES	Portuguese	Presentation	-	https://www.gov.br/dnit/pt-br/1a-semana-do-planejamento/13CalibraoeaferiodomodeloHMD4.pdf
Developing Key Performance Indicators for Climate Change Adaptation and Resilience Planning.	DUKE NICHOLAS INSTITUTE	English	Report	2022	https://nicholasinstitute.duke.edu/sites/default/files/publications/developing-key-performance-indicators-for-climate-change-adaptation-and-resilience-planning.pdf

PRODUTO 6 - MEDIDAS DE ADAPTAÇÃO. Anexo I. Repositório de Pesquisa

MODO: FERROVIÁRIO

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI
Implications of climate change for railway infrastructure	Palin, EJ; Oslakovic, IS; Gavin, K; Quinn, A	WILEY INTERDISCIPLINARY REVIEWS-CLIMATE CHANGE	English	Review	climate change; climate change adaptation; exposure; extreme weather; hazards; infrastructure; railway; risk assessment; vulnerability	STOCHASTIC WEATHER GENERATORS; HIGH SUMMER TEMPERATURES; TRANSPORT INFRASTRUCTURE; EXTREME WEATHER; EXPERT JUDGMENT; CHANGE IMPACTS; FLOOD DAMAGE; RISK; RESILIENCE; ADAPTATION	Weather phenomena can result in severe impacts on railway infrastructure. In future, projected changes to the frequency and/or intensity of extreme weather events could change weather-infrastructure risk profiles. Infrastructure owners and operators need to manage current weather impacts and put in place adequate plans to anticipate and adapt to changes in future weather risks, or mitigate the impacts arising from those risks. The assessment of the risk posed to railway infrastructure from current and future weather is dependent on a good understanding of the constituent components of risk: hazard, vulnerability, and exposure. A good understanding of the baseline and projected future risk is needed in order to understand the potential benefits of various climate change adaptation actions. Traditional risk assessment methods need some modification in order to be applied to climate change timescales, for which decisions need to be made under deep uncertainty. This review paper highlights some key challenges for assessing the risk, including: managing uncertainties; understanding weather-impact relationships and how they could change with climate change; assessing the costs of current and future weather impacts and the potential cost versus benefit of adaptation; and understanding practices and tools for adapting railway infrastructure. The literature reveals examples of progress and good practice in all these areas, providing scope for effective knowledge-sharing-across the railway infrastructure and other sectors-in support of infrastructure resilience and adaptation. This article is categorized under: Assessing Impacts of Climate Change > Evaluating Future Impacts of Climate Change	230	2021	10.1002/wcc.728
Climate change research on transportation systems: Climate risks, adaptation and planning	Wang, TN; Qu, ZH; Yang, ZL; Nichol, T; Clarke, G; Ge, YE	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Climate change; Road; Railway; Climate risk; Adaptation strategy; Transport planning	SEA-LEVEL RISE; HIGH SUMMER TEMPERATURES; ROAD INFRASTRUCTURE; POLICY CAPACITY; LAND-USE; IMPACTS; MANAGEMENT; RESILIENCE; CARBON; VULNERABILITY	With the occurrence of more frequent and intense climate change events, transportation systems, including their infrastructure and operations become increasingly vulnerable. However, the existing research related to climate risks, adaptation and planning in the transport sector is still at an embryonic stage. Understanding such, this paper presents a critical review on climate risks, adaptation strategies and planning in the context of road and rail transportation systems. It aims to conduct a rigorous survey, to highlight any significant research gaps not addressed in past studies and to analyse current emerging topics to guide future directions. It critically dissects the selected papers by categorising them into several dimensions to reveal the status quo and potential challenges, including climate risk assessment, transport asset management, climate planning and policy, and adaptation of transport infrastructure to climate change. It will provide valuable references for future research and constructive insights and empirical guidance on climate adaptation, risk analysis, transport planning and other important relevant topics.	136	2020	10.1016/j.trd.2020.102553
Sea-level rise impacts on transport infrastructure: The notorious case of the coastal railway line at Dawlish, England	Dawson, D; Shaw, J; Gehrels, WR	JOURNAL OF TRANSPORT GEOGRAPHY	English	Article	Climate change; Adaptation; Resilience; Semi-empirical; Rail network; Economic impact	climate change; STAKEHOLDER REPRESENTATION; SEVERE STORMS; PROBABILITIES; MANAGEMENT; INSIGHTS; WEATHER; TRENDS; FLOODS; ROAD	Future climate change is likely to increase the frequency of coastal storms and floods, with major consequences for coastal transport infrastructure. This paper assesses the extent to which projected sea-level rise is likely to impact upon the functioning of the Dawlish to Teignmouth stretch of the London to Penzance railway line, in England. Using a semi-empirical modelling approach, we identify a relationship between sea-level change and rail incidents over the last 150 years and then use model-based sea-level predictions to extrapolate this relationship into the future. We find that days with line restrictions (DLRs) look set to increase by up to 1170%, to as many as 84-120 per year, by 2100 in a high sea-level rise scenario (0.55-0.81 m). Increased costs to the railway industry deriving from maintenance and line restrictions will be small (pound millions) in comparison with damage caused by individual extreme events (10s pound of millions), while the costs of diversion of the railway are higher still (100s pound of millions to billions). Socio-economic costs to the region are likely to be significant although they are more difficult to estimate accurately. Finally, we explain how our methodology is applicable to vulnerable coastal transport infrastructure worldwide. (C) 2015 The Authors. Published by Elsevier Ltd.	102	2016	10.1016/j.jtrangeo.2015.11.009
Climate services in support of climate change impact analyses for the German inland transportation system	Hansel, S; Brendel, C; Haller, M; Krahenmann, S; Razafimaharo, CS; Stanley, K; Brienen, S; Deutschlander, T; Rauthe, M; Walter, A	METEOROLOGISCHE ZEITSCHRIFT	English	Article	climate change; extreme events; transportation; climate impact assessment; climate change adaptation; BMDV Network of Experts	BIAS CORRECTION; SCENARIO FRAMEWORK; ROAD NETWORKS; EURO-CORDEX; MODEL; WEATHER; EXTREMES; TEMPERATURE; MANAGEMENT; INFRASTRUCTURES	Climate change and extreme weather events are an increasing challenge for society and the economy, including the transport sector. A sustainable and resilient transportation system therefore requires information on the temporal and spatial pattern of risks induced by climate change and the assessment of resulting vulnerabilities. Such analyses in the past were usually made separately for each mode of transport based on different observational and climate model datasets and using different methodological approaches to analyse climatic changes and their impacts on the transport infrastructure. Within the research network BMDV Network of Experts an intermodal perspective is taken on transportation. Common observational and climate model datasets as well as a standardized analysis framework were coordinated and agreed upon to form the basis for comparable climate impact assessments for roads, railways and inland waterways. This manuscript introduces the climatological datasets and methodological approaches for the climate change and climate impact analysis used for the transportation sector and beyond. Selected results on the projected increases of extreme temperature and heavy precipitation are exemplarily presented in order to illustrate the need for developing climate change adaptation measures for the German inland transport system.	97	2022	10.1127/metz/2022/1117
Risk assessment of the crushed rock structure embankments of the Qinghai-Tibet Railway under a warming climate	Zhao, HT; Hou, YD; Jiang, GL; Wu, QB	COLD REGIONS SCIENCE AND TECHNOLOGY	English	Article	Risk assessment; Climate warming; Service life; Crushed rock embankments; Qinghai-Tibet Railway	ALASKA PUBLIC INFRASTRUCTURE; PERMAFROST REGIONS; DEFORMATION CHARACTERISTICS; REVETMENT EMBANKMENT; COOLING PERFORMANCE; THERMAL PERFORMANCE; PLATEAU; TEMPERATURE; ADAPTATION; IMPACT	On the Qinghai-Tibet Plateau, transportation infrastructure has been greatly affected by permafrost degradation owing to the increasing air temperature caused by climate change. This study presents a risk assessment model for evaluating the viability of the crushed rock embankment under the scenario of climate warming. The results demonstrate that the service life of an embankment is determined by the time it spends at the lowest or low levels of failure risk. At the failure probability threshold of 0.1, the service lives of open crushed rock-based and Ushaped crushed rock embankments are longer than 100 years, those of closed crushed rock-based embankments are about 66 years, and those of crushed rock revetments are less than 40 years. In essence, the longer an embankment has been in service, the stronger its ability to resist climate warming. Based on these results, Ushaped crushed rock and crushed rock-based embankments are the most capable of offsetting the effects of climate warming on permafrost and should account for a higher proportion of independent embankment structures. The same cannot be said for crushed rock revetments, which should only be used as auxiliary engineering measures. Despite this recommendation, regular maintenance should be conducted on the open system crushed rock embankments because the high winds on the Qinghai-Tibet Plateau fill the embankments with sand, which has a negative effect on the long-term stability of the embankments.	92	2022	10.1016/j.coldregions.2022.103509
Adaptation Methods for Transportation Infrastructure Built on Degrading Permafrost	Dore, G; Niu, FJ; Brooks, H	PERMAFROST AND PERIGLACIAL PROCESSES	English	Review	permafrost degradation; adaptation; mitigation; transportation infrastructure	RAILWAY EMBANKMENT; NUMERICAL-ANALYSIS; NATURAL-CONVECTION; INSULATION; PROTECTION; REGIONS; LAYER	Climate warming since the second half of the 20(th) century has begun to significantly impact infrastructure integrity in permafrost environments and has already resulted in expensive maintenance operations. Engineers in countries with permafrost are actively working to adapt the design of structures to degrading permafrost conditions. Here, we review permafrost degradation processes and their geotechnical impacts. We also summarise mitigation techniques for protecting transportation infrastructure built on permafrost and for preventing permafrost degradation near these facilities based on the results of field and laboratory tests, numerical simulations and engineering practices on such infrastructure. We draw four conclusions: (1) climate warming and local surface changes have caused permafrost degradation, and resulted in instability and damage leading to infrastructure maintenance and repair; (2) passive cooling methods, including high-albedo surfacing, sun-sheds, air convection embankments, air ducts, heat drains and thermosyphons, have shown consistent cooling effects, if designed appropriately; (3) mitigation and adaptation methods are more expensive than conventional construction techniques as shown by construction cost data for a test site in Canada; and (4) the influence of continued climate warming on permafrost and infrastructure design must be considered within the design of new or rehabilitated infrastructure and within the context of the infrastructure's service life. Copyright (c) 2016 John Wiley & Sons, Ltd.	84	2016	10.1002/ppp.1919
A Framework for Identification, Assessment and Prioritization of Climate Change Adaptation Measures for Roads and Railways	Andersson-Skoeld, Y; Nordin, I; Nyberg, E; Johannesson, M	INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	English	Article	adaptation measure sustainability assessment; stepwise methodology; cause-effect-relationship	INFRASTRUCTURE; RISK; IMPACTS; MITIGATION; NETWORKS; SYSTEMS; SECTOR; COSTS; FLOOD	Severe accidents and high costs associated with weather-related events already occur in today's climate. Unless preventive measures are taken, the costs are expected to increase in future due to ongoing climate change. However, the risk reduction measures are costly as well and may result in unwanted impacts. Therefore, it is important to identify, assess and prioritize which measures are necessary to undertake, as well as where and when these are to be undertaken. To be able to make such evaluations, robust (scientifically based), transparent and systematic assessments and valuations are required. This article describes a framework to assess the cause-and-effect relationships and how to estimate the costs and benefits as a basis to assess and prioritize measures for climate adaptation of roads and railways. The framework includes hazard identification, risk analysis and risk assessment, identification, monetary and non-monetary evaluation of possible risk reduction measures and a step regarding distribution-, goal- and sensitivity analyses. The results from applying the framework shall be used to prioritize among potential risk reduction measures as well as when to undertake them.	82	2021	10.3390/ijerph182312314
Adapting Railway Maintenance to Climate Change	Garmabaki, AHS; Thaduri, A; Famurewa, S; Kumar, U	SUSTAINABILITY	English	Article	climate change; climate adaptation; railway infrastructure; resilience of transport	INFRASTRUCTURE; ADAPTATION; IMPACTS; RISK; MANAGEMENT; WEATHER	Railway infrastructure is vulnerable to extreme weather events such as elevated temperature, flooding, storms, intense winds, sea level rise, poor visibility, etc. These events have extreme consequences for the dependability of railway infrastructure and the acceptable level of services by infrastructure managers and other stakeholders. It is quite complex and difficult to quantify the consequences of climate change on railway infrastructure because of the inherent nature of the railway itself. Hence, the main aim of this work is to qualitatively identify and assess the impact of climate change on railway infrastructure with associated risks and consequences. A qualitative research methodology is employed in the study using a questionnaire as a tool for information gathering from experts from several municipalities in Sweden, Swedish transport infrastructure managers, maintenance organizations, and train operators. The outcome of this questionnaire revealed that there was a lower level of awareness about the impact of climate change on the various facets of railway infrastructure. Furthermore, the work identifies the challenges and barriers for climate adaptation of railway infrastructure and suggests recommended actions to improve the resilience towards climate change. It also provides recommendations, including adaptation options to ensure an effective and efficient railway transport service.	76	2021	10.3390/su132413856

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI
Identification of critical sections of the Spanish transport system due to climate scenarios	Ortega, E; Martin, B; Aparicio, A	JOURNAL OF TRANSPORT GEOGRAPHY	English	Article	Accessibility; Climate scenarios; Criticality; Transport planning	HIGH-SPEED RAIL; VULNERABILITY ANALYSIS; CRITICAL LINKS; INFRASTRUCTURE INVESTMENTS; SUPPORT-SYSTEM; SPATIAL EQUITY; IMPACTS; ADAPTATION; RESILIENCE; NETWORKS	In recent years climate change has become a multidisciplinary research topic that addresses the challenges facing transport infrastructure planning, construction and operation. The study of the adaptation of transport systems to new environmental conditions is often based on the interrelated concepts of resilience, vulnerability and criticality. In this paper we assess the criticality of sections of Spain's inland transport network under the effects of changing climate scenarios obtained from a specific climate projection (using the time periods 2010-2020 and 2045-2055). The functionality of the transport system is characterised here in terms of territorial accessibility. The results identify and locate the most critical stretches of the Spanish transport network. In general terms, the most relevant sections in regard to accessibility will not be exposed to the greatest changes in climate variables. Up to 2.8% of the roads and 5.9% of the railways that contribute most significantly to the territorial accessibility of the transport system will undergo the greatest variations between climate scenarios. This paper contributes to this field of research by developing a screening tool that represents a valuable instrument for the infrastructure decision-making process at the strategic level. Action areas for proactive adaptation measures can be identified in order to reduce impacts and costs, while prioritising the maintenance or reconstruction of the most critical stretches in the case of a future climate event.	76	2020	10.1016/j.jtrangeo.2020.102691
Development of a GIS coastal land-use planning tool for coastal erosion adaptation based on the exposure of buildings and infrastructure to coastal erosion, Quebec, Canada	Fraser, C; Bernatchez, P; Dugas, S	GEOMATICS NATURAL HAZARDS & RISK	English	Review	Adaptation tool; GIS planning tool; coastal erosion; coastal hazards; exposure assessment; vulnerability; knowledge transfer process	SEA-LEVEL RISE; climate change; VULNERABILITY ASSESSMENT; ENVIRONMENTAL HAZARDS; VISUALIZATION; GOVERNANCE; INDICATORS; MANAGEMENT; KNOWLEDGE; AREAS	This study presents the development of a geographic information system (GIS) land-use planning tool for coastal areas based on the calculated exposure to coastal erosion of buildings and infrastructure. Responding to the needs of land-use planners, who are involved in the project from the beginning, this tool facilitates identification of adaptation solutions based on coastal sensitivity to erosion. All buildings, roads, railways, aqueducts, sewer systems, hiking trails and bicycle routes were mapped at high resolution, and an exposure value was assigned to each for seven time horizons between 2015 and 2100. The calculations were based on three parameters: (1) the distance between the structure and the shoreline or coastline; (2) the most likely shoreline or coastline migration rate for each coastal geomorphology behaviour unit (CGBU); and (3) the maximum event retreat measured during a storm for each type of coast. This method was applied to Baie des Chaleurs in Quebec, Canada. The area comprises 11 municipalities with a total of 105 km of coast. The approach not only produces current and future portraits of building and infrastructure exposed to erosion, but also provides an original land-use planning and intervention tool for coastal areas.	75	2017	10.1080/19475705.2017.1294114
Flexible Planning for Intercity Multimodal Transport Infrastructure	Hadjidemetriou, GM; Teal, J; Kapetas, L; Parlikad, AK	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Transportation networks; Roadways; Railways; Dynamic adaptive policy pathways; Adaptation; Transport mode switching	ADAPTIVE POLICY PATHWAYS; climate change; ADAPTATION; TRAVEL; FRAMEWORK; DEMAND	Planning transport infrastructure development involves high levels of uncertainty due to socioeconomic, environmental, and technological changes. Methodologies currently used in transport planning often have minimal consideration for adaptiveness, leading to costly redesigns or cancellation of entire projects. Presented herein is the investigation of the applicability of dynamic adaptive policy pathways, which is a methodology predominantly used in the field of flood-risk planning, to long-term transport infrastructure planning. Specifically, the paper investigates whether this methodology could facilitate ongoing adaptation to variations in service demand and capacity. It demonstrates this by examining future demand and capacity of road and rail travel between Manchester, United Kingdom, and London using publicly available data and information sources. The study shows that dynamic adaptive policy pathways is useful for identifying periods of time of significant capacity vulnerability for the examined transport network in the coming decade. The method is demonstrated to be valuable for identifying the points in time when policy-makers will have to make decisions and for assessing the impact of transport mode switching. This can have implications of cost-saving and improved service delivery.	74	2022	10.1061/(ASCE)IS.1943-555X.0000664
Impact analysis of climate change on rail systems for adaptation planning: A UK case	Wang, TN; Qu, ZH; Yang, ZL; Nichol, T; Dimitriu, D; Clarke, G; Bowden, D; Lee, PT	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Climate change; Risk analysis; Adaptation planning; Rail transport; Transport resilience; Bayesian network	HIGH SUMMER TEMPERATURES; SAFETY; RESILIENCE; TRANSPORT; NETWORK; DELAYS	Climate change poses critical challenges for rail infrastructure and operations. However, the systematic analysis of climate risks and the associated costs of tackling them, particularly from a quantitative perspective, is still at an embryonic phase due to the kaleidoscopic nature of climate change impacts and lack of precise climatic data. To cope with such challenges, an advanced Fuzzy Bayesian Reasoning (FBR) model is applied in this paper to understand climate threats of the railway system. This model ranks climate risks under high uncertainty in data and comprehensively evaluates these risks by taking account of infrastructure resilience and specific aspects of severity of consequence. Through conducting a nationwide survey on the British railway system, it dissects the status quo of primary climate risks. The survey implies that the top potential climate threats are heavy precipitation and floods. The primary risks caused by the climate threats are bridges collapsing and bridge foundation damage due to flooding and landslips. The findings can aid transport planners to prioritise climate risks and develop rational adaptation measures and strategies.	69	2020	10.1016/j.trd.2020.102324
A Systematic Review of Civil and Environmental Infrastructures for Coastal Adaptation to Sea Level Rise	Nazarnia, H; Nazarnia, M; Sarmasti, H; Wills, WO	CIVIL ENGINEERING JOURNAL-TEHRAN	English	Review	Sea Level Rise; Coastal Communities; Infrastructure; Resilience	climate change; SEAWATER INTRUSION; IMPACT; VULNERABILITY; RESILIENCE; TRANSPORT; INUNDATION; DRAINAGE; RETREAT; ZONE	Rising levels of seas and oceans due to global warming could drastically affect the daily lives of residents in coastal belts and lowland areas. Many of the most heavily populated regions in the world have been developed on the shorelines. Sea-level rise could directly affect the serviceability of urban structures and infrastructures of coastal regions; effects may include intrusion of salt water into drinking water resources, submergence of roads and railways, flowing of seawater into wastewater networks, and exacerbating land subsidence. These reasons have urged climate-change and infrastructure resilience researchers to focus on methods for prediction and prevention of SLR effects on urbanization systems. Most of the studies have concentrated on environmental aspects or modeling of flooding, however, there is a lack of research on behavior of urban lifelines for long-term planning. Hence, the resilience of coastal cities has become of more interest in recent years. This paper presents a meta- analysis and review of existing literatures on the impacts of SLR on civil infrastructure. We categorize these impacts based on different types of infrastructures (e.g. water, transportation, energy) and regions. The review provides i) an intensive coverage of the existing literature on adaptations ii) an exploration of current gaps and challenges in civil infrastructures in different regions of the world and iii) the engineering perspective of SLR besides managing directions to be useful for engineers, advisory committees, policy makers, and scholars for future studies.	68	2020	10.28991/cej-2020-03091555
Risk assessment of potential thaw settlement hazard in the permafrost regions of Qinghai-Tibet Plateau	Ni, J; Wu, TH; Zhu, XF; Wu, XD; Pang, QQ; Zou, DF; Chen, J; Li, R; Hu, GJ; Du, YZ; Hao, JM; Li, XF; Qiao, YP	SCIENCE OF THE TOTAL ENVIRONMENT	English	Article	Permafrost; Thaw settlement hazard; Engineering construction; Qinghai-Tibet Plateau	climate change; THERMAL STATE; ACTIVE LAYER; DEGRADATION; MAP	Climate warming could exacerbate the occurrence of thaw settlement hazard in the permafrost regions of the Qinghai-Tibet Plateau (QTP), which would threaten the stability of engineering infrastructure in cold regions. The risk associated with permafrost settlement, valuable for the regional sustainable development, remains poorly assessed or understood on the QTP. In this study, three common Geo-hazard indices were used to assess the settlement risks in the permafrost regions of the QTP, including the settlement index, the risk zonation index, and the allowable bearing capacity index. However, large spatial differences existed in simulating the risk maps by using the abovementioned Geo-hazard indices. Hence, we developed a combined index (I-c) by integrating the three indices to reduce the uncertainty of the simulations. The results indicated that the ground ice is a critical factor for assessing the settlement risk in permafrost regions. We also applied the Ic to assess the settlement risk along the Qinghai-Tibet Railway (QTR). The proportion of low-risk area along the QTR would be the highest (45.38%) for the future periods 2061-2080 under Representative Concentration Pathway 4.5. The medium-risk area combined with the high-risk area would be accounted for more than 40%, which were located at the boundary of the present permafrost regions. Therefore, the corresponding adaptation measures should be taken to reduce the potential economic losses caused by the high-risk regions to the infrastructure. Overall, the results would present valuable references for engineering design, construction and maintenance, and provide insights for early warning and prevention of permafrost thaw settlement hazard on the QTP. (C) 2021 Elsevier B.V. All rights reserved.	66	2021	10.1016/j.scitotenv.2021.145855
Assessing storm surge risk under future sea-level rise scenarios: a case study in the North Adriatic coast	Rizzi, J; Torresan, S; Zabeo, A; Critto, A; Tosoni, A; Tomasin, A; Marcomini, A	JOURNAL OF COASTAL CONSERVATION	English	Article	Storm surge; Climate change; Sea-level rise; Regional risk assessment; Joint probability method	climate change; ASSESSMENT METHODOLOGY; NATURAL HAZARDS; FLOOD RISK; VULNERABILITY; SCALE; MAPS	Low-lying coastal areas are often prone to storm surge flooding that can render severe damages to properties, destruction of habitats, threat to human safety and the environment. The impacts of coastal flooding are also expected to increase in the future as a consequence of global climate change and sea-level rise. This paper presents a comprehensive assessment of the potential risks raised by storm surge and sea-level rise on multiple coastal targets (i.e., population, buildings, infrastructures, agriculture, natural and semi-natural environments and cultural heritage) in the Northern Adriatic coast in Italy. Through the assessment of hazard, exposure, vulnerability and risk, a Regional Risk Assessment (RRA) methodology allowed identifying and prioritizing hot-spot risk areas and targets requiring particular attention for the definition of adaptation strategies. Hazard scenarios were based on the analysis of tide gauge data (elaborated with the Joint Probability Method) and of different sea-level rise projections for the year 2100. Geographical-information analysis was then used to characterize vulnerability patterns of exposed natural and human systems and to make a spatial ranking of risks. Maps produced for the worst scenario showed that beaches are the target at higher risk (with more than 90% of the surface in the higher relative risk class) due to the low elevation and high proximity to the coastline. Also cultural heritage (i.e., villas, historical buildings and roads) and wetlands are highly threatened by storm surge flooding. The relative risks will be lower (i.e., between 25% and 40% of their surface/length in the higher relative risk class) for most of the other receptors (i.e., local roads, railways, natural and semi-natural environments and agricultural areas), including population and buildings that are mostly classified in lower risk classes. The overall results of the assessment, including maps and risk metrics, can be useful to rise the attention of coastal managers about the need to adapt to climate change, developing climate-proof policies and programs for the sustainable management of coastal zones.	65	2017	10.1007/s11852-017-0517-5
The treatment of climate change impacts and adaptation in the environmental impact assessment of the standard Gauge railway project in Tanzania	Rweyendela, AG; Mwegoha, WJ	CLIMATE AND DEVELOPMENT	English	Article	Transport infrastructure; climate change; adaptation; environmental impact assessment; environmental impact statement		Transport remains one of the essential infrastructures, crucial for socio-economic development. However, climate change threatens the transport infrastructure development gains already achieved globally. The incorporation of climate change and adaptation capabilities into environmental impact assessment (EIA) processes has been extensively discussed and linked to enhanced project climate resilience. However, a considerable research gap remains unexplored, and that is assessing whether and how EIA has been used to climate-proof development proposals in Africa. This study examined how climate change impacts and adaptation capabilities featured in the EIA of a major transport infrastructure project in Tanzania. It draws on reviewing the project's environmental impact statement (EIS) using review criteria derived from the literature. The findings revealed that all EIA stages addressed climate change in one way or another, with some of the criteria more comprehensively treated than others. A closer examination unveiled several good practices, which evidence appreciation for climate science and considerable strength in climate change preparedness. The results highlight EIA's potential to steer climate efforts among vulnerable communities systematically. This paper will contribute to the international discussion on this issue and offer a basis for further research towards deeper engagement between the actors within EIA, transport planning and climate networks.	64	2022	10.1080/17565529.2021.1911774

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Climate change damages to Alaska public infrastructure and the economics of proactive adaptation	Melvin, AM; Larsen, P; Boehlert, B; Neumann, JE; Chinowsky, P; Espinet, X; Martinich, J; Baumann, MS; Rennels, L; Bothner, A; Nicolsky, DJ; Marchenko, SS	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	English	Article	Alaska; climate change; damages; adaptation; infrastructure	THAW SETTLEMENT; COASTAL-PLAIN; ACTIVE LAYER; FIRE REGIME; PERMAFROST; VULNERABILITY; ROADS; IMPACTS; HAZARD; COSTS	Climate change in the circumpolar region is causing dramatic environmental change that is increasing the vulnerability of infrastructure. We quantified the economic impacts of climate change on Alaska public infrastructure under relatively high and low climate forcing scenarios [representative concentration pathway 8.5 (RCP8.5) and RCP4.5] using an infrastructure model modified to account for unique climate impacts at northern latitudes, including near-surface permafrost thaw. Additionally, we evaluated how proactive adaptation influenced economic impacts on select infrastructure types and developed first-order estimates of potential land losses associated with coastal erosion and lengthening of the coastal ice-free season for 12 communities. Cumulative estimated expenses from climate-related damage to infrastructure without adaptation measures (hereafter damages) from 2015 to 2099 totaled $5.5 billion (2015 dollars, 3% discount) for RCP8.5 and $4.2 billion for RCP4.5, suggesting that reducing greenhouse gas emissions could lessen damages by $1.3 billion this century. The distribution of damages varied across the state, with the largest damages projected for the interior and southcentral Alaska. The largest source of damages was road flooding caused by increased precipitation followed by damages to buildings associated with near-surface permafrost thaw. Smaller damages were observed for airports, railroads, and pipelines. Proactive adaptation reduced total projected cumulative expenditures to $2.9 billion for RCP8.5 and $2.3 billion for RCP4.5. For road flooding, adaptation provided an annual savings of 80-100% across four study eras. For nearly all infrastructure types and time periods evaluated, damages and adaptation costs were larger for RCP8.5 than RCP4.5. Estimated coastal erosion losses were also larger for RCP8.5.	62	2017	10.1073/pnas.1611056113
Flood probability quantification for road infrastructure: Data-driven spatial-statistical approach and case study applications	Kalantari, Z; Cavalli, M; Cantone, C; Crema, S; Destouni, G	SCIENCE OF THE TOTAL ENVIRONMENT	English	Article	Sediment connectivity; Climate change adaptation; GIS; Multivariate statistical model; Decision making	LEAST-SQUARES REGRESSION; SEDIMENT CONNECTIVITY; NATURAL HAZARDS; CATCHMENT-SCALE; AIRBORNE LIDAR; SOIL-EROSION; FRAMEWORK; SYSTEMS; MODEL; MORPHOLOGY	Climate-driven increase in the frequency of extreme hydrological events is expected to impose greater strain on the built environment and major transport infrastructure, such as roads and railways. This study develops a data driven spatial-statistical approach to quantifying and mapping the probability of flooding at critical road-stream intersection locations, where water flow and sediment transport may accumulate and cause serious road damage. The approach is based on novel integration of key watershed and road characteristics, including also measures of sediment connectivity. The approach is concretely applied to and quantified for two specific study case examples in southwest Sweden, with documented road flooding effects of recorded extreme rainfall. The novel contributions of this study in combining a sediment connectivity account with that of soil type, land use, spatial precipitation-runoff variability and road drainage in catchments, and in extending the connectivity measure use for different types of catchments, improve the accuracy of model results for road flood probability. (C) 2016 Elsevier B.V. All rights reserved.	62	2017	10.1016/j.scitotenv.2016.12.147
Impact of summer heat on urban park visitation, perceived health and ecosystem service appreciation	Kabisch, N; Kraemer, R; Masztalerz, O; Hemmerling, J; Puffel, C; Haase, D	URBAN FORESTRY & URBAN GREENING	English	Article	Behaviour; Central Europe; Heat; Leipzig; Perception; Public health; Social survey; Urban green space	GREEN SPACE; PHYSICAL-ACTIVITY; OLDER-PEOPLE; CHALLENGES; CHILDREN; AVAILABILITY; ENVIRONMENTS; BENEFITS; FORESTS; CITY	Urbanization, environmental change and ageing are putting urban health at risk. In many cities, heat stress is projected to increase. Urban green spaces are considered as an important resource to strengthen the resilience of city dwellers. We conducted a questionnaire survey in two structurally distinct parks in Leipzig, Germany, on hot summer days in 2019. We assessed the respondents? activity patterns, satisfaction with the existing infrastructure, heat-related health impairment, changes in park use during heat waves and evaluation of the role of parks in coping with heat stress. We found that the old-grown, tree-rich park was used significantly more frequently for experiencing nature, while the newer, less tree-rich park developed on a former railway-brownfield site was used more often for socializing and having BBQs and picnics. Satisfaction with available drinking fountains and public toilets was generally low and satisfaction with lighting was assessed less satisfactory in the old-grown park. Safety was assessed as satisfactory in general but significantly less satisfactory by female respondents. The heat stress summary score indicating heat-related health impairment was significantly higher for participants in the newer park. A high share of respondents stated that they used parks during heat waves as frequently as usual in the summer (46 %), while some respondents stated that they adapted their park use behaviour (18 %), e.g., by coming later in the evening. Regarding the participants? responses about the role of parks under summer heat conditions, we matched 138 statements to several regulating and cultural ecosystem services, and we found cooling and recreation to be mentioned most often. We concluded that green space planning should diminish usage barriers, such as insufficient lighting and insufficient sanitary infrastructure, to ensure equal park use opportunities for all city dwellers. Specific local environmental and sociocultural conditions, changing environments and climate adaptation must be considered. To maintain ecological processes and functions and to cope with climate change, urban planning should preserve older parks with a large amount of tree coverage while respecting demands for particular built infrastructure.	61	2021	10.1016/j.ufug.2021.127058
Energy infrastructure in India: Profile and risks under climate change	Garg, A; Naswa, P; Shukla, PR	ENERGY POLICY	English	Article	Energy infrastructure; Reverse impact; Vulnerability index	RESOLUTION; ECONOMICS; SECURITY	India has committed large investments to energy infrastructure assets-power plants, refineries, energy ports, pipelines, roads, railways, etc. The coastal infrastructure being developed to meet the rising energy imports is vulnerable to climate extremes. This paper provides an overview of climate risks to energy infrastructures in India and details two case studies - a crude oil importing port and. a western coast railway transporting coal. The climate vulnerability of the port has been mapped using an index while that of the railway has been done through a damage function for RCP 4.5.0 and 8.5 scenarios. Our analysis shows that risk management through adaptation is likely to be very expensive. The system risks can be even greater and might adversely affect energy security and access objectives. Aligning, sustainable development and climate adaptation measures can deliver substantial co-benefits. The key policy recommendations include: i) mandatory vulnerability assessment to future climate risks for energy infrastructures; ii) project and systemic risks in the vulnerability index; iii) adaptation funds for unmitigated climate risks; iv) continuous monitoring of climatic parameters and implementation of adaptation measures, and iv) sustainability actions along energy infrastructures that enhance climate resilience and simultaneously deliver co-benefits to local agents. (C) 2014 Elsevier Ltd. All rights reserved.	60	2015	10.1016/j.enpol.2014.12.007
Adapting rail and road networks to weather extremes: case studies for southern Germany and Austria	Doll, C; Trinks, C; Sedlacek, N; Pelikan, V; Comes, T; Schultmann, F	NATURAL HAZARDS	English	Article	Road networks; Railway operations; Extreme weather events; Climate change; Adaptation; Weather information systems; Investments; Forecasts	climate change; TRANSPORTATION; EVENTS	The assessment of the current impacts of extreme weather conditions on transport systems reveals high costs in specific locations. Prominent examples for Europe are the economic consequences of the harsh winter periods 2009/2010 and 2010/2011 and the floods in Austria, Eastern Europe, Germany and the United Kingdom in 2005 and 2007. Departing from the EC-funded project WEATHER, this paper delves into the subject of adaptation strategies by revisiting the project's general findings on adaptation strategies and by adding two specific cases: (1) advanced winter maintenance on roads in southwest Germany and (2) technical and organizational measures in Alpine rail transport. For these two cases, feasible adaptation strategies are elaborated and their potential is discussed in light of damage cost forecasts up to 2050. For the road sector, we find a high potential to mitigate weather-related costs, although damages here are expected to decline. In contrast, rail systems face strongly increasing damages and the mitigation options offered by improved information and communication systems seem to be largely exploited. Consequently, it is easier to justify expensive adaptation measures for high-cost rail infrastructures than for road transport. A generic analysis of 14 damage cases worldwide, however, revealed that generally awareness raising, cooperation and communication strategies are sufficient to mitigate the most severe damages by natural disasters.	59	2014	10.1007/s11069-013-0969-3
Climate Adaptation of Railways: Lessons from Sweden	Lindgren, J; Jonsson, DK; Carlsson-Kanyama, A	EUROPEAN JOURNAL OF TRANSPORT AND INFRASTRUCTURE RESEARCH	English	Article	climate change; adaptation; vulnerability; transport; railway; Sweden; Europe	INFRASTRUCTURE; IMPACTS; RISK	The current variability in weather and climate is posing a challenge for transport infrastructure. However, during the past decade the need to adapt to a changing climate has attracted increasing attention. This paper summarises a case study on the future vulnerability to climate change of the Swedish railway transport system and its adaptive capacity. The combination of a long time horizon in planning and an expected increasing demand for rail traffic raises many questions regarding how adaptation to climate change can be accounted for in future planning, design and management of railways. The case study was essentially based on interviews with key personnel within the Swedish Rail Administration. Views on vulnerability and adaptation to climate change were documented, and the need for improved methods to assess the vulnerability and adaptive capacity related to climate change for the Swedish railways was addressed. The conclusions of the paper are addressed to the European railway context at large. Firstly, systematic mapping of current climate vulnerabilities and their consequences is important in order to guide the implementation of adaptation measures. Secondly, climate change should be considered in the early stages of planning and included in risk and vulnerability assessments. In assessing future conditions with the aim of prioritising adaptation measures, current methodologies should be complemented with more future-orientated tools. When designing adaptation measures, the effects of potential goal conflicts should also be assessed, in order to avoid the implementation of counter-productive measures. The possibility of creating synergies with climate mitigation goals and other environmental goals should also be investigated.	58	2009	
Organisational uptake of scientific information about climate change by infrastructure managers: the case of adaptation of the French railway company	Depoues, V	CLIMATIC CHANGE	English	Article		WEATHER; TRANSPORT; NETWORKS; SYSTEMS; IMPACT	Future development and renewal of transport infrastructures have to take into account how the effects of climate change will affect these complex sociotechnical systems. This article aims at understanding how to raise this issue to ensure an efficient and systemic uptake of climate change by infrastructure managers. It reports the results of an in-depth case study conducted on the French railway company. This study identifies several adaptation dynamics: one is top-down and stems from climate change impacts; others are more bottom-up and focused on vulnerabilities. However, both types of approaches have, so far, yielded limited results. Building on the existing literature, this paper reveals critical bottlenecks to overcome in order to get the organization ready to adapt. It suggests key components of an enabling framework for a more proactive preparation to climate change and mainstreaming climate adaptation into major organisational decisions.	54	2017	10.1007/s10584-017-2016-y
Collective Learning i+A26n Organizations-Opportunities and Constraints: Case Study of an Avalanche Blocking a Railway Line	Nyman, MR	RISK HAZARDS & CRISIS IN PUBLIC POLICY	English	Article	avalanche; case study; collective learning; critical infrastructure; natural hazard; railway	SAFETY; KNOWLEDGE; CRISIS; CONSTRUCTION; FRAMEWORK; EFFICIENT; CONTEXT; LESSONS; HAZARD; DESIGN	Damaged infrastructures cause costly delays and losses. In this study, a collective learning framework (CLF) and the theory of loops of learning are applied to a case study to develop a conceptual model on how lessons learned may be put to more effective use. Structures for systematic learning from events may serve as important tools in proactive adaptation for a more resilient infrastructure in future. This article studies an avalanche blocking a railway and an adjacent road in northern Sweden, which involves several interdependencies of critical infrastructures and actors. To enhance resilience future risk assessment and SWOT analyses should include the effects from a changing climate on the vulnerabilities of interdependence among multiple stakeholders and infrastructures. Knowledge-sharing foremost resulted in single-loop learning, leading to incremental changes. Respondents expressed an understanding of the importance of double-loops feedback but sensed that they lacked incentives from top levels in the organization for future reporting of experiences. This lack of incentives may impede establishing collective memory. The findings of this study can be used to improve policy recommendations, and support building resilience through products of learning.	53	2019	10.1002/rhc3.12159

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Adaptation Becoming Business as Usual: A Framework for Climate-Change-Ready Transport Infrastructure	Quinn, AD; Ferranti, EJS; Hodgkinson, SP; Jack, ACR; Beckford, J; Dora, JM	INFRASTRUCTURES	English	Article	climate change adaptation; extreme weather; adaptation framework; adaptation pathways; resilience; risk management; sustainability	RAILWAY NETWORK; HEAT-RISK; EVENTS; RESILIENCE; PATHWAYS; SYSTEMS; IMPACT; FLOOD	Extreme weather damages and disrupts transport infrastructure in a multitude of ways. Heavy rainfall and ensuing landslides or flooding may lead to road or rail closures; extreme heat can damage road surfaces, or cause tracks, signalling or electronic equipment to overheat, or thermal discomfort for passengers. As extreme weather is expected to occur more frequently in the future, transport infrastructure owners and operators must increase their preparedness in order to reduce weather-related service disruption and the associated financial costs. This article presents a two-sided framework for use by any organisation to develop climate-change-ready transport infrastructure, regardless of their current level of knowledge or preparedness for climate change. The framework is composed of an adaptation strategy and an implementation plan, and has the overarching ambition to embed climate change adaptation within organisational procedures so it becomes a normal function of business. It advocates adaptation pathways, i.e., sequential adaptive actions that do not compromise future actions. The circular, iterative structure ensures new knowledge, or socio-economic changes may be incorporated, and that previous adaptations are evaluated. Moreover, the framework aligns with existing asset management procedures (e.g., ISO standards) or governmental or organisational approaches to climate change adaptation. By adopting this framework, organisations can self-identify their own level of adaptation readiness and seek to enhance it.	49	2018	10.3390/infrastructures3020010
Impacts of climate change on rail systems: A new climate risk analysis model	Wang, T; Qu, Z; Nichol, T; Yang, Z; Dimitriu, D; Clarke, G; Bowden, D	SAFETY AND RELIABILITY - SAFE SOCIETIES IN A CHANGING WORLD	English	Proceedings Paper		BAYESIAN NETWORK; ADAPTATION	Risk analysis has been widely used in climate adaptation practice. However, traditional probabilistic risk analysis methods are not capable of tackling the unavailability or incompleteness of climate risk data. To deal with such challenges, this paper further applies an advanced Fuzzy Bayesian Reasoning (FBR) model for climate risk analysis of railways system in the UK. Its novelty lies in the realisation of climate risk ranking under high uncertainty in data and its practical contribution on the risk perception of stakeholders in the UK railway systems. To test the feasibility of the developed model in the transport industry, a large scale of surveys are conducted to collect data, regarding the timeframe of climate hazards, likelihood of occurrence, severity of consequences, and infrastructure resilience for the analysis of climate risks threatening British rail systems. The findings will provide transport planners with useful insights on the identification of climate hazards of high risks to facilitate the development of cost-effective climate adaptation strategies.	49	2018	
Competing priorities: how actors and institutions influence adaptation of the German railway system	Rotter, M; Hoffmann, E; Pechan, A; Stecker, R	CLIMATIC CHANGE	English	Article		climate change; ADAPTIVE CAPACITY; SECTOR; SWEDEN	Large-scale infrastructure networks are vulnerable to climate change. Their operation involves public and private actors under complex legislative and market regulations. We analyze climate adaptation of railway infrastructure, based on an in-depth case study of the German railway system. The case includes a unique set of qualitative interviews with key players of operating and regulative organizations, as well as a document study. Our analysis crucially extends previous technology-oriented research on the railway sector by applying core insights and categories from the actor-centered institutionalism. We trace observed obstacles for a climate resilient railway system and adaptation decisions back to deeper causes, in particular political priorities and values. Moreover, diverging perceptions and the competition among different actors hamper adaptation. On the other hand, single actors who display a great willingness to act are able to make use of unclear responsibilities to integrate adaptation concerns into existing institutions. Our research suggests that changes in technical standards and in economic regulation support adaptation of infrastructure systems.	48	2016	10.1007/s10584-016-1702-5
Expanding infrastructure and growing anthropogenic impacts along Arctic coasts	Bartsch, A; Pointner, G; Nitze, I; Efimova, A; Jakober, D; Ley, S; Hogstrom, E; Grosse, G; Schweitzer, P	ENVIRONMENTAL RESEARCH LETTERS	English	Article	Arctic; permafrost; settlements; infrastructure; remote sensing; machine learning; Sentinel	climate change; PERMAFROST; VULNERABILITY; COMMUNITIES; ADAPTATION; DYNAMICS; FIELD; ICE; OIL; MAP	The accelerating climatic changes and new infrastructure development across the Arctic require more robust risk and environmental assessment, but thus far there is no consistent record of human impact. We provide a first panarctic satellite-based record of expanding infrastructure and anthropogenic impacts along all permafrost affected coasts (100 km buffer, approximate to 6.2 Mio km(2)), named the Sentinel-1/2 derived Arctic Coastal Human Impact (SACHI) dataset. The completeness and thematic content goes beyond traditional satellite based approaches as well as other publicly accessible data sources. Three classes are considered: linear transport infrastructure (roads and railways), buildings, and other impacted area. C-band synthetic aperture radar and multi-spectral information (2016-2020) is exploited within a machine learning framework (gradient boosting machines and deep learning) and combined for retrieval with 10 m nominal resolution. In total, an area of 1243 km(2) constitutes human-built infrastructure as of 2016-2020. Depending on region, SACHI contains 8%-48% more information (human presence) than in OpenStreetMap. 221 (78%) more settlements are identified than in a recently published dataset for this region. 47% is not covered in a global night-time light dataset from 2016. At least 15% (180 km(2)) correspond to new or increased detectable human impact since 2000 according to a Landsat-based normalized difference vegetation index trend comparison within the analysis extent. Most of the expanded presence occurred in Russia, but also some in Canada and US. 31% and 5% of impacted area associated predominantly with oil/gas and mining industry respectively has appeared after 2000. 55% of the identified human impacted area will be shifting to above 0 C-circle ground temperature at two meter depth by 2050 if current permafrost warming trends continue at the pace of the last two decades, highlighting the critical importance to better understand how much and where Arctic infrastructure may become threatened by permafrost thaw.	48	2021	10.1088/1748-9326/ac3176
Global warming to increase flood risk on European railways	Bubeck, P; Dillenardt, L; Alfieri, L; Feyen, L; Thieken, AH; Kellermann, P	CLIMATIC CHANGE	English	Article		RIVER FLOOD; DAMAGE; EXTREMES; INFRASTRUCTURE; PROJECTIONS; HAZARD; COSTS	For effective disaster risk management and adaptation planning, a good understanding of current and projected flood risk is required. Recent advances in quantifying flood risk at the regional and global scale have largely neglected critical infrastructure, or addressed this important sector with insufficient detail. Here, we present the first European-wide assessment of current and future flood risk to railway tracks for different global warming scenarios using an infrastructure-specific damage model. We find that the present risk, measured as expected annual damage, to railway networks in Europe is approx. (sic)581 million per year, with the highest risk relative to the length of the network in North Macedonia, Croatia, Norway, Portugal, and Germany. Based on an ensemble of climate projections for RCP8.5, we show that current risk to railway networks is projected to increase by 255% under a 1.5 degrees C, by 281% under a 2 degrees C, and by 310% under a 3 degrees C warming scenario. The largest increases in risk under a 3 degrees C scenario are projected for Slovakia, Austria, Slovenia, and Belgium. Our advances in the projection of flood risk to railway infrastructure are important given their criticality, and because losses to public infrastructure are usually not insured or even uninsurable in the private market. To cover the risk increase due to climate change, European member states would need to increase expenditure in transport by (sic)1.22 billion annually under a 3 degrees C warming scenario without further adaptation. Limiting global warming to the 1.5 degrees C goal of the Paris Agreement would result in avoided losses of (sic)317 million annually.	45	2019	10.1007/s10584-019-02434-5
Evaluating the atmospheric drivers leading to the December 2014 flood in Schleswig-Holstein, Germany	Schade, NH	EARTH SYSTEM DYNAMICS	English	Article		EXTREMES INDEXES; NORTH-SEA; CLIMATE; PRECIPITATION; MOISTURE; WEATHER; SURGE; BASIN	Regional analyses of atmospheric conditions that may cause flooding of important transport infrastructure (railway tracks, highways/roads, rivers/channels) and subsequent adaptation measures are part of topic 1 of the network of experts initiated by the German Federal Ministry of Transport and Digital Infrastructure (BMVI). As an example case study, the December 2014 flood in Schleswig-Holstein, Germany, was investigated. Atmospheric conditions at the onset of the flood event are described and evaluated with respect to the general weather circulation, initial wetness, and event precipitation. Persistent, predominantly westerly general weather circulations (GWCs) directed several low-pressure systems over the North Sea to Schleswig-Holstein during December 2014, accompanied by prolonged rainfall and finally a strong precipitation event in southern Schleswig-Holstein, causing several inland gauges to exceed their, by then maximum, water levels. Results show that the antecedent precipitation index (API) is able to reflect the soil moisture conditions and, in combination with the maximum 3-day precipitation sum (R3d), to capture the two main drivers finally leading to the flood: (1) the initial wetness of north-western Schleswig-Holstein and (2) strong event precipitation in southern and eastern Schleswig-Holstein from 21 to 23 December; at the same time, both indices exceeded their respective 5-year return periods. Further, trend analyses show that both API and R3d have been increasing during recent years, while regional patterns match the north-eastward shift of cyclone pathways, leading to a higher risk of flooding in Schleswig-Holstein. Within the network of experts, investigations of these and further indices/drivers for earth system changes (e.g. wind surge and sea level rise) derived from observations, reanalyses, and regional climate model data are planned for all German coastal areas. Results can be expected to lead to improved adaptation measures to floods under climate change conditions wherever catchments have to be drained and infrastructures and ecosystems may be harmed.	44	2017	10.5194/esd-8-405-2017
Vulnerability assessment framework for interdependent critical infrastructures: case-study for Great Britain's rail network	Pant, R; Hall, JW; Blainey, SP	EUROPEAN JOURNAL OF TRANSPORT AND INFRASTRUCTURE RESEARCH	English	Article	critical infrastructures; interdependencies; vulnerability assessment; railway networks; transport disruptions	climate change; RISK; MODEL	Critical infrastructures vulnerability assessment involves understanding various socio-technological aspects of modern day infrastructures. While vulnerabilities exist at different scales, failures of large-scale installations in infrastructures are significant because they lead towards widespread social and economic disruptions. There is growing awareness of the multiple potential causes of failure, including those due to dependence upon other infrastructures. This paper establishes a framework for national analysis of vulnerability of interdependent infrastructures. We present: (i) A mathematical formulation of the vulnerability assessment; (ii) Network models for infrastructures that take in account the geographic, physical and operational characteristics of connecting nodes and edges; (iii) Interdependency mapping models that establish relationships between different subsystems within and across infrastructures; and (iv) Methods for implementing failure and disruption calculations. The methodology is demonstrated for Great Britain's railway infrastructure, for which we have built detailed interdependency mappings between critical assets and infrastructures that support railway operations. Two key vulnerability assessment results, produced to examine failure impacts of such assets on railway passenger trip flows, include: (i) Random failure outcomes; and (ii) Flood vulnerability outcomes. The results show which critical infrastructure interdependencies potentially have large impacts on railway operations, providing a useful analysis tool for further risk and adaptation planning.	42	2016	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI
Benchmarked RADARSAT-2, SENTINEL-1 and RADARSAT Constellation Mission Change-Detection Monitoring at North Slide, Thompson River Valley, British Columbia: ensuring a Landslide-Resilient National Railway Network	Huntley, D; Rotheram-Clarke, D; Pon, A; Tomaszewicz, A; Leighton, J; Cocking, R; Joseph, J	CANADIAN JOURNAL OF REMOTE SENSING	English	Article		POSITIONING SYSTEM TECHNIQUES; SLOW-MOVING LANDSLIDE; EARTH SLIDES; ASHCROFT	In this research note, we demonstrate the applicability of interferometric analyses (InSAR) of RADARSAT 2 (RS2), SENTINEL 1 (S1) and RADARSAT Constellation Mission (RCM) datasets to characterize and monitor landslides along a high-risk section of the national railway transportation corridor traversing the Thompson River valley, British Columbia. As a geomorphically active landform, the North Slide is an ideal case study for field-testing and evaluating slope change-detection monitoring incorporating satellite, aerial and ground-based geospatial technologies. RS2, S1 and RCM InSAR datasets provide valuable baseline spatial and temporal information on movement of the landslide near critical railway infrastructure when benchmarked with real-time kinematic (RTK) global navigation satellite system (GNSS) measurements, uninhabited aerial vehicle (UAV) photogrammetry, bathymetric soundings, and ground observations. We demonstrate that monitoring unstable slopes and infrastructure at risk with multiple high spatial- and temporal-resolution satellite SAR platforms is a cost-effective natural hazard management practice that also provides important geoscience information to help develop appropriate mitigation and climate adaptation measures.	41	2021	10.1080/07038992.2021.1937968
Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development	Neumann, JE; Chinowsky, P; Helman, J; Black, M; Fant, C; Strzepek, K; Martinich, J	CLIMATIC CHANGE	English	Article	Rail; Roads; Coastal development; Infrastructure; Proactive adaptation	COSTS	Changes in temperature, precipitation, sea level, and coastal storms will likely increase the vulnerability of infrastructure across the USA. Using models that analyze vulnerability, impacts, and adaptation, this paper estimates impacts to railroad, roads, and coastal properties under three infrastructure management response scenarios: No Adaptation; Reactive Adaptation, and Proactive Adaptation. Comparing damages under each of these potential responses provides strong support for facilitating effective adaptation in these three sectors. Under a high greenhouse gas emissions scenario and without adaptation, overall costs are projected to range in the $100s of billions annually by the end of this century. The first (reactive) tier of adaptation action, however, reduces costs by a factor of 10, and the second (proactive) tier reduces total costs across all three sectors to the low $10s of billions annually. For the rail and road sectors, estimated costs for Reactive and Proactive Adaptation scenarios capture a broader share of potential impacts, including selected indirect costs to rail and road users, and so are consistently about a factor of 2 higher than prior estimates. The results highlight the importance of considering climate risks in infrastructure planning and management.	41	2021	10.1007/s10584-021-03179-w
A Bayesian Network-Based Risk Assessment Framework for the Impact of Climate Change on Infrastructure	Wang, T; Wang, XM	CONSTRUCTION RESEARCH CONGRESS 2016: OLD AND NEW CONSTRUCTION TECHNOLOGIES CONVERGE IN HISTORIC SAN JUAN	English	Proceedings Paper		BELIEF NETWORKS; CHANGE ADAPTATION; PERFORMANCE; STRATEGIES; BUILDINGS	In the last few decades, global warming and climate change have had great impact on infrastructures. Increasingly frequent extreme weather conditions, such as heat wave, severe cold, floods, and earthquakes, significantly change the construction and operation process of infrastructures. Huge social and economic lost raises the awareness to address and alleviate possible risks resulted from climate change. Proper assessment approach is needed to appropriately evaluate the added risks from climate change. This research discusses the features of climate change risk assessment, and Bayesian Networks method is proven to be an effective tool to construct the assessment model due to its features. This paper proposes to develop a Bayesian Networks-based risk assessment framework to evaluate the impact of climate change on the infrastructures. The risk assessment steps are presented using a case study of high speed railway operation.	37	2016	
The impacts of the 28 June 2012 storms on UK road and rail transport	Jaroszweski D., Hooper E., Baker C., Chapman L., Quinn A.	Meteorological Applications	English	Article	Climate change adaptation; Data visualization; Delay propagation; Extreme events; Transport; Weather	Climate change; Contracts; Data visualization; Meteorological radar; Railings; Roads and streets; Storms; Supply chains; Weathering; Climate change adaptation; Critical transport infrastructures; Delay propagation; Economic functions; Extreme events; Extreme weather events; Spatial and temporal resolutions; Transport; Atmospheric movements; climate change; extreme event; motorway; qualitative analysis; quantitative analysis; railway transport; road transport; socioeconomic status; spatiotemporal analysis; storm; United Kingdom	Extreme weather events can cause severe disruption to transport systems, greatly reducing the ability to maintain important social and economic functions such as the delivery of goods and materials within the supply chain. There is a need for greater qualitative and quantitative understanding of how transport systems respond under adverse conditions, to inform event management and to aid adaptation actions. The present study uses the intense storms of 28 June 2012 as a case study to present a novel exploration of the impacts of an extreme event using high spatial and temporal resolution transport data for the UK road and rail networks, as well as weather data from the UK Meteorological Office's MIDAS surface station network and NIMROD weather radar. This event caused widespread disruption, severing the main rail links between England and Scotland and causing 10000 delay minutes to train services throughout the country, as well as causing reduced speeds on local roads and motorways. The present study describes the meteorological situation in the build-up to and during the event, and uses Network Rail train delay data to visualize the way in which the failure of several sections of critical transport infrastructure caused disruption that propagated quickly through the rail network of Great Britain. Highway Agency motorway speed data are used to quantify the impact of this event on the M6 motorway in the West Midlands. Ways in which the insights gained from these data can be used to aid the transport sector in the prioritization of adaptation actions are discussed. © 2014 Royal Meteorological Society.	34	2015	10.1002/met.1477
Heat-Related Failures on Southeast England's Railway Network: Insights and Implications for Heat Risk Management	Ferranti, E; Chapman, L; Lowe, C; Mcculloch, S; Jaroszweski, D; Quinn, A	WEATHER CLIMATE AND SOCIETY	English	Article		HIGH SUMMER TEMPERATURES; climate change; WEATHER; DELAYS	High temperatures and heat waves can cause numerous problems for railway infrastructure, such as track buckling, sagging of overhead lines, and the failure of electrical equipment. Without adaptation, these problems are set to increase in a future warmer climate. This study used industry fault data to examine the temporal and spatial distribution of heat-related incidents in southeast England and produce a unique evidence base of the impact of temperature on the rail network. In particular, the analysis explored the concept of failure harvesting, whereby the infrastructure system becomes increasingly resilient to temperature over the course of the summer season (April-September) as the most vulnerable assets fail with each incremental rise in temperature. The analysis supports the hypothesis and clearly shows that a greater number of heat-related incidents occur in the early/midsummer season before reducing significantly, despite equivalently high temperatures. This failure harvesting and the consequential increased resilience of the railway infrastructure system over the course of the summer season could permit an innovative and dynamic new approach to heat risk management on the railway network. New approaches that would reduce the disruption and delays and improve service are explored here.	33	2016	10.1175/WCAS-D-15-0068.1
IMPACT OF REGIONAL CLIMATE CHANGE ON THE INFRASTRUCTURE AND OPERABILITY OF RAILWAY TRANSPORT	Kostianaia, EA; Kostianoy, AG; Scheglov, MA; Karelov, AI; Vasileisky, AS	TRANSPORT AND TELECOMMUNICATION JOURNAL	English	Article	Regional climate change; extreme weather events; rail transport; railways infrastructure; buckling of tracks; flooding of tracks	TRAIN	This article considers various aspects of the impact of climate change on the railway infrastructure and operations. A brief international overview and the importance of this issue for Russia are given. Temperature effects, permafrost thawing, strong winds, floods and sea level rise, long-term effects, and adaptation measures are discussed. In conclusion, the authors give several recommendations on further research in this area, and highlight that special attention should be given to the areas in the Russian Federation which already face or might soon experience damage from storm events or flooding and sea level rise, namely Kaliningrad Region on the Baltic Sea, the area between Tuapse and Adler in Krasnodar Region on the Black Sea, and on Sakhalin Island from the side of the Sea of Japan.	33	2021	10.2478/ttj-2021-0014
Risks of climate change with respect to the Singapore-Malaysia high speed rail system	Sa'adin S.L.B., Kaewunruen S., Jaroszweski D.	Climate	English	Review	Adaptation; Climate change; Global warming; High-speed rail; Management and monitoring; Operational readiness; Project development planning; Railway infrastructure; Risk; Tracks		Warming of the climate system is unequivocal, and many of the observed changes are unprecedented over the past five decades. Globally, the atmosphere and the ocean are becoming increasingly warmer, the amount of ice on the earth is decreasing over the oceans, and the sea level has risen. According to the Intergovernmental Panel on Climate Change, the average increase in global temperature (combined land and surface) between the 1850-1900 period and the 2003-2012 period was 0.78 °C (0.72 to 0.85). But should we prepare for such a relatively small change? The importance is not the means of the warming but the considerable likelihood of climate change that could trigger extreme natural hazards. The impact and the risk of climate change associated with railway infrastructure have not been fully addressed in the literature due to the differences in local environmental parameters. On the other hand, the current railway network in Malaysia, over the last decade, has been significantly affected by severe weather conditions such as rainfall, lightning, wind and very high temperatures. Our research findings based on a critical literature review and expert interviews point out the extremes that can lead to asset system failure, degraded operation and ultimately, delays in train services. During flooding, the embankment of the track can be swept away and bridge can be demolished, while during drought, the embankment of the track can suffer from soil desiccation and embankment deterioration; high temperature increases the risk of track buckling and high winds can result in vegetation or foreign object incursion onto the infrastructure as well as exert an additional quasi-static burden. This review is of significant importance for planning and design of the newly proposed high speed rail link between Malaysia and Singapore. © 2016 by the authors.	30	2016	10.3390/cli4040065
Adapting railways to provide resilience and sustainability	Armstrong, J; Preston, J; Hood, I	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-ENGINEERING SUSTAINABILITY	English	Article	infrastructure planning; railway systems; sustainability	climate change	The reality of anthropogenic climate change is increasingly apparent, with significant implications for railway and other infrastructure networks. As a transport mode with a relatively small environmental impact, rail has a potentially valuable role to play in climate change mitigation. However, this potential can be realised only if railways are adapted to withstand the effects of the increasingly extreme weather associated with climate change. This requirement is widely acknowledged by governments and the railway industry, and the required responses to the specific potential effects of climate change are well known and understood. However, a review of the literature indicates a need for a decision support system to prioritise the interventions required for the adaptation in the face of uncertainty about both the frequency and scale of future extreme weather events and the nature and the levels of future passenger and freight traffic on the railways. This paper proposes a seven-step framework for the classification of the UK railway network, the assessment of the economic value of traffic using the network (and thus the economic costs of weather-related disruption), the identification of appropriate remedial measures and their costs and thus the prioritisation of these measures by means of cost-benefit analysis.	27	2017	10.1680/jensu.15.00017

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI
Assessing Public Transportation Vulnerability to Sea Level Rise: A Case Study Application	Oswald, M; Treat, C	JOURNAL OF PUBLIC TRANSPORTATION	English	Article			The potential for sea level rise inundation of critical transportation infrastructure rises as the threat of climate change continues. Inundation of public transportation including railroads and bus routes, specifically those located in low-lying coastal areas, are vulnerable to these impacts. Therefore, identifying vulnerable facilities in order to implement adaptation planning practices is essential to protecting these facilities and avoiding impacts on mobility. This research focuses on the application of the Transit Inundation Modeling Method (TIMM) to a transit network (railways and bus routes) in Philadelphia County, Pennsylvania. TIMM is developed based on the need to identify transit infrastructure systems that are vulnerable to sea level rise using Geographic Information Systems (GIS). Applying TIMM to a real-world transit network provides an example for how transit agencies throughout the nation can begin to identify at-risk links and nodes based on potential sea level rise inundation levels.	27	2013	10.5038/2375-0901.16.3.4
Assessing the vulnerability of transport network to flood hazard using GIS analysis. Case study along Orient-East Med TEN-T Corridor, on Timis-Cerna Valley, Romania	Stoica-Fuchs, B	PRESENT ENVIRONMENT AND SUSTAINABLE DEVELOPMENT	English	Article	flash flood; road; railway; TEN-T European Network; Geographic Information Systems (GIS)	RISK-MANAGEMENT; ADAPTATION; HIGHWAY; BANAT	In the context of current climate change, it is estimated that flood risk will increase significantly, with important consequences for the human habitat and transport networks. Research literature features a continuous concern both for the improvement of flood hazard modeling and for the quantification of economic costs specific to material and human damage caused by floods. In the present study, we intend to perform an analysis on the vulnerability of the transport network along the Orient-East Med (OEM) Corridor, part of the TEN-T Core network at European level. By integrating flood bands with high (10 years) and medium (100 years) probability of recurrence, as well as various typologies of the transport network in a GIS environment, we successfully identified and characterized road and railway sectors susceptible to flooding events. Vector overlay analysis and statistical methods were validated by means of local research literature, field observations and aerial imagery. Our results feature the geographic distribution and statistical characterization of transport infrastructure vulnerable to flood risk along Timis-Cerna Valley, in south-western Romania. We also discuss the state of current flood risk mitigation measures for transport network in the study area, along with the importance of our research for regional and local spatial planning documentations and investment prioritization activities. Similar spatially-enabled analysis could enable better protection for the current and proposed transport infrastructure and minimize the damaging effects of flash floods.	27	2021	10.15551/pesd2021152012
Analogues for the railway network of Great Britain	Sanderson, MG; Hanlon, HM; Palin, EJ; Quinn, AD; Clark, RT	METEOROLOGICAL APPLICATIONS	English	Article	climate change; analogues; railway; climate models; GB; CMIP5	climate change	In recent years (2013-2016), extreme weather events have caused substantial disruption to Great Britain's (GB's) railway infrastructure. In the coming decades this vulnerability is unlikely to subside as the effects of climate change become more intense. Railway stakeholders in GB are strongly engaged with understanding climate change impacts on the railway system and how the industry could adapt to these impacts. Since 2010, Network Rail and RSSB have supported research into these topics under the Tomorrow's Railway and Climate Change Adaptation programme. Under this programme, an analogue study was performed to determine whether lessons could be learned from other countries' weather management. Two types of analogue were used to identify suitable locations. First, climate data from 20 models of the Coupled Model Intercomparison Project phase 5 (CMIP5) were used to identify regions with similar present-day climate to that projected for GB in the future. The analogue locations were found to be largely insensitive to the climate indicators and the methods used to compare climate at different locations. Next, railway networks in many countries were studied to find those with similar physical and operational characteristics to the GB network. The regions with both climate and railway analogues are France, the Netherlands, Belgium, Germany and Denmark. As part of a wider aim to support the GB railway network's weather resilience and climate change adaptation (WR/CCA) activities, focused stakeholder engagement has been undertaken with representatives of most of these countries' railways. This targeted approach is complementary to a broader collation of existing WR/CCA measures used globally.	26	2016	10.1002/met.1597
Climate Proofing Infrastructure in Bangladesh: The Incremental Cost of Limiting Future Flood Damage	Dasgupta, S; Huq, M; Khan, ZH; Masud, MS; Ahmed, MMZ; Mukherjee, N; Pandey, K	JOURNAL OF ENVIRONMENT & DEVELOPMENT	English	Article	Bangladesh; climate change; infrastructure; adaptation cost		Bangladesh is one of the most flood prone countries in the world. Two thirds of the country is less than 5 m above sea level. Past monsoon flood records indicate that about 21% of the country is subject to annual flooding and an additional 42% is at risk of floods with varied intensity. Although annual regular flooding has traditionally been beneficial, providing nutrient-laden sediments and recharging groundwater aquifers, the country often experiences severe flooding during a monsoon that causes significant damage to crops and properties with adverse impacts on rural livelihoods and production. The 1998 flood inundated two thirds of the land area, resulting in damages and losses of over US$2 billion, or 4.8% of GDP. Climate models suggest increased precipitation, higher transboundary water flows, and sea-level rise will all increase the destructive power of monsoon floods. Using climate change scenarios out to 2050, hydrological and hydrodynamic models, this article estimates an incremental cost to climate-proof roads and railways, river embankments protecting productive agricultural lands, and drainage systems and erosion control measures for major towns of US$2,671 million initially and US$54 million in annual recurrent costs.	25	2011	10.1177/1070496511408401
Climate change impacts on railway structures: bridge scour	Dikanski, H; Hagen-Zanker, A; Imam, B; Avery, K	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-ENGINEERING SUSTAINABILITY	English	Article	bridges; floods & floodworks; weather	SENSITIVITY	Weather-related disruption is a pressing issue for transport infrastructure in the UK, which is expected to aggravate due to climate change. Infrastructure managers, such as Network Rail, need to adapt to these changes, tackling the challenges brought about by wide-ranging uncertainties from various sources. This paper explores the relationship between climate change and bridge scour, identifying barriers to sustainable adaptation. Scour is the removal of riverbed material at bridge foundations due to hydraulic action and is the foremost cause of bridge failure in the UK and worldwide. A model is developed that simulates the causal chain from climate change to scour risk. This is applied to four case study bridges in Wales and the south-west of England, quantifying the effects of climate change and tracing key uncertainties in the process. Results show that the current scour risk models in Network Rail may be insensitive to increases in risk due to climate change. One way to tackle this may be to introduce models to assess absolute risk; current scour risk models are used only for the prioritisation of vulnerable sites.	24	2017	10.1680/jensu.15.00021
Failure investigations into interspersed railway tracks exposed to flood and washaway conditions under moving train loads	Ridho, BKAMA; Kaewunruen, S	ENGINEERING FAILURE ANALYSIS	English	Article	Vulnerability; Resilience; Railway; Interspersed Tracks; Ballasted tracks; Flood; Extreme Condition; Washaway	CONCRETE SLEEPER; FREE-VIBRATIONS	In traditional railway networks globally, timber sleepers have been widely adopted since the advent of railway systems. After a certain period of time, timbers tend to degrade and it becomes more and more difficult to seek cost-effective replacement hardwood sleepers. To provide a shortterm solution, many rail infrastructure managers use an interspersing method of track maintenance. The interspersed sleeper of railway tracks, which is a spot replacement of old timber sleeper with concrete or composite counterparts, is often utilised as a temporary maintenance measure for secondary railway tracks such as low-traffic lines, yards, balloon loops or siding. Reportedly, the performance of railway lines including the interspersed tracks can quickly deteriorate when the tracks are exposed to heavy rains and floods. In many cases, ballast washaway can be often seen. This study is the world first to demonstrate the effects of ballast washaway on the vulnerability assessment of interspersed railway tracks using nonlinear finite element simulations, STRAND7. Two sets of moving point loads representing a bogie along the rails have been established to investigate the worst-case, potential actions for impaired performance of sleepers and differential settlements of the track. In this study, the emphasis is placed on the effects of ballast washaway on the maximum displacement of rails and the relative track geometries (i.e. top and twist). The maximum bending actions causing the failures of the track components are also investigated. The new insights will help track engineers develop appropriate climate change adaptation methods and policies for operations of interspersed railway tracks facing extreme rainfall and flooding conditions.	24	2021	10.1016/j.engfailanal.2021.105726
Impacts of sea-level rise on the Moroccan coastal zone: Quantifying coastal erosion and flooding in the Tangier Bay	Snoussi, M; Ouchani, T; Khouakhi, A; Niang-Diop, I	GEOMORPHOLOGY	English	Article	Moroccan coastal zone; Sea-level rise; Impact assessment; Inundation; Erosion; Adaptation		As part of a broad assessment of climate change impacts in Morocco, an assessment of vulnerability and adaptation of coastal zones to sea-level rise was conducted. Tangier Bay which is the most important socioeconomic pole in Nor-them Morocco represents one of the cases studies. Using a GIS-based inundation analysis and an erosion modelling approach, the potential physical vulnerability to accelerated sea-level rise was investigated, and the most vulnerable socio-economic sectors were assessed. Results indicate that 10% and 24% of the area will be at risk of flooding respectively for minimum (4 m) and maximum (11 m) inundation levels. The most severely impacted sectors are expected to be the coastal defences and the port, the urban area, tourist coastal infrastructures, the railway, and the industrial area. Shoreline erosion would affect nearly 20% and 45% of the total beach areas respectively in 2050 and 2100. Potential response strategies and adaptation options identified include: sand dune fixation, beach nourishment and building of seawalls to protect the urban and industrial areas of high value. It was also recommended that an Integrated Coastal Zone Management Plan for the region, including upgrading awareness, building regulation and urban growth planning should be the most appropriate tool to ensure a long-term sustainable development, while addressing the vulnerability of the coast to future sea-level rise. (c) 2008 Elsevier B.V. All rights reserved.	24	2009	10.1016/j.geomorph.2006.07.043
Heavy rainfall and flood vulnerability of Singapore-Malaysia high speed rail system	Binti Sa'adin S.L., Kaewunruen S., Jaroszweski D.	Australian Journal of Civil Engineering	English	Article	adaptation; climate change; flood; global warming; heavy rain; high speed rail; management and monitoring; operational readiness; Railway infrastructure; risk; tracks	Climate change; Earth atmosphere; Floods; Global warming; International cooperation; Rain; Risks; Sea level; Systems engineering; Urban transportation; adaptation; Heavy rains; High speed rail; Operational readiness; Railway infrastructure; tracks; Railroad transportation	Change of climate is unequivocal, and many of the observed changes are unprecedented over five decades to millennia. It is expected that the global atmosphere and ocean is increasingly getting warmer, the amount of ice on the earth is decreasing over the oceans, and the sea level has risen. According to Intergovernmental Panel on Climate Change, such temperature change is around 0.78 °C over decades. Without international collaboration towards Paris Agreement, the temperature change could potentially rise over 5.5°C in 2100. In addition, it is highly likely that even such a small change can trigger the worst of other extreme natural threats to interdependent urban and transport infrastructure systems. The vulnerability of those infrastructure systems has not been comprehensively addressed in open literature due to the fact that the actual climate change impact depends on specific differences of local environmental and geographical conditions. As a result, our research will highlight the extremes that can lead to system failure, degraded operation and ultimately, delays to train services. The emphasis is placed on the newly proposed Malaysia–Singapore high speed rail network, which can be affected by the most-frequent severe weather conditions including heavy rainfall and flash flood. It is found that tunnelling, steep cutting and ballast foundation are ones of the most vulnerable assets from a heavy rainfall or a flash flood. © 2017 Engineers Australia.	21	2016	10.1080/14488353.2017.1336895

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI
Methodology to assess coastal infrastructure resilience to climate change	Roca, M; Hames, D; Gouldby, B; Zve, ES; Rowlands, O; Barter, P; Grew, J	3RD EUROPEAN CONFERENCE ON FLOOD RISK MANAGEMENT (FLOODRISK 2016)	English	Proceedings Paper		ALGORITHMS	The section of railway which runs along the coastline of south Devon in United Kingdom, from Exeter to Newton Abbot, is one of the most photographed sections of railway in the world. It was opened in 1846 with embankments and seawalls protecting and supporting the railway, providing the route of an atmospheric railway. Despite regular maintenance however, there has been a history of storm damage, one of the most severe occurring in February 2014. This resulted in the collapse of the line, interruption of all rail traffic into and out of the far SouthWest of the United Kingdom (affecting parts of Devon and the whole of Cornwall) and significant damage to the region's economy. In order to improve the resilience of the line, several options have been considered to evaluate and reduce climate change impacts to the railway. This paper describes the methodological approach developed to evaluate the risks of flooding for a range of scenarios in the estuary and open coast reaches of the line. Components to derive the present day and future climate change coastal conditions including some possible adaptation measures are also presented together with the results of the hindcasting analysis to assess the performance of the modelling system. An overview of the modelling results obtained to support the development of a long-term Resilience Strategy for asset management is also discussed.	19	2016	10.1051/e3sconf/20160702004
Implications of climate change for thermal discomfort on underground railways	Jenkins, K; Gilbey, M; Hall, J; Glenis, V; Kilsby, C	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Thermal discomfort; London Underground; Climate change; Heat risk	HEAT; ENVIRONMENT; COMFORT; LONDON	Hot weather events, ventilation assets, changing passenger demand and service expectations have all caused increased attention on thermal comfort on London's Tube. This study provides estimates of the future number of days when passengers travelling on sections of the Tube could be subjected to thermal discomfort under future scenarios of climate change, and the potential number of passengers dissatisfied. A risk based methodology is presented, integrating a spatial weather generator modified for urban areas and a thermal comfort model. The study provides an initial assessment of adaptation options by considering the implications of lowering train temperatures by 2 degrees C and 4 degrees C to represent saloon cooling. Median results under a 2050 high scenario indicate that all Tube lines assessed could experience near-complete passenger dissatisfaction with the thermal environment in trains in the unlikely event that nothing else were to change. Adaptation aimed at lowering train temperatures has the potential to provide tangible improvements in thermal comfort. However, this was not projected to be sufficient to maintain comfortable thermal conditions for many of the lines in the 2050s under high emission scenarios, requiring a combination of other infrastructure cooling measures to be implemented in parallel. (C) 2014 Elsevier Ltd. All rights reserved.	18	2014	10.1016/j.trd.2014.05.002
Impact of climate change on London's transport network	Arkell, BP; Darch, GJC	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-MUNICIPAL ENGINEER	English	Article	infrastructure planning; transport management; weather		There is much discussion about the contribution of transport to global warming, but what about the impact of our changing climate on transport modes, infrastructure and passengers? This paper examines the potential impacts of climate change on London's transport systems, based on the findings of a research study undertaken for the London Climate Change Partnership between 2004 and 2005. Recent extreme weather events have had significant impact on London's transport systems; for example, the effect of high temperatures on London Underground and major flooding of roads and railway stations. Scenarios of climate change show that London will experience hotter summers, wetter winters, more intense rainfall and a rise in sea level over the coming century. This poses a number of risks to the operation and use of transport systems in a city where 26 million trips are made every day. The study focuses on four case studies. Each case study assesses: the issue now, drawing on current weather-related effects; how climate change will affect the future; the action already underway in London to address climate impacts; and options and timescales for adaptation. It is apparent that most risks already exist climate change will simply make them worse. With forward planning, successful and cost-effective adaptation can be achieved.	14	2006	10.1680/muen.2006.159.4.231
Identifying sea level rise vulnerability using GIS: Development of a transit inundation modeling method	Oswald M.R., Treat C.	International Journal of Geoinformatics	English	Article		bus transport; climate change; climate effect; GIS; modeling; railway transport; satellite data; sea level change; transportation infrastructure; transportation planning; vulnerability; Pennsylvania; Philadelphia County; United States	Sea level rise inundation poses risk to critical transportation infrastructure as the threat of climate change continues. Although mitigation efforts are being implemented, these practices are not timely enough to avoid all potential impact. Therefore, adaptation practices are essential to building resilience and protecting transportation facilities, specifically public transit (rail and bus) networks. This research establishes a method, Transit Inundation Modeling Method (TIMM), used to identify transit infrastructure systems that are vulnerable to sea level rise using Geographic Information Systems (GIS). TIMM allows transit agencies to begin adapting by identifying at-risk links and nodes based on various sea level rise inundation levels. This method is applied to a case study application on the Philadelphia County transit system (railway and bus routes). This case study is used to determine the method's applicability and relevance to a real world transit network By using this method to identify vulnerabilities, transit agencies throughout the nation can begin to implement adaptation practices (elevate, relocate or reinforce) in order to protect existing facilities as well as plan for future transit projects. © Geoinformatics International.	11	2013	
Climate Change Adaptation for GeoRisks Mitigation of Railway Turnout Systems	Dindar, S; Kaewunruen, S; Sussman, JM	PROCEEDINGS OF THE INTERNATIONAL SCIENTIFIC CONFERENCE TRANSPORTATION GEOTECHNICS AND GEOECOLOGY (TGG-2017)	English	Proceedings Paper	natural hazards; bayesian network; railway turnout; switch and crossing; trackbed failures		To enhance rail operational flexibility, railway turnouts are special track systems, which are designed to divert or change a train from a particular direction or a particular track onto other directions or other tracks. In reality, the railway turnout is commonly built on complex track geometry and graded terrain, which makes it one of the most unique and critical railway infrastructures. The physical constraints and complexity of turnout systems cause various risks and uncertainty in rail operations. This study critically analyses emerging geotechnical risks on turnout systems considering all aspects that can potentially result in impaired reliability, availability, maintainability and safety (RAMS) of the turnout systems. The annual derailment incidents have been evaluated to identify emerging risk factors. Not only do these incidents yield operational downtime and financial losses, but they also give rise to the casualties and sometimes the loss of lives across the world. In particular, the climate change risks on geotechnical aspects of the turnout systems have been highlighted. This paper thus presents how turnout components work as a system, the diversity of emerging risks considering natural hazards and global warming potential to the system. In addition, it highlights the climate change adaptation strategies for georisk mitigation of the railway turnout systems in order to improve RAMS of the railway turnouts and crossings, focusing on trackbed failures on the systems. (C) 2017 The Authors. Published by Elsevier Ltd.	9	2017	10.1016/j.proeng.2017.05.032
Adaptation investments for transport resilience: Trends and recommendations	Pregnolato M., Dawson D.A.	International Journal of Safety and Security Engineering	English	Article	Adaptation; Flood; Investment; Network; Rail; Resilience; Risk; Road; Transport	Climate change; Economics; Geographical regions; Investments; Network security; Networks (circuits); Rails; Risk analysis; Risk assessment; Risks; Roads and streets; Spatial distribution; Adaptation; Assessment approaches; Methodological frameworks; Resilience; Road; Strategic requirements; Transport; Transport infrastructure; Floods; adaptive management; climate change; comparative study; economic growth; environmental assessment; extreme event; flood; flooding; GIS; investment; methodology; natural hazard; railway transport; risk assessment; road transport; transportation infrastructure; trend analysis; vulnerability; United Kingdom; Wales	Climate change, extreme weather and flooding threaten to increase damage and disruption to our transport networks and the services that they provide. There is increased need for adaptation to maintain current asset conditions and services, and a strategic requirement to prioritise such investments in adaptation to reduce future risks. Physical network risks will not be evenly distributed across nations (e.g. due to geographical and climate change patterns), and some regions will require more investment and adaptive interventions than others to maintain services due their vulnerability to natural hazards. Comparatively, the distribution of investment for transport infrastructure does not have a uniform spatial distribution, and can favour schemes that reduce congestion on networks with high demand without considering the actual risk of being impacted. These two issues, if unchallenged, will present an unfavourable future for areas with high network risks and low transport demand that will widen spatial inequality or resilience, mobility and potential for economic growth. This study advances a methodological framework to analyse the spatial distribution of flood risk on UK road and rail networks in the light of potential bias of regional investment. Using GIS mapping, network data and risk analysis, regional futures are categorised and discussed. There is a clear North/South divide in transport networks at risk from potential coastal and fluvial flooding, with southern regions having 10-30% of their network situated in known flood risk areas. Investment in transport infrastructure is also disproportionately favoured towards regions with high transport demand, and peripheral regional such as Wales and the South West are at risk from increase disparity from high flood risk networks and a low potential for investment. The study provides preliminary evidence for the need to consider assessment approaches for long-term investment in resilience, drawing recommendations for future research. © 2018 wit Press.	5	2018	10.2495/SAFE-V8-N4-515-527
An overview of "resilience" and climate change	Hill A.C., Kakenmaster W.	Bulletin of the Atomic Scientists	English	Article	adaptation; city planning; Climate change; climate denial; future-proof; infrastructure; land-use; resilience; sea level rise		What do we mean when we speak in terms of "resilience?" Why has "resilience" become the hot buzzword, and why is it useful for political leaders who want to avoid saying the words "climate change?" Will the choice of words make a difference when it comes to the need to design infrastructure–roads, bridges, tunnels, houses, factories, power plants, airports, railroads–with rising sea levels, increased storms, and hotter temperatures in mind?. © 2018 Bulletin of the Atomic Scientists.	5	2018	10.1080/00963402.2018.1436803
How does the UK transport system respond to the risks posed by climate change? An analysis from the perspective of adaptation planning	Wang T., Qu Z., Yang Z., Ng A.K.Y.	Maritime Transport and Regional Sustainability	English	Book Chapter	Adaptation planning; Case study; Climate change; Rail; Risks; Road; UK		This chapter studies the adaptation experience of UK road and rail systems in managing the risks posed by climate change (e.g., flooding, rising temperature, and storm surge). In particular, it explores the current and potential issues in climate adaptation planning through in-depth investigation of four cases, namely Highways England, Network Rail, Transport for London and Environment Agency (London), and Devon County Council. Although considerable adaptation measures and actions have been implemented at both the national and regional levels in the last decade, the road and rail systems in the United Kingdom still confront diverse challenges. These include, but are not limited to, insufficient scientific data, aging infrastructure, unclear planning horizon, and unspecialized climate risk management. A combined analysis of the relevant literature, local reports, news, and interviews with domain transport experts offers a broad view of adaptation planning in UK roads and railways and valuable insights for creating an integrated inland transport adaptation system. An analysis of road and rail adaptation measures to climate change not only benefits both sectors by cross-reference but also generates new adaptation solutions in terms of using one system to enhance the resilience of the other when climate risks occur. © 2020 Elsevier Inc. All rights reserved.	4	2019	10.1016/B978-0-12-819134-7.00006-X

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Justification of measures to reduce greenhouse gases emissions by transport and adaptation of transport infrastructure facilities to climate change in permafrost zones	Trofimenko Yu.V., Yakubovich A.N.	Ecology and Industry of Russia	Russian	Article	Adaptation; Climate change; Environmental safety; Greenhouse gases; Permafrost zone; Transport complex; Transport infrastructure facilities		The models, methods, as well as the results of the justification of measures to reduce greenhouse gases (GHG) emissions by the transport complex for the period up to 2030 to improve its environmental safety, as well as assessing the effectiveness of measures (the use of seasonal cooling devices (SOA) - heat stabilizers) are considered transport infrastructure facilities (TIFs) of road, rail, air and water transport when implementing different climate change scenarios in the areas of permafrost. For sections of roads and railways (in the embankment), runways of airfields in the territories examined in the next 30 years, high climatic risks that require the use of heat stabilizers are not forecasted. For these objects can be applied less costly protective measures. The pile foundation of bridges and other transportation facilities can be sufficiently effectively protected by heat stabilizers from the effects of climate change. In relation to the strip and raft foundations of port facilities, other production facilities in the territories examined, the use of the SOA is a very effective measure to reduce climate risks. An increase in the expected effectiveness of measures to adapt them in the case of transition from continuous permafrost to its island and rare island species has been established for all types of TIFs. The reduced efficiency of the use of heat stabilizers in soils of low humidity, especially in sandy soils for all types of TIFs, was recorded. © 2019 Izdatel'stvo Kalvis. All Rights Reserved.	4	2019	10.18412/1816-0395-2019-02-55-61
Risk of increasing temperature due to climate change on operation of the Spanish rail network	Sanchis I.V., Franco R.I., Zuriaga P.S., Fernández P.M.	Transportation Research Procedia	English	Conference Paper	buckling; climate change; Rail transport; risk assesment; temperatures		The rail network in Spain is around 16.000 km of Iberian, standard and narrow gauge, connecting the main population cities and hubs of transport. Due to its geographical location in southern Europe, during the summer months the entire network is subjected to high temperatures variations, including heat wave events, where temperatures become exceptionally elevates. With the use of continuous welded rails and the absence of expansion joints, temperature changes in rails results in significant compressive stresses. Moreover, climate models considers that extreme temperatures are going to become more frequent and intense in the next decades. Thus, understanding the nature of buckling events is required to identify potential causes and develop adaptation strategies and safety procedures. However, the impact in the railway infrastructure in Spain have not been fully addressed due to the differences in local environmental parameters and track characteristics, among others. In this study, the issue of potential impacts of temperatures on the Spanish railway network are analyzed in terms of average track buckling failures until 2100. The approach addresses the frequency of future buckling events considering the spatial and temporal distribution to establish trends between climate projections and track buckling events. Therefore, this work is of significant importance for planning, design and maintenance, providing a predictive track maintenance regime in order to assist the decision-making process. © 2020 The Author(s).	4	2020	10.1016/j.trpro.2020.02.056
RAIL INFRASTRUCTURE DEVELOPMENT AND CLIMATE CHANGE-CHALLENGES FOR RAIL OPERATORS	Princz-Jakovics, T; Bachmann, D	ROAD AND RAIL INFRASTRUCTURE V	English	Proceedings Paper	Rail operation; climate change; adaptation strategies		Significant interaction can be revealed between infrastructure operation of the railway line and climate change effects. Climate protection risk analysis can show us how we assess the climate change sensitivity of rail development projects: modernization of railway lines or railway electrifications. The rail transport facilities are usually less sensitive to the long-term changes in the average values of the climatic parameters - they are mainly affected by the extreme weather events. The planned rail infrastructure and the higher quality of transport services need adaptation strategies to be developed according to assessed risk levels. Strategies should focus on the main problems, like: a) Intensive damage of the earthwork and the substructure due to the rainfall, b) Medical meteorological effects on passengers (heat, UV rays) deterioration of the travel comfort, c) Decrease of the load bearing capacity due to the increase of water content, d) Increased dilatation moves (turnouts). This paper will describe why the application of such adaptation strategies can be advantageous for the European rail operator companies and how these documents provide opportunities for precursory planning and timing of maintenance activities.	3	2018	10.5592/CO/CETRA.2018.924
From climate change impacts to adaptation: A development perspective for India	Garg, A; Shukla, PR; Kapshe, M	NATURAL RESOURCES FORUM	English	Article	impact assessment; sustainable development; climate change; adaptation; infrastructure vulnerability		India has good reasons to be concerned about climate change as it could adversely affect the achievement of vital national development goals related to socio-economic development, human welfare, health, energy availability and use, and infrastructure. The paper attempts to develop a framework for integrated impact assessment and adaptation responses, using a recently built railroad coastal infrastructure asset in India as an example. The framework links climate change variables - temperature, rainfall, sea level rise, extreme events, and other secondary variables - and sustainable development variables - technology, institutions, economic, and other policies. The study indicates that sustainable development variables generally reduce the adverse impacts on the system due to climate change alone, except when they are inadequately applied. The paper concludes that development is a vital variable for integrated impact assessment. Well crafted developmental policies could result in a less-GHG intensive future, enhanced adaptive capacities of communities and systems, and lower impacts due to climate change.	0	2007	10.1111/j.1477-8947.2007.00142.x
Preface: Natural hazard impacts on technological systems and infrastructures	Petrova E., Bostenaru Dan M.	Natural Hazards and Earth System Sciences	English	Article		accident; building; climate change; dam construction; hydrometeorology; ice thickness; landslide; natural hazard; transportation; transportation infrastructure; tsunami	Projected changes to design ice thickness as quantified in the study by Jeong et al. (2019) will be useful information for the development of climate-resilient design standards, codes, and guides for buildings and infrastructure. Caution in designing for ice loads at latitudes higher than 40 N is warranted due to projected increases in extreme ice thickness. As the results show, it is important to examine changes in the future probability of extreme ice loads occurring simultaneously with extreme wind load in northern NA because the compounding effect may lead to an increase in load larger than the increase in ice load or wind load alone. The methodology proposed by Fluixá-Sanmartín et al. (2019) allows a detailed quantification of the effect of climate change on dam safety, which is one of the main concerns of the managers and technicians of this critical infrastructure for water supply and energy production worldwide. It can serve as a useful guide for dam owners and dam safety practitioners in the analysis of other study cases by encompassing different models and data sources. This would eventually allow a more efficient planning of dam safety investments in the long term and even the adaptation of existing dam exploitation rules. Sayão et al. (2020) also deal with dam safety but from a seismic hazard point of view. They introduce the issue of the visualization of databases, while Petrova (2020) and Frolova et al. (2020) also deal with databases of natural hazard impacts on infrastructure, providing useful tools for further research. Williams et al. (2020) conclude that the fragility functions show a trend of lower tsunami vulnerability (through lower probabilities of reaching or exceeding a given damage level) for road-use categories of potentially higher construction standards; bridges are more vulnerable to the impacts of tsunamis than roads; however, bridges are better designed to withstand the forces of tsunami loading and have a lower level of vulnerability at all hazard intensities (inundation depth) compared to buildings; culverts represent particularly vulnerable sections of roads. The topographic setting is also shown to affect the vulnerability of transportation assets in a tsunami. Braud et al. (2020) proposed the methodology that is robust, relevant, and generic enough to evaluate a nonquantitative method of runoff hazard mapping using localized runoffrelated proxy data. The results from their case study confirm that the susceptibility maps produced by the IRIP model provide relevant information related to runoff and that they can be used to design risk management strategies, as illustrated in the railway context. Among all the identified types of natural hazards in the study by Petrova (2020), hydrometeorological hazards such as heavy snowfalls and rains, floods, and ice phenomena, as well as dangerous exogenous slope processes including snow avalanches, debris flows, landslides, and rock falls, were revealed as having the largest contributions to transport accidents and disruptions. The most dangerous is the combination of heavy precipitations and strong winds. Regional differences in the risk of transport accidents between Russian federal regions were found and analyzed. Toma-Danila et al. (2020) and Mossoux et al. (2019) deal with the vulnerability of the transport infrastructure and, more precisely, the road network. This is important in emergency management in the case of a natural disaster (earthquake and volcanic eruption) in order to access such infrastructure as hospitals. Chen et al. (2019) consider the effects of human engineering in increasing landslide susceptibility and effects on infrastructure, providing case studies of two landslides in the vicinity of bridges. If the analysis of transport infrastructure may lead to better planning by providing new road segments and new infrastructure, then in the case of human engineering, land use change, a nonstructural measure, can also be undertaken to provide better land use through regional plans. Looking at the lessons learned from the database and information visualization papers which promote the conversion of data to information – and thus the digital humanities – as well as at the urban, regional, and mobility plans which are necessary to better manage transportation networks and human engineering activities, how other disciplines can contribute to natural hazard research is also highlighted. © 2020 Copernicus GmbH. All rights reserved.		2020	10.5194/nhess-20-2627-2020
Resilient system for a conditioned predictive maintenance of railway infrastructure	Soley G., Morata M., Manzo N., Fontserè V., Peset J.	IABSE Symposium, Guimaraes 2019: Towards a Resilient Built Environment Risk and Asset Management - Report	English	Conference Paper	Adaptation to climate change; Inspection techniques; Railway maintenance; Resilient structures; Structural health monitoring	Architectural design; Asset management; Climate change; Decision making; Environmental management; Maintenance; Railroad plant and structures; Railroads; Structural health monitoring; Adaptation to climate changes; Autonomous monitoring; Industrial technology; Inspection technique; Predictive maintenance; Predictive simulations; Railway infrastructure; Railway maintenance; Railroad transportation	RESILTRACK, “Smart and Resilient System for a Conditioned Predictive Maintenance of Railway Infrastructure”, is a 4-year project co-funded by the Centre for the Development of Industrial Technology (CDTI) in Spain. RESILTRACK brings together 6 Spanish partners (COMSA, Retevisión, Telice, Cemosa, Magtel and Estudios GIS) and 4 research and technological institutions (CIMNE, Tecnalia, Leitat and University of Málaga) to work on the design of a system which provides real time information of the infrastructure state and how it is affected by climatic effects. Data will be obtained by a robust, integral and autonomous monitoring of the railway infrastructure, and it will be analyzed by predictive simulations through DEM-FEM models. Finally, the concepts will be integrated through a BIM tool to facilitate decision making. © 2019 IABSE. All rights reserved.		2019	

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Vulnerability of Interspersed Railway Tracks Exposed to Flood and Washaway Conditions	Kaewunruen S., Nishinomiya Y., Hosoda M.	Springer Tracts in Civil Engineering	English	Book Chapter	Ballasted tracks; Extreme condition; Flood; Interspersed tracks; Railway; Resilience; Vulnerability; Washaway		Railway networks around the world have initially adopted timber sleepers for railway line construction. With time, those timbers deteriorate and emit carbon back to the environment. At present, it is difficult in practice to seek cost-effective hardwood sleepers to replace rotten timber sleepers in time. As a temporary solution, many rail infrastructure managers apply an interspersing method of track maintenance. The interspersing technique is a spot replacement of old timber sleepers with concrete or composite counterparts. This technique is often used as a temporary maintenance for secondary railway lines such as yards, balloon loops or siding. In practice, the interspersed tracks can deteriorate when the tracks are exposed to heavy rains and floods due to the difference in sleeper dimension and stiffness. Under extreme flood events, ballast washaway can be often observed. This study is the world first to demonstrate the vulnerability assessment of interspersed sleeper railways using non-linear finite element simulations, STRAND7. Two moving point loads representing an axle load along each rail have been established to investigate the worst-case, potential instabilities for impaired performance of sleepers and differential settlement of the track. In this study, the emphasis is placed on the effect of ballast washaway on the dynamic displacements and accelerations of rails. The insight will help track engineers develop appropriate climate change adaptation method and policy for versatile operations of interspersed railway tracks facing extreme rainfall and flooding conditions. © 2022, The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd.		2022	10.1007/978-981-16-5312-4_19

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Fragility of transport assets exposed to multiple hazards: State-of-the-art review toward infrastructural resilience	Argyroudis, SA; Mitoulis, SA; Winter, MG; Kaynia, AM	RELIABILITY ENGINEERING & SYSTEM SAFETY	English	Review	Fragility functions; Reliability in quantitative risk analysis; Highway and roadway infrastructure; Numerical modelling; Earthquakes; Landslides; Liquefaction; Flooding; Scouring; Multiple hazards	SOIL-STRUCTURE INTERACTION; SEISMIC RISK-ASSESSMENT; HIGHWAY BRIDGES; ROAD NETWORK; VULNERABILITY EVALUATION; PHYSICAL VULNERABILITY; EMERGENCY MANAGEMENT; NATURAL HAZARDS; SUPPORT-SYSTEM; CLIMATE-CHANGE	Vulnerability is a fundamental component of risk and its understanding is important for characterising the reliability of infrastructure assets and systems and for mitigating risks. The vulnerability analysis of infrastructure exposed to natural hazards has become a key area of research due to the critical role that infrastructure plays for society and this topic has been the subject of significant advances from new data and insights following recent disasters. Transport systems, in particular, are highly vulnerable to natural hazards, and the physical damage of transport assets may cause significant disruption and socioeconomic impact. More importantly, infrastructure assets comprise Systems of Assets (SoA), i.e. a combination of interdependent assets exposed not to one, but to multiple hazards, depending on the environment within which these reside. Thus, it is of paramount importance for their reliability and safety to enable fragility analysis of SoA subjected to a sequence of hazards. In this context, and after understanding the absence of a relevant study, the aim of this paper is to review the recent advances on fragility assessment of critical transport infrastructure subject to diverse geotechnical and climatic hazards. The effects of these hazards on the main transport assets are summarised and common damage modes are described. Frequently in practice, individual fragility functions for each transport asset are employed as part of a quantitative risk analysis (QRA) of the infrastructure. A comprehensive review of the available fragility functions is provided for different hazards. Engineering advances in the development of numerical fragility functions for individual assets are discussed including soil-structure interaction, deterioration, and multiple hazard effects. The concept of SoA in diverse ecosystems is introduced, where infrastructure is classified based on (i) the road capacity and speed limits and (ii) the geomorphological and topographical conditions. A methodological framework for the development of numerical fragility functions of SoA under multiple hazards is proposed and demonstrated. The paper concludes by detailing the opportunities for future developments in the fragility analysis of transport SoA under multiple hazards, which is of paramount importance in decision-making processes around adaptation, mitigation, and recovery planning in respect of geotechnical and climatic hazards.	208	2019	10.1016/j.ress.2019.106567	
Sustainable Urban Drainage Systems in Spain: Analysis of the Research on SUDS Based on Climatology	Garcia, AIA; Perez, NC; Santamarta, JC	SUSTAINABILITY	English	Article	sustainable urban drainage systems; green infrastructures; stormwater green infrastructure; Mediterranean climate; arid climate; template climate; Spain	RAINWATER HARVESTING SYSTEMS; EXTENSIVE GREEN ROOFS; DECISION-SUPPORT TOOL; LIFE-CYCLE ASSESSMENT; ENVIRONMENTAL-ANALYSIS; PERMEABLE PAVEMENTS; RUBBER CRUMBS; INFILTRATION CAPACITY; ECOSYSTEM SERVICES; THERMAL-BEHAVIOR	Sustainable urban drainage systems (SUDS), or urban green infrastructure for stormwater control, emerged for more sustainable management of runoff in cities and provide other benefits such as urban mitigation and adaptation to climate change. Research in Spain began a little over twenty years ago, which was later than in other European countries, and it began in a heterogeneous way, both in the SUDS typology and spatially within the peninsular geography. The main objective of this work has been to know through bibliographic review the state of the art of scientific research of these systems and their relationship with the different types of climates in the country. These structures have a complex and sensitive dependence on the climate, which in the Iberian Peninsula is mostly type B and C (according to the Koppen classification). This means little water availability for the vegetation of some SUDS, which can affect the performance of the technique. To date, for this work, research has focused mainly on green roofs, their capabilities as a sustainable construction tool, and the performance of different plant species used in these systems in arid climates. The next technique with the most real cases analyzed is permeable pavements in temperate climates, proving to be effective in reducing flows and runoff volumes. Other specific investigations have focused on the economic feasibility of installing rainwater harvesting systems for the laundry and the hydraulic performance of retention systems located specifically in the northeast of the Iberian Peninsula. On the contrary, few scientific articles have appeared that describe other SUDS with vegetation such as bioretention systems or green ditches, which are characteristic of sustainable cities, on which the weather can be a very limiting factor for their development.	152	2021	10.3390/su13137258	
Climate Change Impacts on Urban Sanitation: A Systematic Review and Failure Mode Analysis	Hyde-Smith, L; Zhan, Z; Roelich, K; Mdee, A; Evans, B	ENVIRONMENTAL SCIENCE & TECHNOLOGY	English	Review	extreme weather; sewer; CSO; combined sewer overflow; emptying; FSM; flood	WASTE-WATER TREATMENT; COMBINED SEWER OVERFLOWS; RAPID DETERIORATION; DRAINAGE SYSTEMS; PERFORMANCE; INFRASTRUCTURE; TEMPERATURE; FLOOD; VULNERABILITY; ADAPTATION	Climate change will stress urban sanitation systems. Although urban sanitation uses various infrastructure types andservice systems, current research appears skewed toward a smallsubset of cases. We conducted a systematic literature review tocritically appraise the evidence for climate change impacts on allurban sanitation system types. We included road-based transportnetworks, an essential part of fecal sludge management systems.We combined the evidence on climate change impacts with theexisting knowledge about modes of urban sanitation failures. Wefound a predominance of studies that assess climate impacts oncentralized sewerage in high-income contexts. The implications ofclimate change for urban nonsewered and complex, fragmented,and (partially) decentralized sanitation systems remain under-researched. In addition, the understanding of the impacts of climate change on urban sanitation systems fails to take acomprehensive citywide perspective considering interdependencies with other sectors and combinations of climate effects. Weconclude that the evidence for climate change impacts on urban sanitation systems is weak. To date, research neither adequatelyrepresents the variety of urban sanitation infrastructure and service systems nor reflects the operational and management challenges of already stressed systems	150	2022	10.1021/acs.est.1c07424	
Climate change research on transportation systems: Climate risks, adaptation and planning	Wang, TN; Qu, ZH; Yang, ZL; Nichol, T; Clarke, G; Ge, YE	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Climate change; Road; Railway; Climate risk; Adaptation strategy; Transport planning	SEA-LEVEL RISE; HIGH SUMMER TEMPERATURES; ROAD INFRASTRUCTURE; POLICY CAPACITY; LAND-USE; IMPACTS; MANAGEMENT; RESILIENCE; CARBON; VULNERABILITY	With the occurrence of more frequent and intense climate change events, transportation systems, including their infrastructure and operations become increasingly vulnerable. However, the existing research related to climate risks, adaptation and planning in the transport sector is still at an embryonic stage. Understanding such, this paper presents a critical review on climate risks, adaptation strategies and planning in the context of road and rail transportation systems. It aims to conduct a rigorous survey, to highlight any significant research gaps not addressed in past studies and to analyse current emerging topics to guide future directions. It critically dissects the selected papers by categorising them into several dimensions to reveal the status quo and potential challenges, including climate risk assessment, transport asset management, climate planning and policy, and adaptation of transport infrastructure to climate change. It will provide valuable references for future research and constructive insights and empirical guidance on climate adaptation, risk analysis, transport planning and other important relevant topics.	136	2020	10.1016/j.trd.2020.102553	
Airports and environmental sustainability: a comprehensive review	Greer, F; Rakas, J; Horvath, A	ENVIRONMENTAL RESEARCH LETTERS	English	Review	aviation; greenhouse gases; environmental impact; environmental footprint; infrastructure	LIFE-CYCLE ASSESSMENT; INDOOR AIR-QUALITY; INTERNATIONAL AIRPORT; PERFORMANCE ANALYSIS; TERMINAL BUILDINGS; CONTROL TOWER; AIRCRAFT; SYSTEM; ENERGY; EMISSIONS	Over 2500 airports worldwide provide critical infrastructure that supports 4 billion annual passengers. To meet changes in capacity and post-COVID-19 passenger processing, airport infrastructure such as terminal buildings, airfields, and ground service equipment require substantial upgrades. Aviation accounts for 2.5% of global greenhouse gas (GHG) emissions, but that estimate excludes airport construction and operation. Metrics that assess an airport's sustainability, in addition to environmental impacts that are sometimes unaccounted for (e.g. water consumption), are necessary for a more complete environmental accounting of the entire aviation sector. This review synthesizes the current state of environmental sustainability metrics and methods (e.g. life-cycle assessment, Scope GHG emissions) for airports as identified in 108 peer-reviewed journal articles and technical reports. Articles are grouped according to six categories (Energy and Atmosphere, Comfort and Health, Water and Wastewater, Site and Habitat, Material and Resources, Multidimensional) of an existing airport sustainability assessment framework. A case study application of the framework is evaluated for its efficacy in yielding performance objectives. Research interest in airport environmental sustainability is steadily increasing, but there is ample opportunity for more systematic assessment that accounts for a variety of emissions and regional variation. Prominent research themes include analysing the GHG emissions from airfield pavements and energy management strategies for airport buildings. Research on water conservation, climate change resilience, and waste management is more limited, indicating that airport environmental accounting requires more analysis. A disconnect exists between research efforts and practices implemented by airports. Effective practices such as sourcing low-emission electricity and electrifying ground transportation and gate equipment can in the short term aid airports in moving towards sustainability goals. Future research must emphasize stakeholder involvement, life-cycle assessment, linking environmental impacts with operational outcomes, and global challenges (e.g. resilience, climate change adaptation, mitigation of infectious diseases).	133	2020	10.1088/1748-9326/abb42a	
Climate Change Policy Coherence across Policies, Plans, and Strategies in Pakistan-Implications for the China-Pakistan Economic Corridor Plan	Waheed, A; Fischer, TB; Khan, MI	ENVIRONMENTAL MANAGEMENT	English	Article	Climate change policy coherence; Adaptation and mitigation; CPEC; Pakistan	CHANGE ADAPTATION; SUSTAINABLE DEVELOPMENT; ENERGY; COAL; PERCEPTIONS; CONSUMPTION; ENVIRONMENT; GOVERNANCE; MITIGATION; EMISSIONS	Climate Change (CC) adaptation and mitigation policy coherence (PC) across sectors is essential to effectively address CC challenges and support synergies. Pakistan is highly vulnerable to CC. In this paper, the extent to which Pakistan's national and provincial water, agriculture, and energy sector policies, development plans and strategies are aligned in a CC policy coherent manner is established. In this context, a qualitative content document analysis with associated scoring is used to assess government documents. Furthermore, implications of the China-Pakistan Economic Corridor Initiative (CPEC; 2017-2030), the biggest infrastructure investment program ever in Pakistan, are discussed. An important result is that sectoral policies are found to have different degrees of PC. Better coherence is found at federal than at provincial levels. Furthermore, CC policies are found to be more coherently addressed in water and agriculture policies than in energy policies. It is suggested that to achieve higher levels of CC PC, federal and provincial governments should establish mechanisms of intergovernmental consultation for policy-making and cross-sectoral planning, especially in the energy sector. Our findings can help the Government of Pakistan to transform CPEC into a model green Belt and Road Initiative (BRI) in the region. In this context, there are important implications with regards to e.g., reducing coal-based energy projects and environmentally damaging infrastructure activities in sensitive ecosystems. With this paper, the authors want to raise awareness of the key importance of CC PC, particular in context of the BRI. Many countries participating in the initiative have carbon reduction targets in place.	131	2021	10.1007/s00267-021-01449-y	
THE ROLE OF GRAPEVINE LEAF MORPHOANATOMICAL TRAITS IN DETERMINING CAPACITY FOR COPING WITH ABIOTIC STRESSES: A REVIEW	MacMillan, P; Teixeira, G; Lopes, CM; Monteiro, A	CIENCIA E TECNICA VITIVINICOLA	English	Review	hydraulic conductivity; leaf epidermis; mesophyll; morphoanatomy; stomata; xylem	VITIS-VINIFERA L.; DROUGHT-INDUCED EMBOLISM; WATER-USE EFFICIENCY; HYDRAULIC CONDUCTANCE; VULNERABILITY CURVES; ADAPTIVE STRATEGIES; INDUCED CAVITATION; CONDUIT DIAMETER; FIELD CONDITIONS; PLANT CUTICLES	Worldwide, there are thousands of Vitis vinifera grape cultivars used for wine production, creating a large morphological, anatomical, physiological and molecular diversity that needs to be further characterised and explored, with a focus on their capacity to withstand biotic and abiotic stresses. This knowledge can then be used to select better adapted genotypes in order to help face the challenges of the expected climate changes in the near future. It will also assist grape growers in choosing the most suitable cultivar(s) for each terroir; with adaptation to drought and heat stresses being a fundamental characteristic. The leaf blade of grapevines is the most exposed organ to abiotic stresses, therefore its study regarding the tolerance to water and heat stress is becoming particularly important, mainly in Mediterranean viticulture. This review focuses on grapevine leaf morphoanatomy - leaf blade form, leaf epidermis characteristics (cuticle, indumentum, pavement cells and stomata) and anatomy of mesophyll - and their adaptation to abiotic stresses. V. vinifera xylem architecture and its adaptation capacity when the grapevine is subjected to water stress is also highlighted since grapevines have been observed to exhibit a large variability in responses to water availability. The hydraulic properties of the petiole, shoot and trunk are also reviewed. Summarising, this paper reviews recent advances related to the adaptation of grapevine leaf morphoanatomical features and hydraulic architecture to abiotic stresses, mainly water and heat stress, induced primarily by an ever-changing global climate.	131	2021	10.1051/ctv/ctv20213601 75	
Enhancing the Ecological Value of Sea Dikes	Scheres, B; Schuttrumpf, H	WATER	English	Review	green sea dikes; ecological enhancement; ecological engineering; nature-based solutions; ecosystem services	COASTAL INFRASTRUCTURE; SALT MARSHES; PLANT-ROOTS; EROSION; ENHANCEMENT; ECOSYSTEMS; OPPORTUNITIES; ADAPTATION; ORGANISMS; OUTCOMES	Sea dikes protect low-lying hinterlands along many coasts all around the world. Commonly, they are designed as embankments with grass covers or grey revetments accounting for the prevailing hydraulic loads. So far, incorporation of ecological aspects in the dike design is limited. With regard to increasing environmental awareness and climate change adaptation needs, the present study reviews methods for ecological enhancement of sea dikes and discusses limitations and challenges related to these methods. In doing so, one key aspect is to maintain dike safety while increasing the ecological value. Potential for ecological enhancement of sea dikes has been found regarding natural or nature-based solutions in the foreshore, dike surface protection measures (vegetated dike covers, hard revetments and dike roads) and the dike geometry. While natural and nature-based solutions in the foreland are investigated thoroughly, so far only few experiences with ecological enhancements of the dike structure itself were gained resulting in uncertainties and knowledge gaps concerning the implementation and efficiency. Additional to technical uncertainties, engineers and ecologists meet the challenge of interdisciplinary collaboration under consideration of societal needs and expectations.	126	2019	10.3390/w11081617	
Transformations for Resilient Rural Futures: The Case of Kaikura, Aotearoa-New Zealand	Cradock-Henry, NA; Fountain, J; Buelow, F	SUSTAINABILITY	English	Article	resilience; disaster; earthquake; recovery; transformation; New Zealand	GLOBAL ENVIRONMENTAL-CHANGE; CLIMATE-CHANGE; ECOLOGICAL RESILIENCE; GROUND MOTION; 2016 KAIKOURA; GOVERNANCE; ADAPTATION; EARTHQUAKE; COMMUNITY; MANAGEMENT	On 14 November 2016, a magnitude (M-w) 7.8 earthquake struck the small coastal settlement of Kaikura, Aotearoa-New Zealand. With an economy based on tourism, agriculture, and fishing, Kaikura was immediately faced with significant logistical, economic, and social challenges caused by damage to critical infrastructure and lifelines, essential to its main industries. Massive landslips cut off road and rail access, stranding hundreds of tourists, and halting the collection, processing and distribution of agricultural products. At the coast, the seabed rose two metres, limiting harbour-access to high tide, with implications for whale watching tours and commercial fisheries. Throughout the region there was significant damage to homes, businesses, and farmland, leaving owners and residents facing an uncertain future. This paper uses qualitative case study analysis to explore post-quake transformations in a rural context. The aim is to gain insight into the distinctive dynamics of disaster response mechanisms, focusing on two initiatives that have emerged in direct response to the disaster. The first examines the ways in which agriculture, food harvesting, production and distribution are being reimagined with the potential to enhance regional food security. The second examines the rescaling of power in decision-making processes following the disaster, specifically examining the ways in which rural actors are leveraging networks to meet their needs and the consequences of that repositioning on rural (and national) governance arrangements. In these and other ways, the local economy is being revitalised, and regional resilience enhanced through diversification, capitalising not on the disaster but the region's natural, social, and cultural capital. Drawing on insights and experience of local stakeholders, policy- and decision-makers, and community representatives we highlight the diverse ways in which these endeavours are an attempt to create something new, revealing also the barriers which needed to be overcome to reshape local livelihoods. Results reveal that the process of transformation as part of rural recovery must be grounded in the lived reality of local residents and their understanding of place, incorporating and building on regional social, environmental, and economic characteristics. In this, the need to respond rapidly to realise opportunities must be balanced with the community-centric approach, with greater recognition given to the contested nature of the decisions to be made. Insights from the case examples can inform preparedness and recovery planning elsewhere, and provide a rich, real-time example of the ways in which disasters can create opportunities for reimagining resilient futures.	110	2018	10.3390/su10061952	
Adaptation of agricultural crop production to climate change: A policy framework for Sri Lanka	De Costa, WAJM	JOURNAL OF THE NATIONAL SCIENCE FOUNDATION OF SRI LANKA	English	Article	Adaptation; climate change impacts; policy; rice; tea; vulnerability	ATMOSPHERIC CARBON-DIOXIDE; RICE ORYZA-SATIVA; PLANT-DISEASE; ELEVATED CO2; GLOBAL CLIMATE; FOOD SECURITY; WATER-USE; YIELD; UNCERTAINTY; TEMPERATURE	Agriculture is one of the key sectors of the Sri Lankan economy, which contributes a significant percentage to its gross domestic product (GDP) and provides direct or indirect employment to a sizeable proportion of its population. Climate change involves long-term slow changes in climate, short-term year-to-year climatic variability and unpredictable extreme climatic events. Agriculture, especially crop production, is highly dependent on the prevailing weather conditions and therefore is highly sensitive to climate change, both short-term and long-term. Almost all General Circulation Models predict that the processes of climate change such as increasing atmospheric concentrations of greenhouse gases and global warming will continue well into the 21(st) century even if the mitigation measures to minimize the causes of climate change exert maximum effect. Therefore, it is imperative that a well-co-ordinated and sustained effort is set in motion to increase the capacity of Sri Lankan agriculture to adapt to short and long-term climate change. Adaptation involves measures to minimize the impacts of climate change. At present, implementation of climate change adaptation measures in Sri Lanka is piecemeal and lacks co-ordination and direction. Hence, a clear policy framework identifying the measures to be pursued and the roles of different stakeholders is needed for allocating and channelling the necessary financial and human resources for successful adaptation to climate change. A clear and comprehensive policy framework also becomes the basis for development of an effective road map and an action plan to achieve successful adaptation. This paper discusses a policy framework for adaptation of Sri Lankan agriculture to climate change based on the following components: (a) Quantification and forecasting of climate change; (b) Assessment of impacts and vulnerability to climate change; (c) Identification and formulation of responses to adapt to climate change; (d) Creating and strengthening the institutional framework and infrastructure to implement and monitor adaptation measures to climate change. Major advances in scientific research on components a, b and c, both locally and internationally, are briefly discussed and key policy measures to facilitate and accelerate their progress along with the relevant stakeholders are identified. Importance of allocating adequate resources to promote research on all aspects of climate change and their impacts by developing infrastructure, a critical mass of experts and an institutional framework to effectively link all stakeholders to channel the formulated adaptation measures to the farming communities at the grass-root level are emphasized.	105	2010	10.4038/jnsfsr.v38i2.2032	
An approach for assessing adaptive capacity to climate change in resource dependent communities in the Nikachu watershed, Bhutan	Choden, K; Keenan, RJ; Nitschke, CR	ECOLOGICAL INDICATORS	English	Article	Climate change; Adaptive capacity; Econometric data; Socio-economic; Vulnerability; Sustainable livelihood framework	LIVELIHOOD VULNERABILITY; OPHIOCORDYCEPS-SINENSIS; HOUSEHOLD VULNERABILITY; SUSTAINABLE DEVELOPMENT; SOCIAL VULNERABILITY; MULTIPLE STRESSORS; UTTARAKHAND STATE; ADAPTATION; VARIABILITY; STRATEGIES	Vulnerability to climate change is a function of exposure, sensitivity and adaptive capacity. Econometric and indicator-based approaches have been used to assess vulnerability at regional, national and global scales. However, these approaches often fail to capture how vulnerability varies within regions and communities. Within regions there is often little capacity to distinguish between exposure and sensitivity, while there is potentially considerable variability in adaptive capacity. This study presents a new approach for assessing adaptive capacity at household and village-levels by combining econometric data and landscape ecology measures to generate new types of indicators that provide new insights into local level adaptive capacity. Livelihood security is a key contributor to adaptation and we used the sustainable livelihood framework as a basis for analysis. We conducted social survey information with spatial data on different livelihood captials and integrated these using multivariate statistical methods to generate indicators of adaptive capacity for households and villages. A mixed method approach was used in two contrasting localities in the Nikachu watershed in central Bhutan to gather social and economic data and spatial data on landscape variables. A total of 144 households were selected through simple random sampling and were interviewed across 22 villages in the watershed. Indicators revealed a strong link between adaptive capacity and landscape position. Households at higher elevations generally had lower adaptive capacity, and therefore higher vulnerability to climate change, due to differences in physical, financial, natural and human capitals. These households and villages had lower diversity in income sources, greater dependence on natural resources, less education and training, less access to infrastructure (such as roads), and access to markets than households at lower elevations. Gender was also important, with female headed households having lower adaptive capacity scores. However, some higher elevation households had higher adaptive capacity scores than others due to their capacity to collect the valuable insect fungus, Ophiocordyceps sinensis, from high altitude meadows. These new indicators provide insights into how adaptive capacity varies across scales. They can be used to identify policies and actions to improve adaptive capacity of vulnerable households and communities.	103	2020	10.1016/j.ecolind.2020.106293	
Arctic permafrost landscapes in transition: towards an integrated Earth system approach	Vincent, WF; Lemay, M; Allard, M	ARCTIC SCIENCE	English	Review	adaptation; Arctic; climate change; cryosphere; permafrost; thermokarst	CLIMATE-CHANGE; SURFACE TEMPERATURES; AQUATIC ECOSYSTEMS; THERMOKARST LAKES; THERMAL STATE; SNOW COVER; CARBON; ICE; INFRASTRUCTURE; ALASKA	Permafrost science and engineering are of vital importance for northern development and climate adaptation given that buildings, roads, and other infrastructure in many parts of the Arctic depend on permafrost stability. Permafrost also has wide-ranging effects on other features of the Arctic environment including geomorphology, biogeochemical fluxes, tundra plant and animal ecology, and the functioning of lake, river, and coastal marine ecosystems. This review presents an Earth system perspective on permafrost landscapes as an approach towards integration across disciplines. The permafrost system can be described by a three-layer conceptual model, with an upper buffer layer that contains vegetation or infrastructure. Snow and liquid water strongly affect the thermal properties and stability of these layers and their associated interfaces, resulting in critical times and places for accelerated degradation of permafrost and for exchanges of mass and heat with the hydrosphere and atmosphere. Northern permafrost landscapes are now in rapid transition as a result of climate warming and socioeconomic development, which is affecting their ability to provide geosystem and ecosystem services. The Earth system approach provides a framework for identifying linkages, thresholds, and feedbacks among system components, including human systems, and for the development of management strategies to cope with permafrost change.	103	2017	10.1139/as-2016-0027	

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Farmers Perceptions of Climate Change Related Events in Shendam and Riyom, Nigeria	Goyol, S; Pathirage, C	ECONOMIES	English	Article	agrarian infrastructure (AI); agrarian livelihoods; climate change; cascading effects; perception	SUB-SAHARAN AFRICA; CROP PRODUCTION; FUTURE CLIMATE; INFRASTRUCTURE; VARIABILITY; ADAPTATION; IMPACTS; SYSTEMS; VULNERABILITY; TEMPERATURE	Although agriculture in Nigeria is the major source of income for about 70% of the active population, the impact of agrarian infrastructure on boosting productivity and supporting livelihoods has increased. Climate change and the increasing trend of climate-related events in Nigeria challenge both the stability of agrarian infrastructure and livelihood systems. Based on case studies of two local communities in Plateau state in Nigeria, this paper utilizes a range of perceptions to examine the impacts of climate-related events on agrarian infrastructures and how agrarian livelihood systems are, in turn, affected. Data are obtained from a questionnaire survey (n = 175 farmers) and semi-structured interviews (n = 14 key informants). The study identifies local indicators of climate change, high risks climate events and the components of agrarian infrastructures that are at risk from climate events. Findings reveal that, changes in rainfall and temperature patterns increase the probability of floods and droughts. They also reveal that, although locational differences account for the high impact of floods on road transport systems and droughts on irrigation infrastructures, both have a chain of negative effects on agricultural activities, economic activities and livelihood systems. A binomial logistic regression model is used to predict the perceived impact levels of floods and droughts, while an in-depth analysis is utilised to corroborate the quantitative results. The paper further stresses the need to strengthen the institutional capacity for risk reduction through the provision of resilient infrastructures, as the poor conditions of agrarian infrastructure were identified as dominant factors on the high impact levels.	103	2018	10.3390/economies6040070	
Network-Level Risk-Based Framework for Optimal Bridge Adaptation Management Considering Scour and Climate Change	Liu, L; Yang, DY; Frangopol, DM	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Climate change; Adaptation planning; Bridge management; Optimization; Transportation network	UNITED-STATES; DAMAGE RISKS; LOCAL SCOUR; OPTIMIZATION; PRECIPITATION; RELIABILITY; IMPACTS; HAZARD	Transportation networks, as an essential ingredient of civil infrastructure, are subjected to various natural hazards over their service life. Failure of bridges may severely disrupt the serviceability of transportation networks, causing considerable economic and social losses. Recently, climate change has been found to be liable for the increasing bridge vulnerability due to intensification of extreme hydrologic events (e.g., floods, sea level rise, and hurricanes). With the limited resources for infrastructure management and the growing risk compounded by climate change, effective risk-informed management for bridge adaptation actions is imperative for the safety and serviceability of transportation networks. This paper formulates a network-level, risk-based framework that determines the optimal adaptation schedules for bridges in a transportation network considering climate change effects. Bridge scour, one of the most common failure modes for bridges under floods, is investigated. The proposed framework (1) evaluates the consequences of bridge failure at the transportation network level, (2) considers climate change effects related to bridge scour using hydrologic modeling under different climate change scenarios, and (3) investigates the effects of budget availability and risk perception on the decision-making process. The proposed framework is demonstrated using an existing highway bridge network located in the Lehigh River watershed in Pennsylvania.	103	2020	10.1061/(ASCE)IS.1943-555X.0000516	
Sea-level rise impacts on transport infrastructure: The notorious case of the coastal railway line at Dawlish, England	Dawson, D; Shaw, J; Gehrels, WR	JOURNAL OF TRANSPORT GEOGRAPHY	English	Article	Climate change; Adaptation; Resilience; Semi-empirical; Rail network; Economic impact	CLIMATE-CHANGE; STAKEHOLDER REPRESENTATION; SEVERE STORMS; PROBABILITIES; MANAGEMENT; INSIGHTS; WEATHER; TRENDS; FLOODS; ROAD	Future climate change is likely to increase the frequency of coastal storms and floods, with major consequences for coastal transport infrastructure. This paper assesses the extent to which projected sea-level rise is likely to impact upon the functioning of the Dawlish to Teignmouth stretch of the London to Penzance railway line, in England. Using a semi-empirical modelling approach, we identify a relationship between sea-level change and rail incidents over the last 150 years and then use model-based sea-level predictions to extrapolate this relationship into the future. We find that days with line restrictions (DLRs) look set to increase by up to 1170%, to as many as 84–120 per year, by 2100 in a high sea-level rise scenario (0.55-0.81 m). Increased costs to the railway industry deriving from maintenance and line restrictions will be small (pound millions) in comparison with damage caused by individual extreme events (10s pound of millions), while the costs of diversion of the railway are higher still (100s pound of millions to billions). Socio-economic costs to the region are likely to be significant although they are more difficult to estimate accurately. Finally, we explain how our methodology is applicable to vulnerable coastal transport infrastructure worldwide. (C) 2015 The Authors. Published by Elsevier Ltd.	102	2016	10.1016/j.jtrangeo.2015.11.009	
The impact of climate change on urban transport resilience in a changing world	Jaroszweski, D; Hooper, E; Chapman, L	PROGRESS IN PHYSICAL GEOGRAPHY-EARTH AND ENVIRONMENT	English	Review	CCIA; Climate Change Impact Assessment; climate change; climate projections; socio-economic scenarios; transport; transport meteorology	HIGH SUMMER TEMPERATURES; TRAFFIC ACCIDENTS; WEATHER; ROAD; HEAT; PRECIPITATION; RAINFALL; ADAPTATION; SCENARIOS; VEHICLES	The assessment of the potential impact of climate change on transport is an area of research very much in its infancy, and one that requires input from a multitude of disciplines including geography, engineering and technology, meteorology, climatology and futures studies. This paper investigates the current state of the art for assessments on urban surface transport, where rising populations and increasing dependence on efficient and reliable mobility have increased the importance placed on resilience to weather. The standard structure of climate change impact assessment (CIA) requires understanding in three important areas: how weather currently affects infrastructure and operations; how climate change may alter the frequency and magnitude of these impacts; and how concurrent technological and socio-economic development may shape the transport network of the future, either ameliorating or exacerbating the effects of climate change. The extent to which the requisite knowledge exists for a successful CIA is observed to decrease from the former to the latter. This paper traces a number of developments in the extrapolation of physical and behavioural relationships on to future climates, including a broad move away from previous deterministic methods and towards probabilistic projections which make use of a much broader range of climate change model output, giving a better representation of the uncertainty involved. Studies increasingly demand spatially and temporally downscaled climate projections that can represent realistic sub-daily fluctuations in weather that transport systems are sensitive to. It is recommended that future climate change impact assessments should focus on several key areas, including better representation of sub-daily extremes in climate tools, and recreation of realistic spatially coherent weather. Greater use of the increasing amounts of data created and captured by intelligent infrastructure' and 'smart cities' is also needed to develop behavioural and physical models of the response of transport to weather and to develop a better understanding of how stakeholders respond to probabilistic climate change impact projections.	102	2014	10.1177/0309133314538741	
Incorporating Climate Change in Pavement Maintenance Policies: Application to Temperature Rise in the Isfahan County, Iran	Mahpour, A; El-Diraby, T	SUSTAINABLE CITIES AND SOCIETY	English	Article	Temperature Rise; Sustainable Pavement Maintenance; Machine-Learning; Markov Chain Model	CHANGE ADAPTATION; CHANGE IMPACTS; PERFORMANCE; LIFE; DESERTIFICATION; THRESHOLDS; REGRESSION; COSTS; BASIN	Although temperature rise is imminent in Iran and could damage asphalt pavements, no national guide exists to adapt them. To ensure the sustainability of pavements against temperature rise, a county-level methodology based on machine-learning algorithms was developed. To show the applicability of the framework, the Isfahan County was studied. The county's climate was found to change from cold-semi-desert to relatively-warm-semidesert in future decades. Then, optimal maintenance policies before and after climate change were identified. It was concluded that optimal policies of arterial roads before and after climate change were more intense than those of local roads. Furthermore, optimal policies after climate change were more intense than those before climate change at additional costs of 1379.57 MR/KM and 632.49 MR/KM respectively for arterial and local roads. The same methodology could be applied to sustainably adapt asphalt pavements of other counties. To validate the research, a questionnaire survey of pavement management and climate change experts was done. The experts confirmed that the methodology facilitates achieving sustainable development goals #9, #11, and #13 by improving maintenance budget allocation, enhancing policy-makers communication with authorities, maintaining adequate technical and end-user levels of service, and adapting pavements to climate change through cost-effective and performance-effective maintenance policies.	99	2021	10.1016/j.scs.2021.102960	
How can the UK road system be adapted to the impacts posed by climate change? By creating a climate adaptation framework	Wang, TN; Qu, ZH; Yang, ZL; Nichol, T; Dimitriu, D; Clarke, G; Bowden, D	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Climate change; Adaptation measure; Risk analysis; Road planning; Transportation; Bayesian networks; Evidential reasoning	BAYESIAN NETWORK; INFRASTRUCTURE; TRANSPORT; SAFETY; RESILIENCE; PORTS	This paper aims to analyse the impacts of climate change to the current and predicted future situations of road transportation in the UK and evaluate the corresponding adaptation plans to cope with them. A conceptual framework of long-term adaptation planning for climate change in road systems is proposed to ensure the resilience and sustainability of road transport systems under various climate risks such as flooding and increased temperature. To do so, an advanced Fuzzy Bayesian Reasoning (FBR) model is first employed to evaluate the climate risks in the UK road transport networks. This modelling approach can tackle the high uncertainty in risk data and thus facilitate the development of the climate adaptation framework and its application in the UK road sector. To examine the feasibility of this model, a nationwide survey is conducted among the stakeholders to analyse the climate risks, in terms of the timeframe of climate threats, the likelihood of occurrence, the severity of consequences, and infrastructure resilience. From the modelling perspective, this work brings novelty by expanding the risk attribute the severity of consequence into three sub-attributes including economic loss, damage to the environment, and injuries and/or loss of life. It advances the-state-of-the-art technique in the current relevant literature from a single to multiple tier climate risk modelling structure. Secondly, an Evidential Reasoning (ER) approach is used to prioritise the best adaptation measure(s) by considering both the risk analysis results from the FBR and the implementation costs simultaneously. The main new contributions of this part lie in the rich raw data collected from the real world to provide useful practical insights for achieving road resilience when facing increasing climate risk challenges. During this process, a qualitative analysis of several national reports regarding the impacts posed by climate change, risk assessment and adaptation measures in the UK road sector is conducted for the relevant decision data (i.e. risk and cost). It is also supplemented by an in-depth interview with a senior planner from Highways England. The findings provide road planners and decision makers with useful insights on identification and prioritisation of climate threats as well as selection of cost-effective climate adaptation measures to rationalise adaptation planning.	98	2019	10.1016/j.trd.2019.02.007	
Climate services in support of climate change impact analyses for the German inland transportation system	Hansel, S; Brendel, C; Haller, M; Krahenmann, S; Razafimaharo, CS; Stanley, K; Brienen, S; Deutschlander, T; Rauthe, M; Walter, A	METEOROLOGISCHE ZEITSCHRIFT	English	Article	climate change; extreme events; transportation; climate impact assessment; climate change adaptation; BMDV Network of Experts	BIAS CORRECTION; SCENARIO FRAMEWORK; ROAD NETWORKS; EURO-CORDEX; MODEL; WEATHER; EXTREMES; TEMPERATURE; MANAGEMENT; INFRASTRUCTURES	Climate change and extreme weather events are an increasing challenge for society and the economy, including the transport sector. A sustainable and resilient transportation system therefore requires information on the temporal and spatial pattern of risks induced by climate change and the assessment of resulting vulnerabilities. Such analyses in the past were usually made separately for each mode of transport based on different observational and climate model datasets and using different methodological approaches to analyse climatic changes and their impacts on the transport infrastructure. Within the research network BMDV Network of Experts an intermodal perspective is taken on transportation. Common observational and climate model datasets as well as a standardized analysis framework were coordinated and agreed upon to form the basis for comparable climate impact assessments for roads, railways and inland waterways. This manuscript introduces the climatological datasets and methodological approaches for the climate change and climate impact analysis used for the transportation sector and beyond. Selected results on the projected increases of extreme temperature and heavy precipitation are exemplarily presented in order to illustrate the need for developing climate change adaptation measures for the German inland transport system.	97	2022	10.1127/metz/2022/1117	
A Location Intelligence System for the Assessment of Pluvial Flooding Risk and the Identification of Storm Water Pollutant Sources from Roads in Suburbanised Areas	Szewranski, S; Chruscinski, J; van Hoof, J; Kazak, JK; Swader, M; Tokarczyk-Dorociak, K; Zmuda, R	WATER	English	Article	location intelligence; pluvial flood risk assessment; road run-off management; storm water pollutant sources; green infrastructure; blue infrastructure; urban climate adaptation	LOW-IMPACT DEVELOPMENT; NONPOINT-SOURCE POLLUTION; HEAVY-METALS; RUNOFF QUALITY; CLIMATE-CHANGE; URBAN RUNOFF; WASH-OFF; MANAGEMENT; CATCHMENT; DAMAGE	The interplay of an ever-growing number of inhabitants, sprawl development, soil sealing, changes in urban traffic characteristics, as well as observed climate trends gives rise to more frequent pluvial flooding in cities, a higher run-off of water, and an increasing pollution of surface water. The aim of this research is to develop a location intelligence system for the assessment of pluvial flooding risks and the identification of storm water pollutant sources from roads in newly-developed areas. The system combines geographic information systems and business intelligence software, and it is based on the original Pluvial Flood Risk Assessment tool. The location intelligence system effectively identifies the spatial and temporal distribution of pluvial flood risks, allows to preliminarily evaluate the total run-off from roads, and helps localise potential places for new water management infrastructure. Further improvements concern the modelling of a flow accumulation and drainage system, the application of weather radar precipitation data, and traffic monitoring and modelling.	95	2018	10.3390/w10060746	
A review of the adaptation and mitigation of global climate change using sustainable drainage in cities	Charlesworth, SM	JOURNAL OF WATER AND CLIMATE CHANGE	English	Review	carbon sequestration and storage; flooding resilience; human health and well-being; mitigation and adaptation; sustainable drainage; urban heat island effect	PERMEABLE PAVEMENT; GREEN SPACE; LAND-COVER; URBAN; SEQUESTRATION; TEMPERATURE; PERFORMANCE; ENVIRONMENT; MERSEYSIDE; IMPACTS	Sustainable drainage (SUDS) is well known for its equal emphasis on water quality, water quantity, amenity and biodiversity. What is now beginning to be realised is that this approach can also help mitigate the impacts of global climate change (GCC) and provide assistance to city dwellers in adapting to the changes which have already occurred. By using case studies from around the world, this paper illustrates how vegetated SUDS devices can sequester and store carbon, cool urban areas and increase perceptions of health and well-being in the populace. Both vegetated and hard engineered structures can store water contained within them and are thus being used in cities to cool the overlying air. Also shown is the extent to which SUDS devices such as green roofs and wet pavements are being used to mitigate the urban heat island effect, which, while not caused by climate change, exacerbates its impacts. Of the houses needed by 2040 in the UK, 80% already exist. In order to take advantage of the ability of SUDS to tackle some of the impacts of GCC, the emphasis must be placed on retrofitting technologies to existing buildings and this review proposes a simple hierarchy of suitable measures based on the density and land-use of the built-up area.	95	2010	10.2166/wcc.2010.035	
Adaptation Policy Framework for Climate Change Impacts on Transportation Sector in Developing Countries	Vajjarapu, H; Verma, A; Gulzar, S	TRANSPORTATION IN DEVELOPING ECONOMIES	English	Article	Climate change; Transportation; Developing countries; Adaptation; Policy; Urban flooding	WEATHER; CITY	The global response to climate change threat has been through mitigation by reducing the GHG emissions; however, some of the climate change effects are inevitable and unavoidable. Adaptation is seen as a necessary means of addressing these inevitable climate change effects, some of which are projected to bring more frequent and severe precipitation resulting in floods. This threat of floods reinforced by rapid urbanization, resulting in urban flooding has become a looming threat to road transportation which disproportionally affects developing countries. There is an urgent need to adapt transport infrastructure to the anticipated climate change effects to minimize human as well as economic losses. In this paper, a consolidated review of literature on road transport-related climate change adaptation measures adopted across different countries around the world has been done, followed by the identification of barriers and adaptation challenges in developing countries such as India. Further, a novel methodological approach has been proposed for shaping adaptation policies in developing countries. It is aimed to enhance the resilience of transportation system specifically against urban flooding induced by climate change, reduce its impacts and strengthen the adaptive capacity of the system.	93	2019	10.1007/s40890-019-0071-y	
LOCAL CLIMATE CHANGE AND URBAN HEAT ISLAND MITIGATION TECHNIQUES - THE STATE OF THE ART	Akbari, H; Cartalis, C; Kolokotsa, D; Muscio, A; Pisello, AL; Rossi, F; Santamouris, M; Synnefa, A; Wong, NH; Zinzi, M	JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT	English	Article	urban heat island; mitigation; adaptation; cool materials	INDOOR ENVIRONMENTAL-QUALITY; SPECTRAL OPTICAL-PROPERTIES; BUILDING ENVELOPE SURFACES; THERMAL COMFORT CONDITIONS; LOW-INCOME HOUSEHOLDS; COOL ROOFS; RESIDENTIAL BUILDINGS; SOLAR REFLECTANCE; ENERGY-CONSUMPTION; HOT SUMMER	Increase of the ambient air temperature in cities caused by the urban heat island phenomenon has a seri- ous impact on the economic and social system of cities. to counterbalance the consequences of the increased urban temperatures important research has been carried out resulting in the development of efficient mitigation technologies. the present paper aims to present the state of the art in terms of local climate change and urban heat island mitigation techniques. In particular, developments in the field on highly reflective materials, cool and green roofs, cool pavements, urban green and of other mitigation technologies are presented in detail, while examples of implemented projects are given.	93	2016	10.3846/13923730.2015.1111934	
Mapping socio-ecological resilience along the seven economic corridors of the Belt and Road Initiative	Battamo, AY; Varis, O; Sun, PZ; Yang, YK; Oba, BT; Zhao, L	JOURNAL OF CLEANER PRODUCTION	English	Article	Adaptation; Belt and road initiative; Ecological vulnerability; Resilience; Sustainability; Water resources management	CLIMATE-CHANGE; ADAPTIVE CAPACITY; RIVER-BASINS; CHINA BELT; ENVIRONMENTAL VULNERABILITY; HUMAN DIMENSIONS; ADAPTATION; FOOTPRINT; DROUGHT; RISK	China's Belt and Road Initiative (BRI) is a massive development plan in terms of scale and scope. It aims at facilitating China's connectivity with the rest of the world through trade, investment, and infrastructure projects. BRI encompasses seven economic corridors, which cover over 100 countries. Consequently, the spectrum of their social and ecological conditions is diverse and broad. To date, no systematic BRI scale study exists to assess the ecological challenges of these economic corridors and associate the challenges with the BRI's capacity to cope with them. Thus, it is of profound importance to understand the complex interactions between human (socialeconomic) and natural (ecological) systems, which are essential to design sustainable development policies in this vast region. This challenging task requires innovative and interdisciplinary research approaches in a policy relevant way. We address this gap by presenting a data-driven geospatial analysis on this complex entity using the Social-Ecological Systems approach. Methodologically, we use resilience analysis, as an equilibrium concept of Ecological Vulnerability (EV) and Adaptive Capacity (AC). A high-resolution geospatial resilience (the ability to withstand and recognize disruptions when experiencing changes) mapping is made for the river basins along the BRI corridors to identify the drivers of resilience from 1990 to 2015. The results reveal highly diverse patterns of these drivers across the BRI economic corridors. The differences among the corridors grew within the study period. The root cause for the low resilience along the 21st-C Maritime Silk Road (predominantly the African continent) is low adaptive capacity, whereas higher ecological vulnerability is the main reason along the Bangladesh-China-India-Myanmar, China-Pakistan, China-Central-Asia-West Asia, and China-Indochina Peninsula economic corridors. Further adaptation measures are needed to mitigate the risks related to decreased AC levels and increased EV levels. Investments under the initiative should better combine adequate physical infrastructure with improving institutional (both human talent development and efficient governance) and economic capacities to cope with the existing ecological vulnerability challenges. Finally, this study highlights that over time, AC has shown notable improvements, particularly in Asia, and in contrast to a less volatile EV. The equilibrium analysis between AC and EV offers a valuable resource for policy and decision-makers to plan and manage social-ecological resilience challenges within the seven economic corridors of the BRI, and plan adaptation and mitigation strategies.	93	2021	10.1016/j.jclepro.2021.127341	
Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities	Cortinovis, C; Olsson, P; Boke-Olen, N; Hedlund, K	URBAN FORESTRY & URBAN GREENING	English	Article	Green roofs; Street trees; Urban parks; Permeable pavements; Scenarios; Runoff reduction; Heat mitigation; Carbon storage; Biodiversity potential; Greenness	URBAN GREEN-SPACE; OF-THE-ART; ECOSYSTEM SERVICES; TRADE-OFFS; LAND-USE; AREAS; INFRASTRUCTURE; IMPLEMENTATION; MANCHESTER; MITIGATION	Many exemplary projects have demonstrated that Nature-based Solutions (NBS) can contribute to climate change adaptation, but now the challenge is to scale up their use. Setting realistic policy goals requires knowing the amount of different NBS types that can fit in the urban space and the benefits that can be expected. This research aims to assess the potential for a full-scale implementation of NBS for climate-change adaptation in European cities, the expected benefits and co-benefits, and how these quantities relate to the urban structure of the cities. We selected three case studies: Barcelona (Spain), Malmo (Sweden), and Utrecht (the Netherlands), and developed six scenarios that simulate the current condition, the full-scale implementation of different NBS strategies (i.e., installing green roofs, de-sealing parking areas, enhancing vegetation in urban parks, and planting street trees), and a combination of them. Then we applied spatially-explicit methods to assess, for each scenario, two climate change-related benefits, i.e. heat mitigation and stormwater regulation, and three co benefits, namely carbon storage, biodiversity potential, and overall greenness. Finally, by breaking down the results per land use class, we investigated how the potential and benefits vary depending on the urban form. Most scenarios provide multiple benefits, but each one is characterized by a specific mix. In all cities, a full-scale deployment of green roofs shows the greatest potential to reduce runoff and increase biodiversity, while tree planting-either along streets or in urban parks- produces the greatest impact on heat mitigation and greenness. However, these results entail interventions of different size and in different locations. Planting street trees maximizes interventions in residential areas, but key opportunities for integrating most NBS types also lie in commercial and industrial areas. The results on the pros and cons of each scenario can support policy-makers in designing targeted NBS strategies for climate change adaptation.	93	2022	10.1016/j.ufug.2021.127450	
A framework of biophilic urbanism for improving climate change adaptability in urban environments	Lee, S; Kim, Y	URBAN FORESTRY & URBAN GREENING	English	Review	Adaptability; Biophilic urbanism; Biophilic design; Climate change; Framework; Urban environment	PHASE-CHANGE MATERIALS; LOW IMPACT DEVELOPMENT; GREEN INFRASTRUCTURE; HEAT-ISLAND; PERMEABLE PAVEMENT; URBANIZATION; MITIGATION; SYSTEMS; STRESS; HEALTH	This study proposes a framework of biophilic urbanism that focuses on the adaptation of climate change, which is a representative urban problem facing modern cities. We derived a basic framework of biophilic urbanism by analyzing and reviewing the concepts and strategies of biophilic urbanism presented in previous studies. Based on this review, an advanced biophilic urbanism framework is suggested to examine the application of biophilic elements in cities. The framework consists of (1) the spatial range divided into region and city, neighborhood and street, and building and (2) the degree of biophilic method, which includes the natural, technical, and functional method. In addition, the representative biophilic elements for climate change adaptation are categorized using the framework. This framework provides an opportunity to identify and supplement the lack of biophilic elements in a city by enabling a systematic review of the biophilic elements according to the various spatial ranges and biophilic methods. Therefore, biophilic elements can be effectively applied within a city, and it is possible to create an environment where humans can experience various benefits as well as obtain psychological stability from nature.	91	2021	10.1016/j.ufug.2021.127104	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Low-Impact Development Practices to Mitigate Climate Change Effects on Urban Stormwater Runoff: Case Study of New York City	Zahmatkesh, Z; Burian, SJ; Karamouz, M; Tavakol-Davani, H; Goharian, E	JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING	English	Article	Climate change; Climate adaptation; Change factor; Green infrastructure; Urban runoff	PERMEABLE PAVEMENT; MANAGEMENT-PRACTICES; GREEN ROOF; QUALITY; PERSPECTIVE; PERFORMANCE; QUANTITY; MODELS	Urban stormwater runoff management systems are usually designed to meet performance standards based on historical climate data, which are assumed to be stationary. Based on the evidence from climate change impact studies, in the near future, stormwater management systems, within the built environment, may need to meet performance expectations under climatic conditions different from historical climate. Considering the impacts of climate change on rainfall intensities and stormwater runoff peak flow and volumes, and in turn the effectiveness of mitigation, practices for urban stormwater management are desirable. This paper presents the results of a climate change impact study on urban stormwater runoff in the Bronx River watershed, New York City. Considering the impacts of climate change on watershed runoff, the potential for low-impact development (LID) controls to mitigate the impacts was investigated. Stormwater runoff and LID controls were modeled using the U.S. EPA Storm Water Management Model version 5 (EPA SWMM5). The simulations were driven by historical precipitation modified to represent future projections using a change factor methodology based on precipitation from the Coupled Model Intercomparison Project Phase 5 (CMIP5). Using the change factor method, historical precipitation was perturbed to obtain future data, based on three climate scenarios projecting maximum, mean, and minimum values for rainfall. Results of frequency analysis performed on the simulated peak flow rates, with different recurrence intervals, showed a noticeable increase in the frequency of occurrence of extreme storm events and their peak values, under future extreme climate conditions. An LID control scenario consisting of rainwater harvesting, porous pavement, and bioretention was designed and evaluated using the SWMM model. The results showed that, while average increase in historical annual runoff volume under climate change impacts was approximately 48%, the LID controls could provide an average reduction of 41% in annual runoff volume. Application of the LID controls also reduced peak flow rates by an average of 8 to 13%. LID implementation decreased watershed runoff corresponding to 2-year and 50-year return periods, by 28 and 14%, respectively. In conclusion, retrofits with LID controls may provide not only their inherent benefits (e.g., runoff volume and water quality), but also additional climate impact mitigation benefits for stormwater runoff. (C) 2014 American Society of Civil Engineers.	89	2015	10.1061/(ASCE)IR.1943-4774.0000770	
Evaluation of Life Cycle Assessment (LCA) for Roadway Drainage Systems	Byrne, DM; Grabowski, MK; Benitez, ACB; Schmidt, AR; Guest, JS	ENVIRONMENTAL SCIENCE & TECHNOLOGY	English	Article		HIGHWAY STORMWATER RUNOFF; CLIMATE-CHANGE ADAPTATION; SOLID-WASTE INCINERATION; POLLUTANT REMOVAL; WATER-TREATMENT; GRASSED SWALES; GREEN INFRASTRUCTURE; SEDIMENT TRANSPORT; IMPACT ASSESSMENT; FATE FACTORS	Roadway drainage design has traditionally focused on cost-effectively managing water quantity; however, runoff carries pollutants, posing risks to the local environment and public health. Additionally, construction and maintenance incur costs and contribute to global environmental impacts. While life cycle assessment (LCA) can potentially capture local and global environmental impacts of roadway drainage and other stormwater systems, LCA methodology must be evaluated because stormwater systems differ from wastewater and drinking water systems to which LCA is more frequently applied. To this end, this research developed a comprehensive model linking roadway drainage design parameters to LCA and life cycle costing (LCC) under uncertainty. This framework was applied to 10 highway drainage projects to evaluate LCA methodological choices by characterizing environmental and economic impacts of drainage projects and individual components (basin, bioswale, culvert, grass swale, storm sewer, and pipe underdrain). The relative impacts of drainage components varied based on functional unit choice. LCA inventory cutoff criteria evaluation showed the potential for cost-based criteria, which performed better than mass-based criteria. Finally, the local aquatic benefits of grass swales and bioswales offset global environmental impacts for four impact categories, highlighting the need to explicitly consider local impacts (i.e., direct emissions) when evaluating drainage technologies.	88	2017	10.1021/acs.est.7b01856	
Roadway flooding as a bellwether for household retreat in rural, coastal regions vulnerable to sea-level rise	Jasour, ZY; Reilly, AC; Tonn, GL; Ferreira, CM	CLIMATE RISK MANAGEMENT	English	Article	Sea-level rise; Adaptation; Transportation infrastructure; Accessibility; Coastal Flooding; Retreat	CLIMATE-CHANGE; INFRASTRUCTURE PROTECTION; ACCESSIBILITY; IMPACTS; TRANSPORTATION; RESILIENCE; DAMAGE; SYSTEMS; BOSTON	Sea-level rise (SLR) and coastal flooding in low-lying rural coastal areas will significantly impact residents' daily lives. The need to understand who may be affected and when is widely acknowledged in order to enable inclusive and cost-effective adaptation planning. Presently, planning resources generally focus on housing impacts; when will a house or neighborhood be inundated and which adaptation strategies are useful to improve the homeowner's fate? Housing, though, is but one of many types of reliable infrastructure needed to enable habitation at a parcel. Reliable roadways are another. In this study, we evaluate parcel-level impacts of SLR on local residents' ability to access key local amenities such as emergency services and grocery stores. More specifically, we focus on the impact of probabilistic SLR inundation scenarios on road infrastructure, and availability of alternative routes to meet the needs of residents. We find that in some instances, accessibility loss may come years before parcel inundation and could portend an earlier need for retreat than initially expected. We use Dorchester County, Maryland, U.S. as a case study. The county is extremely low-lying and is currently the second largest in the state by acreage, though its land area is expected to shrink in half by the turn of the century due to SLR. The results from the case study indicate that some parcels are not expected to be inundated by SLR but are expected to experience accessibility impacts. Limited access appears to be a bellwether for future household inundation and the forewarning stemming from accessibility loss can be significant in some locations. This work also shows the need for consensus surrounding which future scenario is planned for. While the results presented here are fairly insensitive to the degree of global carbon abatement, they are sensitive to exceedance probabilities.	88	2022	10.1016/j.crm.2022.100425	
Ecohydrological model for the quantification of ecosystem services provided by urban street trees	Revelli, R; Porporato, A	URBAN ECOSYSTEMS	English	Article	Ecosystem services; Ecohydrology; Urban green spaces; Street trees; Soil moisture; Nutrients; Soil carbon content; Pervious-impervious surfaces; Seasonality	CLIMATE-CHANGE ADAPTATION; UNDERLYING BASE LAYER; GREEN INFRASTRUCTURE; PERMEABLE PAVEMENTS; NITROGEN CYCLES; CARBON STORAGE; SOIL-MOISTURE; VEGETATION; LANDSCAPE; SPACE	Urban green spaces have been recognized as an important source of ecosystem services, whose quantification requires the determination of quantities related to energy, water, carbon and soil nutrient content. In this paper we propose a stochastic ecohydrological model that couples two existing models for water and nutrients in urban soil at the single street-tree scale. The model input are rainfall and irrigation, for water, and deposition and fertilization, for nitrogen, while the output are evapotranspiration, runoff and deep percolation, for water, and plant uptake and leaching, for nitrogen. The various terms are related to the amount of paved and impervious surfaces that surround the tree trunk and regulate the water and nutrient fluxes in and out the soil. Particular attention is paid to the effects of seasonal variations on plant water and nutrients through a temporal variation of the hydrologic variables (i.e., temperature and rainfall intensity and frequencies). The average model outputs are preliminarily compared with the scant existing literature data, supporting the model application to cities with different climatic conditions. The model results are used to estimate the potential for ecosystem services like tree cooling effects, soil carbon sequestration or storm-water management. Because of the minimal structure of the proposed model, it requires a very low amount of data, while accounting for the stochastic input of rainfall. In the context of climate change and increasing urbanization, the model may offer useful indications to urban planners to enhance ecosystem services while minimizing irrigation, fertilization and their related costs.	87	2018	10.1007/s11252-018-0741-2	
Impact of Climate Change on Disruption to Urban Transport Networks from Pluvial Flooding	Pregnolato, M; Ford, A; Glenis, V; Wilkinson, S; Dawson, R	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article		WEATHER; PRECIPITATION; VULNERABILITY; RESILIENCE; HAZARD	Short-duration, high-intensity rainfall causes significant disruption to transport operations, and climate change is projected to increase the frequency and intensity of these events. Disruption costs of flooding are currently calculated using crude approaches. To support improved business cases for adapting urban infrastructure to climate change, this paper presents an integrated framework that couples simulations of flooding and transport to calculate the impacts of disruption. A function, constructed from a range of observational and experimental data sources, is used to relate flood depth to vehicle speed, which is more realistic than the typical approach of categorizing a road as either blocked or free flowing. The framework is demonstrated on Newcastle upon Tyne in the United Kingdom and shows that by the 2080s disruption across the city from a 1-in-50-year event could increase by 66%. A criticality index is developed and is shown to provide an effective metric to prioritize intervention options in the road network. In this case, just two adaptation interventions can reduce travel delays across the city by 32%.	87	2017	10.1061/(ASCE)IS.1943-555X.0000372	
Roadless and Low-Traffic Areas as Conservation Targets in Europe	Selva, N; Kreft, S; Kati, V; Schluck, M; Jonsson, BG; Mihok, B; Okarma, H; Ibisch, PL	ENVIRONMENTAL MANAGEMENT	English	Article	Transport policy; Natura 2000; Fragmentation; Conservation law; Conservation targets; Climate change adaptation	OLD-GROWTH FORESTS; CLIMATE-CHANGE; BIODIVERSITY CONSERVATION; LANDSCAPE FRAGMENTATION; HABITAT FRAGMENTATION; BIRD POPULATIONS; GENE FLOW; ROADS; CONNECTIVITY; POLICY	With increasing road encroachment, habitat fragmentation by transport infrastructures has been a serious threat for European biodiversity. Areas with no roads or little traffic (roadless and low-traffic areas) represent relatively undisturbed natural habitats and functioning ecosystems. They provide many benefits for biodiversity and human societies (e.g., landscape connectivity, barrier against pests and invasions, ecosystem services). Roadless and low-traffic areas, with a lower level of anthropogenic disturbances, are of special relevance in Europe because of their rarity and, in the context of climate change, because of their contribution to higher resilience and buffering capacity within landscape ecosystems. An analysis of European legal instruments illustrates that, although most laws aimed at protecting targets which are inherent to fragmentation, like connectivity, ecosystem processes or integrity, roadless areas are widely neglected as a legal target. A case study in Germany underlines this finding. Although the Natura 2000 network covers a significant proportion of the country (16%), Natura 2000 sites are highly fragmented and most low-traffic areas (75%) lie unprotected outside this network. This proportion is even higher for the old Federal States (western Germany), where only 20% of the low-traffic areas are protected. We propose that the few remaining roadless and low-traffic areas in Europe should be an important focus of conservation efforts; they should be urgently inventoried, included more explicitly in the law and accounted for in transport and urban planning. Considering them as complementary conservation targets would represent a concrete step towards the strengthening and adaptation of the Natura 2000 network to climate change.	87	2011	10.1007/s00267-011-9751-z	
Socio-Ecological Conflicts in a Global South Metropolis: Opportunities and Threats of a Potential Greenway in the Sao Paulo Metropolitan Region	Moreno, RD; Braga, DRGC; Xavier, LF	FRONTIERS IN SUSTAINABLE CITIES	English	Review	Urban Greenways; Global South; Atlantic Rainforest; Green infrastructures; Informal settlements; Dump sites; Landfills	URBAN; INFRASTRUCTURE; RESILIENCE; LANDFILLS; ECOSYSTEM; SERVICES; ECOLOGY; SPACE	Greenways are a measure of environmental remediation within a broad framework aimed at promoting urban greening and adaptation to climate change. The typical characteristics of large urban agglomerations, including land use (such as commercial, industrial, and residential areas) with few public spaces and fragmented landscapes, make it difficult to apply these solutions to the urban fabric, forcing decision-makers and planners to act in informal settlements, highways, and industrial parks. One proposed area is an enclave with unused or underutilized lots, where fragments of the Atlantic Forest, parks, landfills, and rapidly expanding informal settlements can be found. This manuscript examines the socioeconomic and environmental processes that shaped this potential urban greenway between Santo Andre, Maua, and Ribeirao Pires, which are part of the Sao Paulo Metropolitan Region (SPRM), the largest in South America. A survey was conducted based on municipal and regional plans, the environmental and urban laws of Brazil, and the socioeconomic history of this part of the SPRM. In addition, satellite images were used to analyze land use evolution through geotechnologies. Finally, we prepared land use recommendations, considering opportunities and threats, highlighting the possibilities of protection and expansion of the Atlantic Forest. To this end, we examined the literature on environmental urban planning and design, green infrastructure, and other concepts. This study intends to stimulate researchers, planners, and decision-makers regarding the urban greening process in the Global South. According to the recommendations, this stimulus would develop these concepts according to the real situation of the region, which would combine the protection of wild habitats and urban environmental amenities. However, this effort makes no sense if one of the defining Global South characteristics not addressed is social inequality. Therefore, we recommend that an effort be made to develop and incorporate processes from urban greening in slum upgrading.	86	2021	10.3389/frsc.2021.706857	
Climate change impact on infrastructure: A machine learning solution for predicting pavement condition index	Piryonesi, SM; El-Diraby, T	CONSTRUCTION AND BUILDING MATERIALS	English	Article	Climate change; Pavement condition index; Data analytics; Gradient boosted trees; Infrastructure asset management; Climate Change Adaptation; Pavement performance modelling; LTPP	ASPHALT PAVEMENTS; CRACK INITIATION; LTPP DATA; PERFORMANCE; MODEL; ROUGHNESS; REGRESSION; IRI; ANN	A decision-support tool was developed to predict the condition of asphalt roads in 2, 3, 5 and 6 years. The tool was developed based on analyzing a large dataset (more than 3000 road sections) extracted from the Long-Term Pavement Performance (LTPP) database. Several algorithms were examined: two decision trees, k-nearest neighbors (k-NN), naive Bayes classifier, naive Bayes coupled with kernel estimator, random forest and gradient boosted trees. The last three achieved the highest accuracy levels (above 90%). The attributes used were intentionally selected to be related to climate stressors (such as temperature ranges, perspiration and freeze-thaw cycles) or basic road attributes (such as age and functional class) to enable the models quantify the impact of climate change. A major caveat of this study is that some climate stressors such as storm frequency and severity were not included in the model as there was no data available about them in the LTPP dataset. With the proposed tool, the impacts of different climate scenarios can be examined by running the model with inputs that reflect the attributes of each scenario. To illustrate this, we examined the deterioration of two sets of roads: one from Ontario and one from Texas. Each set was examined in two climate scenarios. The analysis showed lower levels of deterioration for the Ontario roads and exacerbation of deterioration for the roads in Texas. It means that climate change may exacerbate or alleviate road deterioration depending on location. This type of analysis can be beneficial to the long-term policymaking in road infrastructure. For example, notwithstanding the impact of climate attributes that are not considered in this study, an Ontario policymaker should expect that with the same design standards and the same maintenance regimes, the service levels of roads will be enhanced.	85	2021	10.1016/j.conbuildmat.2021.124905	
Evidence of Warming From Long-Term Records of Climate and Permafrost in the Hinterland of the Qinghai-Tibet Plateau	Zhou, FJ; Yao, MM; Fan, XW; Yin, GA; Meng, XL; Lin, ZJ	FRONTIERS IN ENVIRONMENTAL SCIENCE	English	Article	climate change; permafrost warming; active-layer thickness; ground temperature; Qinghai-Tibet Plateau	THERMAL REGIME; ENGINEERING CORRIDOR; GROUND TEMPERATURES; THERMOKARST LAKES; REGIONS; DEGRADATION; BASIN; PRECIPITATION; DISTURBANCE; VEGETATION	The Qinghai-Tibet Plateau (QTP) is characterized by its extreme climate and dominated by periglacial processes. Permafrost conditions very greatly, and the recent changes on the QTP are not well known in the hinterland. Here, we examine the changes in climate and permafrost temperatures in several different regions. Climate data were obtained from three weather stations from 1957 to 2019. Annual mean air temperature (T-a) has gradually increased at .031 degrees C/yr-.039 degrees C/yr. Climate warming has been more rapid in the past two decades, particularly during the cold season (November to February). Precipitation has also been slowly increasing during the instrumental record. However, there is pronounced heterogeneity in the seasonal distribution of precipitation, with very little falling between October and April. Ground temperatures and active-layer thickness (ALT) have been investigated over similar to 20 years at five sites representative of the hinterland of the QTP. These sites are located along the Qinghai-Tibet Highway, which crosses the permafrost zone and traverses the mountainous area and basin areas. Annual mean ground temperatures within the active layer (T-af similar to 1 m depth) indicate recent ground warming at all sites, at rates near .05 degrees C/yr. The ALT at five sites has been increasing steadily by 2-9 cm/yr, with an average of 4.6 cm/yr. The temperature near the permafrost table (T-ps) has been increasing at .01 degrees C/yr and .06 degrees C/yr, with an average of .03 degrees C/yr. Permafrost temperatures at 15 m depth (T-g) have been increasing by about .01 degrees C/yr-.02 degrees C/yr. The southern boundary (AD site) of the permafrost has warmed the least among the five locations. In high mountainous areas where permafrost temperatures are low (e.g., KLS site), the annual mean T-g has increased by nearly .02 degrees C/yr. The rate of permafrost warming at a basin site (BLH), with relatively high ground temperatures, was approximately .01 degrees C/yr. The GIPL2.0 model simulation results indicate that the annual mean permafrost temperature at 1 m depth at these sites will increase by .6 degrees C-1.8 degrees C in the next 100 years (to 2100) and that ALT will increase by similar to 40-100 cm. We also discuss the impacts of permafrost changes on the environment and infrastructure on the QTP. This study provides useful information to understand observed and anticipated permafrost changes in this region, under different shared socioeconomic pathways, which will allow engineers to develop adaptation measures.	85	2022	10.3389/fenvs.2022.836085	
Sustainable Drainage Systems for transitioning to sustainable urban flood management in the European Union: A review	Gimenez-Maranges, M; Breuste, J; Hof, A	JOURNAL OF CLEANER PRODUCTION	English	Review	Transition; Flood management; Sustainable drainage systems (SuDS); Urban; European union (EU)	SURFACE-WATER MANAGEMENT; STORMWATER MANAGEMENT; CLIMATE-CHANGE; GREEN ROOF; SOCIOTECHNICAL SYSTEMS; PERMEABLE PAVEMENTS; PERFORMANCE; ADAPTATION; COPENHAGEN; INNOVATION	Technical and governing approaches to urban flooding in the European Union (EU) are currently conventional and centralised. This widespread paradigm has become increasingly ineffective and needs radical transformation. A promising alternative strategy involves the development of Sustainable Drainage Systems (SuDS), which mimic natural processes to manage floods. In this article, the effects of SuDS, as a transitional pathway from conventional to sustainable flood management, are reviewed. Levels of development and support of SuDS in various contexts and at different scales within the European Union are also examined. Scholarly work to date has been limited and technically focused. The transition remains a local, slow, and mainly northern European phenomenon. The research attention on technical performance indicates a continuing need for evidence of the effectiveness of SuDS. Further research is needed to gain a broad-based perspective on the transformation process. (C) 2020 Elsevier Ltd. All rights reserved.	85	2020	10.1016/j.jclepro.2020.120191	
Drought-induced xylem cavitation and hydraulic deterioration: Risk factors for urban trees under climate change?	Savi T., Bertuzzi S., Branca S., Tretiach M., Nardini A.	New Phytologist	English	Article	Climate change; Dieback; Embolism; Hydraulic deterioration; Quercus ilex; Towns; Urban trees; Xylem vulnerability	adaptation; climate change; gas exchange; mortality; risk factor; tree; urban area; water stress; Quercus ilex; chlorophyll; gas; soil; water; water vapor; city; climate change; drought; fluorescence; gas; Italy; metabolism; oak; photosynthesis; physiology; plant leaf; plant stem; risk factor; season; soil; tree; water vapor; wood; xylem; Chlorophyll; Cities; Climate Change; Droughts; Fluorescence; Gases; Italy; Photosynthesis; Plant Leaves; Plant Stems; Quercus; Risk Factors; Seasons; Soil; Steam; Trees; Water; Wood; Xylem	Urban trees help towns to cope with climate warming by cooling both air and surfaces. The challenges imposed by the urban environment, with special reference to low water availability due to the presence of extensive pavements, result in high rates of mortality of street trees, that can be increased by climatic extremes. We investigated the water relations and xylem hydraulic safety/efficiency of Quercus ilex trees growing at urban sites with different percentages of surrounding impervious pavements. Seasonal changes of plant water potential and gas exchange, vulnerability to cavitation and embolism level, and morpho-anatomical traits were measured. We found patterns of increasing water stress and vulnerability to drought at increasing percentages of impervious pavement cover, with a consequent reduction in gas exchange rates, decreased safety margins toward embolism development, and increased vulnerability to cavitation, suggesting the occurrence of stress-induced hydraulic deterioration. The amount of impermeable surface and chronic exposure to water stress influence the site-specific risk of drought-induced dieback of urban trees under extreme drought. Besides providing directions for management of green spaces in towns, our data suggest that xylem hydraulics is key to a full understanding of the responses of urban trees to global change. © 2014 New Phytologist Trust.	83	2015	10.1111/nph.13112	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Responding to the barriers in climate adaptation planning among transport systems: Insights from the case of the port of Montreal	Wang, T; Ng, AKY	INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION	English	Article; Early Access	Adaptation planning; barriers; climate change; dropping water level; St; Lawrence River; the port of Montreal	IMPACT; ROADS; VULNERABILITY; MANAGEMENT; COMPLEX	With the accelerating pace of climate change, there has been no scarcity of research, in recent years, that assess climate risks and cost-effectiveness of adaptation measures in the transport sector. Nevertheless, existing literature associated with adaptation planning for climate change is still at an embryonic stage with little attention on certain potential dilemmas. Understanding such, this paper focuses on the question of how to respond to the barriers in climate adaptation planning in transport systems. This is achieved mainly through reviewing the literature in transport adaptation to climate change impacts to summarize eights conditions (potential barriers) that the shortage of those might lead to the failure of climate adaptation planning. Next, those conditions are examined by a historical case study between 2014 and 2015 on the Canadian port of Montreal's experience in tackling the Great Lakes and St. Lawrence River's dropping water level. The findings, via semi-structured interviews with affiliated senior experts, closely mirror the enablers influencing the success of a climate adaptation plan, revealing the impediments and opportunities in the existing and future planning. It offers constructive recommendations on how to improve the port of Montreal's, and ports and transport infrastructures in general, process and practice of adaptation planning. The study strives to bridge the research gaps and provide decision-makers with a novel thinking pattern and workable recommendations from design, implementation to the reconstruction of adaptation planning and facilitate a paradigm shift in broader sustainable transport management.	83	2021	10.1080/15568318.2021.1960450	
A Framework for Identification, Assessment and Prioritization of Climate Change Adaptation Measures for Roads and Railways	Andersson-Skold, Y; Nordin, L; Nyberg, E; Johannesson, M	INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	English	Article	adaptation measure sustainability assessment; stepwise methodology; cause-effect-relationship	INFRASTRUCTURE; RISK; IMPACTS; MITIGATION; NETWORKS; SYSTEMS; SECTOR; COSTS; FLOOD	Severe accidents and high costs associated with weather-related events already occur in today's climate. Unless preventive measures are taken, the costs are expected to increase in future due to ongoing climate change. However, the risk reduction measures are costly as well and may result in unwanted impacts. Therefore, it is important to identify, assess and prioritize which measures are necessary to undertake, as well as where and when these are to be undertaken. To be able to make such evaluations, robust (scientifically based), transparent and systematic assessments and valuations are required. This article describes a framework to assess the cause-and-effect relationships and how to estimate the costs and benefits as a basis to assess and prioritize measures for climate adaptation of roads and railways. The framework includes hazard identification, risk analysis and risk assessment, identification, monetary and non-monetary evaluation of possible risk reduction measures and a step regarding distribution-, goal- and sensitivity analyses. The results from applying the framework shall be used to prioritize among potential risk reduction measures as well as when to undertake them.	82	2021	10.3390/ijerph182312314	
A framework for the mitigation and adaptation from heat-related risks to infrastructure	Radford, DAG; Lawler, TC; Edwards, BR; Disher, BRW; Maier, HR; Ostendorf, B; Naim, J; van Delden, H; Goodsite, M	SUSTAINABLE CITIES AND SOCIETY	English	Article	Climate change; Heat; Risk; Resilience; Adaptation; Infrastructure; Road networks; Extreme temperatures	CLIMATE-CHANGE; FUTURE; ISLAND; RESILIENCE; PATHWAYS; IMPACTS; SUPPORT; COSTS	The rising frequency of heat-related hazards as a result of climate change will increasingly affect heat-sensitive infrastructure assets. Recent studies quantify the heat-related risk to infrastructure, with some exploration of individual mitigation strategies, however missing in literature is an infrastructure sector-transferable and comprehensive framework for analysing future risk and performing evaluation of several options for risk reduction. This paper introduces a generic framework to: quantify heat-related risks to infrastructure assets in a transferable manner; assess the effects of future exogenous systems changes, and; evaluate several practical mitigation strategies. The framework is applied to the asphalt road network in Adelaide, Australia. This case study explores heat-related risk under present and future climate hazard and traffic stressor scenarios and critical evaluation of mitigation strategies. The strategies explored affect both hazard and vulnerability elements of risk, including: asphalt binder materials, reflectivity additives, and traffic volume, loading or speed management. Results indicate up to a 19% increase in risk from 2020 to 2090 as a result of climate change. Road replacement strategies are identified as most effective, reducing risk by up to 33% in 2090. The framework shows value in developing comprehensive and practical strategies for managing heat-sensitive infrastructure assets into the future.	81	2022	10.1016/j.scs.2022.103820	
The Canadian Federation of Earth Sciences Scientific Statement on Climate Change - Its Impacts in Canada, and the Critical Role of Earth Scientists in Mitigation and Adaptation	Burn, CR; Cooper, M; Morison, SR; Pronk, T; Calders, JH	GEOSCIENCE CANADA	English	Article		PERMAFROST CARBON; SEA-LEVEL; ACCUMULATION; THAW; CO2	The Canadian Federation of Earth Sciences (CFES) has issued this statement to summarize the science, effects, and implications of climate change. We highlight the role of Earth scientists in documenting and mitigating climate change, and in managing and adapting to its consequences in Canada. CFES is the coordinated voice of Canada's Earth Sciences community with 14 member organizations representing some 15,000 geoscientists. Our members are drawn from academia, industry, education, and government. The mission of CFES is to ensure decision makers and the public understand the contributions of Earth Science to Canadian society and the economy. Climate change has become a national and global priority for all levels of government. The geological record shows us that the global climate has changed throughout. Earth's history, but the current rates of change are almost unprecedented. Over the last 70 years, levels of common greenhouse gasses (GHGs) in the atmosphere have steadily increased. Carbon dioxide (CO2) concentration is now 418 parts per million - its highest of the last three million years. The chemical (isotopic) composition of carbon in the atmosphere indicates the increase in GHGs is due to burning fossil fuels. GHGs absorb energy emitted from Earth's surface and re-radiate it back, warming the lower levels of the atmosphere. Climatic adjustments that have recently occurred are, in practical terms, irreversible, but further change can be mitigated by lowering emissions of GHGs. Climate change is amplified by three important Earth system processes and effects. First, as the climate warms evaporation increases, raising atmospheric concentrations of water vapour, itself a GHG - and adding to warming. Second, loss of ice cover from the polar ice sheets and glaciers exposes larger areas of land and open water - leading to greater absorption of heat from the sun. Third, thawing of near-surface permafrost releases additional GHGs (primarily CO2 and methane) during decay of organic matter previously preserved frozen in the ground. Some impacts of climate change are incremental and steadily occurring, such as melting of glaciers and ice sheets, with consequent sea level rise. Others are intermittent, such as extreme weather events, like hurricanes - but are becoming more frequent. Summer water shortages are increasingly common in western Canada as mountain snowpacks melt earlier and summer river flows decline. In northern Canada, warming and thawing of near-surface permafrost has led to deterioration of infrastructure and increased costs for buildings that now require chilled foundations. Other consequences of unchecked climate change include increased coastal erosion, increases in the number and size of wildfires, and reduction in winter road access to isolated northern communities. Reductions in net GHG emissions are urgently required to mitigate the many effects of further climate change. Industrial and public works development projects must now assess the effects of climate change in their planning, design, and management. Cities, municipalities, and rural communities need to plan new residential development carefully to avoid enhanced risk of flooding, coastal erosion, or wildfire. Earth Science knowledge and expertise is integral to exploration and development of new metals and Earth materials required for a carbon-neutral future, and in the capture and storage of CO2 within the Earth. Earth Science is also central to society's adaptation to new climatic regimes and reduction of risks. This includes anticipation, assessment, and management of extreme events, development of new standards and guidelines for geotechnical and engineering practice, and revision to regulations that consider climate change. Geoscientists also have an important role in the education of students and the public on the reasons for necessary action. Canada is uniquely positioned with its strong global geoscientific leadership, its vast landmass, and its northern terrain to effectively leverage research activities around climate change. Geoscience tools and geoscientists' skills will be integral to Canada's preparation for climate change.	80	2021	10.12789/geocanj.2021.48.173	
Resilience of Infrastructure Systems to Sea-Level Rise in Coastal Areas: Impacts, Adaptation Measures, and Implementation Challenges	de Almeida, BA; Mostafavi, A	SUSTAINABILITY	English	Review	sea level rise; infrastructure systems; coastal areas; impacts; adaptation measures; implementation challenges; energy; water and wastewater; transportation	CLIMATE-CHANGE ADAPTATION; LAND SUBSIDENCE; STORM-SURGE; VULNERABILITY; MANAGEMENT; FRAMEWORK; WATER	Expansive areas of low elevation in many densely populated coastal areas are at elevated risk of storm surges and flooding due to torrential precipitation, as a result of sea level rise. These phenomena could have catastrophic impacts on coastal communities and result in the destruction of critical infrastructure, disruption of economic activities and salt water contamination of the water supply. The objective of the study presented in this paper was to identify various impacts of sea level rise on civil infrastructures in coastal areas and examine the adaptation measures suggested in the existing literature. To this end, a systemic review of the existing literature was conducted in order to identify a repository of studies addressing sea level rise impacts and adaptation measures in the context of infrastructure systems. The study focused on three infrastructure sectors: water and wastewater, energy, and road transportation. The collected information was then analyzed in order to identify different categories of sea level rise impacts and corresponding adaptation measures. The findings of the study are threefold: (1) the major categories of sea level rise impacts on different infrastructure systems; (2) measures for protection, accommodation, and retreat in response to sea level rise impacts; and (3) challenges related to implementing adaptation measures.	79	2016	10.3390/su8111115	
Composite adaptability index to evaluate climate change adaptation policies for urban transport	Vajjarapu, H; Verma, A	INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION	English	Article	Climate change adaptation; Composite index; Urban flooding; Transportation; Indicators; Resilience	FLOOD VULNERABILITY INDEX; ROAD NETWORK; RISK; RESILIENCE; FRAMEWORK; MANAGEMENT; INDIA	The uncontrolled expansion of human-made structures is creating more impervious urban areas. These changes, coupled with extreme rainfalls and inadequate flood channelling infrastructure, lead to urban flooding. The urban transport sector is at constant risk from urban flooding, and it should adapt to these climate change effects. This study focuses on developing an indicator-based approach called composite adaptability index (CAI) to assess the urban transportation system's adaptability to urban flooding based on exposure, susceptibility, and resilience. The weights of the indicators are estimated using Analytical Hierarchy Process (AHP), and the consistency tests are conducted to assess the efficiency of the weights. The index is tested on three adaptation policy bundles designed to improve the urban transportation system's resiliency compared to the Business as usual scenario for the years 2030 and 2050 in Bangalore, India. Testing of CAI showed that all the adaptation bundles showed increased adaptability. Overall, bundle 1 gave the best CAI results with 0.662 and 0.680 for 2030 and 2050, respectively and a 2% gain from the BAU scenario.	78	2021	10.1016/j.ijdrr.2021.102205	
Identification of critical sections of the Spanish transport system due to climate scenarios	Ortega, E; Martin, B; Aparicio, A	JOURNAL OF TRANSPORT GEOGRAPHY	English	Article	Accessibility; Climate scenarios; Criticality; Transport planning	HIGH-SPEED RAIL; VULNERABILITY ANALYSIS; CRITICAL LINKS; INFRASTRUCTURE INVESTMENTS; SUPPORT-SYSTEM; SPATIAL EQUITY; IMPACTS; ADAPTATION; RESILIENCE; NETWORKS	In recent years climate change has become a multidisciplinary research topic that addresses the challenges facing transport infrastructure planning, construction and operation. The study of the adaptation of transport systems to new environmental conditions is often based on the interrelated concepts of resilience, vulnerability and criticality. In this paper we assess the criticality of sections of Spain's inland transport network under the effects of changing climate scenarios obtained from a specific climate projection (using the time periods 2010-2020 and 2045-2055). The functionality of the transport system is characterised here in terms of territorial accessibility. The results identify and locate the most critical stretches of the Spanish transport network. In general terms, the most relevant sections in regard to accessibility will not be exposed to the greatest changes in climate variables. Up to 2.8% of the roads and 5.9% of the railways that contribute most significantly to the territorial accessibility of the transport system will undergo the greatest variations between climate scenarios. This paper contributes to this field of research by developing a screening tool that represents a valuable instrument for the infrastructure decision-making process at the strategic level. Action areas for proactive adaptation measures can be identified in order to reduce impacts and costs, while prioritising the maintenance or reconstruction of the most critical stretches in the case of a future climate event.	76	2020	10.1016/j.jtrangeo.2020.102691	
Soft-Cliff Retreat in a Tropical Coast: The Minuto de Dios Sector, Caribbean Coast of Colombia	Paniagua-Arroyave, JF; Correa, ID; Anfuso, G; Adams, PN	JOURNAL OF COASTAL RESEARCH	English	Article	Global climate change; coastal erosion; cliff retreat; mud diapirism; coastal management; geomorphological modeling; DSAS	SEA-LEVEL RISE; CLIMATE-CHANGE IMPACTS; SHORELINE RECESSION; EROSION; MODEL; EQUILIBRIUM; ADAPTATION; PREDICTION; DYNAMICS; PROFILE	Projections for the year 2100 predict a global mean sea level 1 m above pre-industrial levels that will likely exacerbate coastal impacts worldwide and especially along vulnerable coastlines of developing countries. Recent studies have predicted a future shoreline retreat linked to the expected acceleration in global sea level rise along the soft-cliffs of Minuto de Dios on the Caribbean coast of Colombia. This study discusses previous results by arguing that an accurate quantification of relative sea level rise was not implemented and cliff retreat predictions are therefore not feasible. Future cliff-top positions and future sediment release were instead calculated by assuming that the historical retreat rate will remain unchanged. Mean end-point retreat between 1938 and 2010 was 1.7 +/- 0.4 m/year, which would produce between 2010 and 2060 a shoreline recession of 85 m with a cumulative release of similar to 530,000 m(3) of sediment (for a similar to 1 km of similar to 6 m cliffs). The projected coastal retreat is expected to produce significant impacts to local infrastructure, including the loss of approximately 100 urban constructions. In addition, the 2060 coastline would be located ca. 50 m from the main road that connects Arboletes with the city of Monteria. As discussed in this study, climate change-driven sea level rise will likely augment coastal hazards, but with limited data in the region, predictive modeling of future impacts remains speculative. This issue highlights the need for local stakeholders to dedicate resources to further observations. Such efforts will improve predictions, helping inform policy makers to implement successful local coastal management solutions.	76	2018	10.2112/SI81-006.1	
Urban flood adaptation and optimization for net-zero: Case study of Dongjak-gu, Seoul	Kim, J; Lee, J; Hwang, S; Kang, J	JOURNAL OF HYDROLOGY-REGIONAL STUDIES	English	Article	Hydrology; LID-pipe network; Climate change scenario; Net-Zero; RCP 2; 6; Storm water management	MITIGATION	Study region: Sangdo-dong, Dongjak-gu, which is classified as inland water disaster risk zone within Seoul, Republic of Korea. Study focus: This study evaluated the amount of flooding that could occur in the carbon-neutral era, and optimized low-impact development (LID) technology for an urban flood adaptation. The optimal scenario of LID technologies was proposed for the Sangdo-dong area at the urban level, and the amount of runoff and flood reduction was evaluated. New hydrological insights: The LID controls provided by the storm water management model were used to analyze the flood damage that may occur under RCP 2.6 scenario. The evaluation simulated eight combinations of three optimized techniques: green roofs, permeable pavements, and vegetative swales to construct evidence-based data for the use by decision makers. In Scenario 8, which was evaluated as the most efficient, both peak and total flooding could be reduced by 55-60% respectively. This study not only evaluate the runoff but also the flooding value reflecting the interactions among LID-pipe networks. The LID installation area and runoff damage scale are inversely proportional. In contrast, as total flooding considers the capacity of the sewage network, a non uniform graph can be seen compared to the runoff. Results of this study can be used as guidance for LID evidence-based design and construction as well as strategies for decision maker.	76	2022	10.1016/j.ejrh.2022.101110	
A framework for addressing urban heat challenges and associated adaptive behavior by the public and the issue of willingness to pay for heat resilient infrastructure in Chongqing, China	He, BJ; Zhao, DX; Xiong, K; Qi, JD; Ulpiani, G; Pignatta, G; Prasad, D; Jones, P	SUSTAINABLE CITIES AND SOCIETY	English	Article	Demographic structure; Mitigation and adaptation strategies; Prevention and control system; Urban heat island; Urban overheating; Willingness to pay	SUPER-COOL MATERIALS; LOCAL CLIMATE ZONES; ENERGY-CONSUMPTION; STREET DESIGN; HEALTH; PRODUCTIVITY; ENVIRONMENT; MORTALITY; IMPACTS; ISLANDS	This study investigates public participation in heat impact reduction by analysing adaptive behaviours, familiarity with urban heat island (UHI) and cooling strategies, the perceived urgency of heat impact actions and citizen's willingness to pay through a questionnaire survey in Chongqing, China. The results indicate that airconditioning systems are the dominant cooling facility in both work and living environments. Respondents had a moderately familiar understanding of several cooling strategies such as urban vegetation, shading devices, water-based artificial facilities, urban design for shading and ventilation and water bodies. Familiarity with innovative materials and techniques for pavements, roofs and facades was less than moderate. Urban planning and design for heat resilient cities was thought to be the most urgent intervention, followed by the establishment of temporary cooling facilities. Most respondents indicated that cost-sharing mechanisms for urban heat prevention and control systems should at least include the government, whilst 50% of the respondents preferred collaborative payment among government, developers, and owners. Only 41.6% of the interviewees expressed their willingness to pay, with a share varying between 20 and 80 RMB. A conservative estimate indicated that there could be an average payment of 45.95 RMB and 19.10 RMB among the 234 respondents who were willing to pay and all 562 respondents regardless of willingness, respectively. Respondents' heat-related responses and actions towards urban heat challenges were dependent on a wide range of factors like gender, age, education, economic status, health, exposure, habit formation and behavior change, social acceptance, etc. Moreover, such factors could interact with each other affecting public behavior with different weights. Overall, this study increases our understanding of people's perceptions and proactiveness in reducing urban heat and provides guidance for decision-makers towards a novel user-aware approach to the implementation of urban heat prevention, adaptation, and mitigation strategies.	75	2021	10.1016/j.scs.2021.103361	
Can climate information salvage livelihoods in arid and semiarid lands? An evaluation of access, use and impact in Namibia	Gitonga, ZM; Visser, M; Mulwa, C	WORLD DEVELOPMENT PERSPECTIVES	English	Article	Impact evaluation; Climate information; Namibia; Adaptive capacity; Food security; Dietary diversity	AGRICULTURAL PRODUCTION; FORECAST APPLICATIONS; SUBSISTENCE FARMERS; ADAPTIVE CAPACITY; CHANGE ADAPTATION; PROPENSITY SCORE; DECISION-MAKING; ECONOMIC-GROWTH; SOUTHERN AFRICA; VARIABILITY	Climate forecasting is a crucial tool for managing risks in climate-sensitive economic sectors like agriculture. Although rainfed subsistence farming dominates livelihoods in Africa, information on access, integration in farm decisions and impact of improved seasonal climate forecasting remains scanty. This paper addresses this gap using representative data of 653 households across three regions in North-Central Namibia. The study employed propensity score matching, with a sensitivity analysis for hidden bias, to evaluate the impact of climate information on adaptive capacity and food security. Although half of the households received climate information, many rated it as insufficient for decision-making and relied on traditional knowledge. The main channels were the radio and farmer's peers, but trust was low. Farmers were found to attach high importance to climate information in relation to decisions about sale of livestock and stocking livestock feed, restocking, storing food for consumption smoothing and in making crop choices. Households receiving climate information had more diversified diets, higher food expenditure and engaged in more adaptive strategies, but on a small scale. Effective response to climate information for risk mitigation will require enhanced community awareness of available adaptive choices, development of market value chains, institutional support like extension services, and improvement of rural road and communication infrastructure. Working with local leaders and integrating climate information into local knowledge systems can enhance access and utilization in farm decisions.	75	2020	10.1016/j.wdp.2020.100239	
Development of a GIS coastal land-use planning tool for coastal erosion adaptation based on the exposure of buildings and infrastructure to coastal erosion, Quebec, Canada	Fraser, C; Bernatchez, P; Dugas, S	GEOMATICS NATURAL HAZARDS & RISK	English	Review	Adaptation tool; GIS planning tool; coastal erosion; coastal hazards; exposure assessment; vulnerability; knowledge transfer process	SEA-LEVEL RISE; CLIMATE-CHANGE; VULNERABILITY ASSESSMENT; ENVIRONMENTAL HAZARDS; VISUALIZATION; GOVERNANCE; INDICATORS; MANAGEMENT; KNOWLEDGE; AREAS	This study presents the development of a geographic information system (GIS) land-use planning tool for coastal areas based on the calculated exposure to coastal erosion of buildings and infrastructure. Responding to the needs of land-use planners, who are involved in the project from the beginning, this tool facilitates identification of adaptation solutions based on coastal sensitivity to erosion. All buildings, roads, railways, aqueducts, sewer systems, hiking trails and bicycle routes were mapped at high resolution, and an exposure value was assigned to each for seven time horizons between 2015 and 2100. The calculations were based on three parameters: (1) the distance between the structure and the shoreline or coastline; (2) the most likely shoreline or coastline migration rate for each coastal geomorphology behaviour unit (CGBU); and (3) the maximum event retreat measured during a storm for each type of coast. This method was applied to Baie des Chaleurs in Quebec, Canada. The area comprises 11 municipalities with a total of 105 km of coast. The approach not only produces current and future portraits of building and infrastructure exposed to erosion, but also provides an original land-use planning and intervention tool for coastal areas.	75	2017	10.1080/19475705.2017.1294114	
Multiagent Simulation for Complex Adaptive Modeling of Road Infrastructure Resilience to Sea-Level Rise	Batouli, M; Mostafavi, A	COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING	English	Article		CLIMATE-CHANGE; PAVEMENT MAINTENANCE; MANAGEMENT; FRAMEWORK; ADAPTATION; IMPACTS; FLOOD; WORLD	Infrastructure systems in coastal areas are exposed to episodic flooding exacerbated by sea-level rise stressors. To enable assessing the long-term resilience of infrastructure to such chronic impacts of sea-level rise, the present study created a novel complex system modeling framework that integrates: (i) stochastic simulation of sea-level rise stressors, based on the data obtained from downscaled climate studies pertaining to future projections of sea-level and precipitation; (ii) dynamic modeling of infrastructure conditions by considering regular decay of infrastructure, as well as structural damages caused by flooding; and (iii) a decision-theoretic modeling of infrastructure management and adaptation processes based on bounded rationality and regret theories. Using the proposed framework and data collected from a road network in Miami, a multiagent computational simulation model was created to assess the long-term cost and performance of the road network under various sea-level rise scenarios, adaptation approaches, and network degradation effects. The results showed the capabilities of the proposed computational model for robust planning and scenario analysis to enhance the resilience of infrastructure systems to sea-level rise impacts.	75	2018	10.1111/mice.12348	
Urban Climate Justice, Human Health, and Citizen Science in Nairobi's Informal Settlements	Corburn, J; Njoroge, P; Weru, J; Musya, M	URBAN SCIENCE	English	Article	climate change; informal settlements; citizen science; public health; Nairobi	RESILIENCE; CITY; KNOWLEDGE	Urban informal settlements or slums are among the most vulnerable places to climate-change-related health risks. Yet, little data exist documenting environmental and human health vulnerabilities in slums or how to move research to action. Citizen science, where residents co-define research objectives with professionals, collect and analyze data, and help translate findings into ameliorative actions, can help fill data gaps and contribute to more locally relevant climate justice interventions. This paper highlights a citizen-science, climate justice planning process in the Mukuru informal settlement of Nairobi, Kenya. We describe how residents, non-governmental organizations and academics partnered to co-create data-gathering processes and generate evidence to inform an integrated, climate justice strategy called the Mukuru Special Planning Area Integrated Development Plan. The citizen science processes revealed that <1% of residents had access to a private in-home toilet, and 37% lacked regular access to safe and affordable drinking water. We found that 42% of households were subject to regular flooding, 39% reported fair or poor health, and 40% reported a child in the household was stunted. These and other data were used in a community planning process where thousands of residents co-designed improvement and climate change adaptation strategies, such as flood mitigation, formalizing roads and pathways with drainage, and a water and sanitation infrastructure plan for all. We describe the participatory processes used by citizen scientists to generate data and move evidence into immediate actions to protect human health and a draft a long-range, climate justice strategy. The processes used to create the Mukuru Special Planning Area redevelopment plan suggest that participatory, citizen-led urban science can inform local efforts for health equity and global goals of climate justice.	75	2022	10.3390/urbansci6020036	
Climate adaptation of interconnected infrastructures: a framework for supporting governance	Bollinger, LA; Bogmans, CWJ; Chappin, EJL; Dijkema, GPJ; Hulbregtse, JN; Maas, N; Schenk, T; Sneider, M; van Thienen, P; de Wit, S; Wols, B; Tavasszy, LA	REGIONAL ENVIRONMENTAL CHANGE	English	Article	Climate change adaptation; Governance; Road; Electricity; Drinking water; Socio-technical systems; Systems of systems	CHANGE IMPACTS; TRANSPORT; WEATHER; ENERGY; EUROPE; MODEL	Infrastructures are critical for human society, but vulnerable to climate change. The current body of research on infrastructure adaptation does not adequately account for the interconnectedness of infrastructures, both internally and with one another. We take a step toward addressing this gap through the introduction of a framework for infrastructure adaptation that conceptualizes infrastructures as complex socio-technical systems of systems embedded in a changing natural environment. We demonstrate the use of this framework by structuring potential climate change impacts and identifying adaptation options for a preliminary set of cases-road, electricity and drinking water infrastructures. By helping to clarify the relationships between impacts at different levels, we find that the framework facilitates the identification of key nodes in the web of possible impacts and helps in the identification of particularly nocuous weather conditions. We also explore how the framework may be applied more comprehensively to facilitate adaptation governance. We suggest that it may help to ensure that the mental models of stakeholders and the quantitative models of researchers incorporate the essential aspects of interacting climate and infrastructure systems. Further research is necessary to test the framework in these contexts and to determine when and where its application may be most beneficial.	74	2014	10.1007/s10113-013-0428-4	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Environmental impacts of climate change adaptation	Enriquez-de-Salamanca, A; Diaz-Sierra, R; Martin-Aranda, RM; Santos, MJ	ENVIRONMENTAL IMPACT ASSESSMENT REVIEW	English	Article	Climate change; Climate change adaptation; Environmental assessment; Environmental impacts; Secondary impacts	ROAD INFRASTRUCTURE; DESALINATION PLANT; CHANGE MITIGATION; SEA; POLICY	Climate change adaptation reduces adverse effects of climate change but may also have undesirable environmental impacts. However, these impacts are yet poorly defined and analysed in the existing literature. To complement this knowledge-gap, we reviewed the literature to unveil the relationship between climate change adaptation and environmental impact assessment, and the degree to which environmental impacts are included in climate change adaptation theory and practice. Our literature review showed that technical, social and economic perspectives on climate change adaptation receive much more attention than the environmental perspective. The scarce interest on the environmental impacts of adaptation may be attributed to (1) an excessive sectoral approach, with dominance of non-environmental perspectives, (2) greater interest in mitigation and direct climate change impacts rather than in adaptation impacts, (3) a tendency to consider adaptation as inherently good, and (4) subjective/preconceived notions on which measures are good or bad, without a comprehensive assessment. Environmental Assessment (EA) has a long established history as an effective tool to include environment into decision-making, although it does not yet guarantee a proper assessment of adaptation, because it is still possible to postpone or even circumvent the processes of assessing the impacts of climate adaptation. Our results suggest that there is a need to address adaptation proactively by including it in EA, to update current policy frameworks, and to demand robust and reliable evaluation of alternatives. Only through the full EA of adaptation measures can we improve our understanding of the primary and secondary impacts of adaptation to global environmental change. (C) 2017 Elsevier Inc. All rights reserved.	74	2017	10.1016/j.eiar.2017.03.005	
Flexible Planning for Intercity Multimodal Transport Infrastructure	Hadjidemetriou, GM; Teal, J; Kapetas, L; Parlikad, AK	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Transportation networks; Roadways; Railways; Dynamic adaptive policy pathways; Adaptation; Transport mode switching	ADAPTIVE POLICY PATHWAYS; CLIMATE-CHANGE; ADAPTATION; TRAVEL; FRAMEWORK; DEMAND	Planning transport infrastructure development involves high levels of uncertainty due to socioeconomic, environmental, and technological changes. Methodologies currently used in transport planning often have minimal consideration for adaptiveness, leading to costly redesigns or cancellation of entire projects. Presented herein is the investigation of the applicability of dynamic adaptive policy pathways, which is a methodology predominantly used in the field of flood-risk planning, to long-term transport infrastructure planning. Specifically, the paper investigates whether this methodology could facilitate ongoing adaptation to variations in service demand and capacity. It demonstrates this by examining future demand and capacity of road and rail travel between Manchester, United Kingdom, and London using publicly available data and information sources. The study shows that dynamic adaptive policy pathways is useful for identifying periods of time of significant capacity vulnerability for the examined transport network in the coming decade. The method is demonstrated to be valuable for identifying the points in time when policy-makers will have to make decisions and for assessing the impact of transport mode switching. This can have implications of cost-saving and improved service delivery.	74	2022	10.1061/(ASCE)IS.1943-555X.0000664	
Sustainable stormwater management under the impact of climate change and urban densification	Rosenberger, L; Leandro, J; Pauleit, S; Erlwein, S	JOURNAL OF HYDROLOGY	English	Article	Urban climate adaptation; Low-impact development; Nature-based solutions; Sewer system; Sustainable urban drainage system; SWMM; Blue green infrastructure	WATER MANAGEMENT; PERFORMANCE; QUANTITY; QUALITY; URBANIZATION	The demand for living space is rising in growing cities. To restrict urban expansion in the outskirts, a common strategy is to densify existing neighbourhoods. Densification implies the increase of water impervious area which increases the vulnerability to flooding during extreme precipitation events. Sustainable urban drainage systems are considered as a strategy to handle stormwater runoff locally and thus relieve the sewage system. This study investigates the combined quantitative hydrological impact of densification and sustainable stormwater management measures in a residential neighbourhood in Munich, Germany. The living-lab approach pursues the application of nature-based solutions in a real planning case to achieve positive climate effects while densifying the neighbourhood. The study is based on single event simulations of three return periods with the physically based software PCSWMM. The events are implemented for both current and climate change precipitation intensities of the RCP 8.5 projection for 2040-2069. Three scenarios are implemented: a status quo, a business as usual scenario (additional buildings without compensation measures) and a best-case scenario (one additional floor with green roofs disconnected from the sewers in combination with rain gardens and porous pavements on the land parcels). The comparison between the different scenarios focuses on three main aspects of the water balance, namely, infiltration, runoff and storage. The results show that measures for sustainable stormwater management are crucial elements to cope with an increasing number of heavy precipitation events due to climate change. The best-case scenario significantly outperforms the other two concerning water infiltration, surface runoff and storage. Most notably is the impact of climate change projection rainfall intensities for 2040-2069. The outcomes for these intensities clearly show the positive impact of sustainable water-sensitive design. The results demonstrate that it is in fact possible to enhance the water balance and gain new living space simultaneously if a sustainable urban planning strategy is implemented that includes future-oriented stormwater management.	74	2021	10.1016/j.jhydrol.2021.126137	
Climate change impact and adaptation for highway asphalt pavements: a literature review	Swarna, ST; Hossain, K	CANADIAN JOURNAL OF CIVIL ENGINEERING	English	Review; Early Access	climate change; pavement performance; pavement maintenance; pavement service life; life cycle cost analysis; temperature rise	PERFORMANCE; TEMPERATURE; UNCERTAINTY; PROJECTIONS; MAXIMUM; DESIGN; TRENDS	For the past few decades, researchers all over the world have agreed that the service life of civil infrastructure is significantly affected by climate change. Pavement is one of these significant infrastructures that can be easily affected by climate change. However, it is well known that predicting climate change is highly complex and dynamic. Hence, a review has been done on available climate change models and the uncertainties involved in climate change prediction. This review addresses various important questions, such as (i) what climate change is, (ii) how to use climate change models, (iii) uncertainties involved in using climate change models, (iv) how climate change impacts pavement infrastructure, (v) the adaptation and mitigation strategies available, and (vi) how economic costs and emissions change due to climate change. This review is useful to understand climate change and its implications on pavement infrastructure.	73	2022	10.1139/cjce-2021-0209	
Climate change-induced heat risks for migrant populations working at brick kilns in India: a transdisciplinary approach	Lundgren-Kownacki, K; Kjellberg, SM; Gooch, P; Dabaieh, M; Anandh, L; Venugopal, V	INTERNATIONAL JOURNAL OF BIOMETEOROLOGY	English	Article	Brick kilns; Climate change; Heat stress; India; Migrant work; Technical and socio-cultural solutions; Transdisciplinary approach	FRAME ANALYSIS; ADAPTATION; HEALTH; PRODUCTIVITY; CHALLENGES; EXPOSURE; IMPACT; FUTURE; WBGT	During the summer of 2015, India was hit by a scorching heat wave that melted pavements in Delhi and caused thousands of deaths, mainly among the most marginalized populations. One such group facing growing heat risks from both occupational and meteorological causes are migrant brick kiln workers. This study evaluates both current heat risks and the potential future impacts of heat caused by climate change, for the people working at brick kilns in India. A case study of heat stress faced by people working at brick kilns near Chennai, India, is the anchor point around which a transdisciplinary approach was applied. Around Chennai, the situation is alarming since occupational heat exposure in the hot season from March to July is already at the upper limits of what humans can tolerate before risking serious impairment. The aim of the study was to identify new pathways for change and soft solutions by both reframing the problem and expanding the solution space being considered in order to improve the quality of life for the migrant populations at the brick kilns. Technical solutions evaluated include the use of sun-dried mud bricks and other locally appropriate technologies that could mitigate the worsening of climate change-induced heat. Socio-cultural solutions discussed for empowering the people who work at the brick kilns include participatory approaches such as open re-localization, and rights-based approaches including the environmental sustainability and the human rights-based approach framework. Our analysis suggests that an integrative, transdisciplinary approach could incorporate a more holistic range of technical and socio-culturally informed solutions in order to protect the health of people threatened by India's brick kiln industry...	73	2018	10.1007/s00484-017-1476-0	
Integrating sketch mapping and hot spot analysis to enhance capacity for community-level flood and disaster risk management	Brandt, K; Graham, L; Hawthorne, T; Jeanty, J; Burkholder, B; Munisteri, C; Visaggi, CC	GEOGRAPHICAL JOURNAL	English	Article	Belize; community-based risk management; flooding; hot spot analysis; participatory GIS; participatory sketch mapping	GEOGRAPHIC INFORMATION-SYSTEMS; CLIMATE-CHANGE; PARTICIPATORY-GIS; LOCAL KNOWLEDGE; VULNERABILITY; ADAPTATION; PLACE; PERCEPTIONS; POLICY; SENSE	This community-based research aims to enhance local-level flood management by utilising participatory geographic information systems (PGIS) methods to capture the spatial dimensions of community member flooding concerns in Hopkins Village, Belize. We offer a mixed methodology, applying participatory sketch mapping as a way to collect local knowledge about community perceptions of flooding in this data-scarce context. We combine this local knowledge with quantitative geostatistical hot spot analysis of basic village infrastructure characteristics to reveal insights about community perceptions of and response to flood risk. The significance of this research lies in the application of PGIS methods to create two different primary datasets, which when analysed together offer a more complete story about community understanding and needs for flood management. One set of data (more qualitative in nature) originated from sketch maps with community members and answers descriptive questions about how people spatially conceptualise hydro-meteorological hazards within their community. The other (more quantitative in nature) is the village's first publicly accessible infrastructure dataset (including information on building structures, roads, and drainage infrastructure) digitised by our research team from high-resolution drone imagery. Attributes for the infrastructure dataset were developed in collaboration with community members to reflect their desires for data and information suited to conduct flood vulnerability assessment. Application of thematic coding and hot spot analysis to the data reveals concerns about hazards within their community and the measures they have taken to protect themselves in the absence of resources to develop community-wide mitigation plans. Our work offers contributions to the participatory GIS literature by providing an example of sketch mapping methods to facilitate multi-level management of community-level flood risk in a data-scarce setting, and demonstrating the multiple benefits of applied participatory GIS methods as a means of overcoming data scarcity.	73	2020	10.1111/geoj.12330	
Quantifying road vulnerability to coastal hazards: Development of a synthetic index	Drejza, S; Bernatchez, P; Marie, G; Friesinger, S	OCEAN & COASTAL MANAGEMENT	English	Article	Coastal erosion; Coastal flooding; Vulnerability index; Transport network; Quebec; Canada	SEA-LEVEL RISE; CLIMATE-CHANGE; ADAPTIVE CAPACITY; EROSION; ADAPTATION; INDICATORS; INFRASTRUCTURE; CONSTRAINTS; ASSESSMENTS; IMPACTS	As part of a collaborative study with the Ministry of Transport of Quebec, a Coastal Road Erosion and Flooding Vulnerability Index (CREFVI) was developed for the short (2020), medium (2060) and long term (2100). Nine study sites in Eastern Quebec (Canada) were used to develop the index, for a total of 122.4 km of roads. The index includes 14 parameters relating to the following: the exposure of a site to erosion and coastal flooding hazard; the characteristics of the road segment; the characteristic of the road network; and adaptation to erosion (e.g. the presence of defence structures). Each parameter received a score between 1 and 5 according to its propensity to increase (5) or not (1) the vulnerability of the road. CREFVI values for the study sites vary between 0 and 159.1 and have been divided into 5 classes reflecting the actions needed to reduce the site's vulnerability: Not vulnerable (no intervention necessary), Low, Medium, High, Critical (immediate intervention required). For the roads analyzed, 0.5 km have a critical CREFVI value as of 2020, 1.7 km as of 2060 and 2.6 km by 2100. Currently, only 20.6% of the road segments are vulnerable to coastal hazards, but this percentage rises to 36.4% by 2060 and to 54.3% by 2100. This index is an important decision-making tool for improving road management, prioritizing future actions and determining which parameters require intervention.	72	2019	10.1016/j.ocecoaman.2019.104894	
The triple bottom line: bringing a sustainability framework to prioritize climate change investments for infrastructure planning	Schweikert, A; Espinet, X; Chinowsky, P	SUSTAINABILITY SCIENCE	English	Article	Road infrastructure; Climate change; Adaptation; Sustainability; Triple bottom line	CHANGE ADAPTATION; VULNERABILITY; RISK; IMPACT; RESILIENCE; TRANSPORT; COSTS	Climate change is an increasing concern of agencies, governments, and communities around the world. It poses potential adverse impacts to civil infrastructure, with consequences that include increased financial resources, economic impacts, social impacts, and planning issues. This paper aims to enhance and broaden the discussion on sustainability and the importance of the consideration of social, environmental, and technical aspects in relation to infrastructure planning. Particularly under climate change, these considerations allow for more holistic, effective, and long-term benefits to communities and economies. This paper introduces the triple bottom line (TBL) approach to sustainability as a framework for holistic infrastructure planning under the uncertainty of climate change. The economic pillar will focus on the impacts of climate change on road infrastructure and the cost-benefit of potential adaptation options; environmental considerations include quantifying the potential increase in GHG emissions from increased roadworks required by climate change damages; and the social pillar will be quantified using an index based upon the SoVI method. Each of these 'pillars' of sustainability will be analyzed individually and mapped using geographic information systems (GIS). Finally, a 'holistic' approach will be discussed, where these individual layers are combined using GIS to display the information. A case study focused on the Sacramento Region of California is used as a proof-of-concept for how the triple bottom line framework introduced here can be utilized to provide actionable, more equitable decision-making for investment in critical infrastructure adaptation policy.	72	2018	10.1007/s11625-017-0431-7	
Greenhouse Gas Emissions and Sustainability in Victoria Falls: Focus on Hotels, Tour Operators and Related Attractions	Dube, K; Nhamo, G	AFRICAN GEOGRAPHICAL REVIEW	English	Article	Tourism; sdgs; sustainability; victoria Falls; hotels; climate change	CLIMATE-CHANGE; NATIONAL-PARK; PERCEPTIONS; ADAPTATION; MPUMALANGA; PROGRESS; IMPACTS; QUALITY; AGENDA	This study investigates sources of greenhouse gas (GHG) emissions in Victoria Falls town and the treatment of sustainability issues thereof. Making use of a survey, interviews and field observations for data generation, the results show that Victoria Falls town hosts a wide range of GHG emitting and ecologically sensitive hospitality infrastructure, including hotels and tour operators. The primary sources of GHG emissions come from the hospitality subsector, followed by the use of road transport, which is dominated by old Japanese vehicles. The study recommends a raft of measures to curb carbon emissions, including the use of renewable energy.	71	2021	10.1080/19376812.2020.1777437	
Integrating solutions to adapt cities for climate change	Lin, BB; Ossola, A; Alberti, M; Andersson, E; Bai, XM; Dobbs, C; Elmqvist, T; Evans, KL; Frantzeskaki, N; Fuller, RA; Gaston, KJ; Haase, D; Jim, CY; Konijnendijk, C; Nagendra, H; Niemela, J; McPhearson, T; Moonnaw, WR; Parnell, S; Pataki, D; Ripple, WJ; Tan, PY	LANCET PLANETARY HEALTH	English	Article		URBAN; RESILIENCE; ENERGY; WATER; TRANSFORMATIONS; SUSTAINABILITY; OPPORTUNITIES; CHALLENGES; MITIGATION; KNOWLEDGE	Record climate extremes are reducing urban liveability, compounding inequality, and threatening infrastructure. Adaptation measures that integrate technological, nature-based, and social solutions can provide multiple co-benefits to address complex socioecological issues in cities while increasing resilience to potential impacts. However, there remain many challenges to developing and implementing integrated solutions. In this Viewpoint, we consider the value of integrating across the three solution sets, the challenges and potential enablers for integrating solution sets, and present examples of challenges and adopted solutions in three cities with different urban contexts and climates (Freiburg, Germany; Durban, South Africa; and Singapore). We conclude with a discussion of research directions and provide a road map to identify the actions that enable successful implementation of integrated climate solutions. We highlight the need for more systematic research that targets enabling environments for integration; achieving integrated solutions in different contexts to avoid maladaptation; simultaneously improving liveability, sustainability, and equality; and replicating via transfer and scale-up of local solutions. Cities in systematically disadvantaged countries (sometimes referred to as the Global South) are central to future urban development and must be prioritised. Helping decision makers and communities understand the potential opportunities associated with integrated solutions for climate change will encourage urgent and deliberate strides towards adapting cities to the dynamic climate reality.	71	2021		
Livelihood diversification in managing catastrophic risks: evidence from flood-disaster regions of Khyber Pakhtunkhwa Province of Pakistan	Shah, AA; Gong, ZW; Khan, NA; Khan, I; Ali, M; Naqvi, SAA	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	English	Article	Climate change; Agriculture; On-farm; off-farm livelihood diversification; Farm households; Khyber Pakhtunkhwa; Pakistan		Pakistan's agricultural productivity is considered to be low despite several agriculture promotion policies. Such policies concentrate primarily on on-farm development and overlook rich prospects for off-farm diversification. Livelihood diversification of small-scale farmers plays a major role in reducing hunger and mitigating the adverse impacts of climate change. Therefore, this paper seeks to analyze livelihood diversification in managing catastrophic risks among rural farm households of Khyber Pakhtunkhwa Province of Pakistan. We have interviewed a total of 600 farm households through a standardized questionnaire in two districts (Nowshera and Charsadda) of Khyber Pakhtunkhwa Province of Pakistan that were badly affected by the 2010 flood. For empirical analysis, a logistic regression model was chosen to analyze the important attributes that are correlated to livelihood diversification of the rural households in flood-susceptible areas of Pakistan. The survey findings indicate that 50% of the total sample respondents adopted off-farm livelihood diversification strategies, while 40.5% of farm households adopted on-farm livelihood diversification strategies in managing catastrophic risks. The logistic regression model results show that attributes including socioeconomic and demographic, institutional, and risk perception significantly influenced households' choices of livelihood diversification. Also, the findings indicated a wide range of livelihood diversification constrained including climatic risks and uncertainties (23%), inadequate natural resources (17%), limited level of skills and training (15%), lack of credit facilities (11%), poor infrastructure including markets and roads (16%), and lack of labor availability (4%). The study urges the need for robust climate change adaptation policies, in particular, by aiming at training initiatives, improving access to services, and enhancing institutional assistance, and better infrastructure. The livelihood of small-scale farmers could only improve if the Government pays due consideration and adopts the right policy initiatives that promote the diversification of livelihoods as part of the creation of national jobs to save many lives and improve livelihoods.	71	2021	10.1007/s11356-021-13598-y	
Factors distinguishing the decision to migrate from the flooded and inundated community of Sayung, Demak: A suburban area of Semarang City, Indonesia	Buchori, I; Pramitasari, A; Pangi, P; Sugiri, A; Maryono, M; Basuki, Y; Sejati, AW	INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION	English	Article	Migration; Flood; Inundation; Suburban area; Coastal community; Climate change	SEA-LEVEL RISE; CLIMATE-CHANGE ADAPTATION; INDIGENOUS KNOWLEDGE; HOUSEHOLD ADAPTATION; LAND SUBSIDENCE; COASTAL; VULNERABILITY; REDUCTION; RESILIENCE; JAVA	This study is aimed at investigating the differentiating factors underlying the intention to migrate from a flooded and inundated community in suburban areas; in this case, the community is the Sayung subdistrict of Demak Regency. Previous studies have observed a variety of self-mitigation and patterns of local migrations among the communities in the city of Semarang. The suburban case, however, is frequently overlooked by local governments, which often focus more on handling city centre problems. In this study, we employed a quantitative approach using statistical descriptive analysis and Discriminant Analysis. In addition, an in-depth interview with key informants provided a complementary qualitative approach, to deepen understanding of the quantitative findings. The results suggested the factors distinguishing the residents' desire to migrate or not were: income, private vehicle possession, community cooperation in maintaining environment cleaning and security, road condition and access, proximity to educational and health facilities and electricity, and the intensity of the flood entering the house. Unlike the urban case society, the willingness to move of the suburban society was not only affected by their financial capability, the availability of settlement infrastructures, and the severe level of the flood but also their emotional bonds to the place and the community.	70	2021	10.1016/j.ijdrr.2020.101946	
Green Enough Ain't Good Enough: Public Perceptions and Emotions Related to Green Infrastructure in Environmental Justice Communities	Meenar, M; Heckert, M; Adlakha, D	INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	English	Article	biophilic urban planning; green stormwater infrastructure; social benefits; health equity; emotions; perceptions; mental health; Camden	CLIMATE-CHANGE ADAPTATION; STORMWATER INFRASTRUCTURE; HEALTH; SPACE; IMPACT; CITIES; PLACE; CITY; PERSPECTIVES; BENEFITS	The concept of biophilic urban planning has inspired neighborhood greening projects in many older urban communities in the USA and beyond. The strengths (e.g., environmental management, biodiversity, heat island mitigation) and challenges (e.g., greenwashing, green gentrification) of such projects are well-documented. Additional research on the relationship between these projects and various social factors (e.g., public perceptions, feelings, and mental health and well-being) is necessary to better understand how people adapt to said projects while struggling to navigate other more pressing socioeconomic issues, especially in communities facing environmental injustice and health inequity. In this article, we focus on one aspect of biophilic urban planning-green stormwater infrastructure (GSI) (e.g., rain gardens, bio-swales, pervious pavements, and wildflower meadows)-in Waterfront South, a post-industrial neighborhood in Camden, NJ, USA, where residents have faced environmental injustices for decades. Our qualitative analysis of in-depth semi-structured interviews of sixteen residents offered a thorough insight into their perceptions and emotions regarding different types of urban GSI projects. Residents acknowledge the many benefits that GSI offers to combat the neighborhood's social and environmental injustices, but they are cautious about the possibility of some projects prompting new issues and concerns within the community. Our findings reveal potential implications in GSI planning, research, and practice in this neighborhood and similar urban places elsewhere that have yet to undergo gentrification.	70	2022	10.3390/ijerph19031448	
Integrating climate change adaptation into community planning using a participatory process: The case of Saebat Maeul community in Busan, Korea	Kim, D; Kang, JE	ENVIRONMENT AND PLANNING B-URBAN ANALYTICS AND CITY SCIENCE	English	Article	Community-based adaptation; participatory planning; local knowledge; community development; climate change adaptation	RISK; RESILIENCE; BARRIERS; DURBAN; POLICY; POOR	Climate change is certain, given the sufficient evidence for it. Thus, it needs to be integrated into the process of spatial and community planning to empower communities so they can adapt to it. This study addresses the critical gap in the literature on community planning and climate change adaptations by creating planning methodologies based on the participatory method, and simulating application of the process to the Saebat Maeul community in Busan, Korea. In the Saebat Maeul community, the study area, people have struggled with urban flooding, which is related to the poor sewer system and heat waves. Green infrastructures were used as the main tools to mitigate the negative impacts of climate change. The suggested community plan includes physical and socioeconomic measures, such as new parking structures with green roofs and pervious pavement, drainage facilities that reduce flooding, repairs to homes with cool roofs, and installation of rainwater harvesting facilities to lower the impact of heat waves. If planners have proper knowledge about climate change and if they guide the participatory planning process (thus reflecting local knowledge and suggestions), we concluded that it is possible to consider climate change adaptations within the context of spatial and community planning.	70	2018	10.1177/2399808318368388	
The Multifunctional Benefits of Green Infrastructure in Community Development: An Analytical Review Based on 447 Cases	Kim, D; Song, SK	SUSTAINABILITY	English	Review	multifunctionality; green infrastructure; ecosystem services; sustainable development; urban planning	IMPACT DEVELOPMENT PRACTICES; URBAN; ECOSYSTEM; FUTURE; BIODIVERSITY; VALUATION; LAND; TOOL	This article describes the relationship between the design features of green infrastructure and the benefits of multifunctionality. To do so, it examines the descriptive linkages between 12 design features and nine benefits using 447 project case studies from the American Society of Landscape Architects. Multiple benefits of green infrastructure were found in 65% of the projects, regardless of the number of applied design features. The major green infrastructure design features with multiple benefits were: bioretention areas, permeable pavements, grassed swales, rainwater harvesting, rain gardens, and curb cuts. The major benefits of applied design features were: enhanced economic capacity, educational opportunities, improvements to the built environment, and enhanced environmental soundness. The findings show that the multiple benefits of green infrastructure's multifunctionality can be inferred in many current cases. Knowing the relationship between design features and their benefits for green infrastructure would facilitate selecting optimal design features to achieve specific goals and planning outcomes. For communities that require a range of complex benefits, a multifunctionality-based green infrastructure will advance highly acceptable climate change adaptation measures.	70	2019	10.3390/su1143917	
Methodology for holistic assessment of grey-green flood mitigation measures for climate change adaptation in urban basins	Kourtis, IM; Bellos, V; Kopsiaftis, G; Psiloglou, B; Tsihrintzis, VA	JOURNAL OF HYDROLOGY	English	Article	Future IDF curves; Climate variability adaptation index (CVAI); Storm water management model (SWMM); Ecosystem services; Global sensitivity analysis; Forward uncertainty propagation	LOW IMPACT DEVELOPMENT; WATER AVAILABILITY; IDF CURVES; RAINFALL; MODEL; URBANIZATION; DRAINAGE; TRENDS; RISK; NONSTATIONARITY	A novel methodological framework for urban drainage adaptation to climate change is introduced and tested in a small urban basin. The impact of climate change on Intensity-Duration-Frequency curves and on urban drainage is reported. The flood mitigation measures comprised both green and grey alternatives, i.e., permeable surfaces and sewer enlargement. The Storm Water Management Model (SWMM5) was calibrated and employed. Prior to calibration, sensitivity analysis of SWMM hydrologic-hydraulic and permeable surfaces input parameters was conducted using a global sensitivity analysis method. Two novel indices, the Index for Reliability of Urban Drainage Adaptation (IRUDA) and the Climate Variability Adaptation Index (CVAI), were also introduced. IRUDA assesses the total reliability of an urban drainage network in hydraulic, temporal and volumetric terms. Sizing of flood mitigation measures was undertaken employing construction cost along with IRUDA. CVAI was used for alternative selection among different flood mitigation scenarios. CVAI assesses the total adaptive capacity of the drainage network based on hydrological, hydraulic and economic aspects of the proposed adaptation plan. A forward uncertainty propagation scheme was employed on the selected alternative in order to examine input data and parametric uncertainty with respect to the peak discharge at the outlet of the basin. Finally, monetization of ecosystem services offered by green measures is presented. The simulation results for the study area illustrated that under the non-stationarity assumption future rainfall intensities and urban flooding risk will increase, and therefore, further flood mitigation measures will be required. Furthermore, the majority of the adaptation strategies examined were found to improve the capacity and reliability of the drainage network. Moreover, the results revealed that permeable pavements perform better for storm events with return period of up to five years. Overall, it can be concluded that design criteria need to be reviewed and also green measures, such as permeable surfaces, can be introduced in the design procedure.	69	2021	10.1016/j.jhydrol.2021.126885	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Robust Prioritization Framework for Transport Infrastructure Adaptation Investments under Uncertainty of Climate Change	Espinet, X; Schweikert, A; Chinowsky, P	ASCE-ASME JOURNAL OF RISK AND UNCERTAINTY IN ENGINEERING SYSTEMS PART A-CIVIL ENGINEERING	English	Article	Infrastructure; Adaptation; Climate change; Resilience; Sustainability; Decision analysis; Uncertainty; Robustness	DECISION-MAKING; IMPACT; MANAGEMENT; RISK	To create and sustain resilient infrastructure systems, decision makers must consider a changing climate in their design and maintenance planning. However, significant barriers exist to constrain the understanding and implementation of climate change considerations, including the inherent uncertainty in climate change model projections. The high level of uncertainty related to climate projections makes the engineering planning process difficult because it is impossible to fully know future climate conditions relative to historical design standards. This paper seeks to address this challenge by introducing a new method for calculating robust decisions rooted in existing decision theory and uncertainty. This paper details the framework used for the new decision-making process and describes how the framework can provide guidance about achieving low-regret adaptation options for resilient road infrastructure design. A case study of a province in Mexico illustrates the application of the framework to an actual transportation planning effort. (C) 2015 American Society of Civil Engineers.	69	2017	10.1061/AJRUA6.0000852	
Sewing climate-resilient seeds: implementing climate change adaptation best practices in rural Cambodia	D'Agostino, AL; Sovacool, BK	MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE	English	Article	Cambodia; Climate change adaptation; Development aid; UNDP; Water resources management	TONLE SAP LAKE; IMPACTS; VULNERABILITY; WATER	Multilateral support through programs like the Least Developed Countries Fund (LDCF) targets countries widely considered to be the most vulnerable to climate change. Cambodia is one of the six Asian LDCF recipients and with UNDP support is implementing the first adaptation project to arise from its National Adaptation Program of Action. Drawing on primary research conducted in August 2010 through interviews with key stakeholders, this article investigates the project for the likely benefits and challenges it will face in promoting institutional, infrastructural, and community resilience to climate change impacts. We find that the country's ongoing decentralization reforms offer an effective opportunity to mainstream climate change planning into sub-national government operations, but that competing priorities for immediate investment in education, roads, and healthcare may prevent government officers from sustaining a focus on preventative adaptation measures. We conclude that through careful planning, water resources infrastructure and agricultural practices can be designed to withstand climate variability and avoid the need to replace or rehabilitate systems whose specifications were prematurely determined by international donors.	69	2011	10.1007/s11027-011-9289-7	
A Framework for Introducing Climate-Change Adaptation in Pavement Management	Knott, JE; Jacobs, JM; Sias, JE; Kirshen, P; Dave, EV	SUSTAINABILITY	English	Article	pavements; climate change; sea-level rise; adaptation planning; groundwater rise; temperature rise; infrastructure; resiliency; life-cycle costs; pavement management systems	ADAPTIVE POLICY PATHWAYS; DESIGN; COSTS; INFRASTRUCTURE; TEMPERATURE; PERFORMANCE	Greenhouse gas emissions have caused global temperatures to rise since the mid-20th century accompanied by sea-level rise (SLR). Temperature increases and SLR-induced groundwater rise have been shown to cause premature pavement failure in many roadway structures. Hybrid bottom-up/top-down (hybrid) adaptation approaches have shown promise by initially investigating an asset's response to incremental environmental change and then identifying the timing of critical effects for budgetary planning. This improves practitioners' understanding of the asset's climate resiliency and informs adaptation-plan development to minimize both cost and risk. In this study, a hybrid approach to pavement adaptation with climate-change-induced temperature and groundwater rise is demonstrated at a case-study site in coastal New Hampshire. The hot-mix-asphalt (HMA) thickness that achieves a minimum of 85% reliability is calculated for 70 combinations of incremental temperature and groundwater rise. Increasing the base-layer thickness improves resiliency against rising temperatures, but rising groundwater diminishes this improvement demonstrating that both HMA and base-layer thickness increases are needed. Thirteen adaptation pathways are evaluated for pavement performance, life-cycle costs, and road-surface inundation over a 60-year pavement management period. A stepwise and flexible adaptation plan is developed that includes HMA overlays with prescribed thickness and application timing, base-layer rehabilitation options, and re-evaluation opportunities.	68	2019	10.3390/su1164382	
A Modified Eco-Efficiency Framework and Methodology for Advancing the State of Practice of Sustainability Analysis as Applied to Green Infrastructure	Ghimire, SR; Johnston, JM	INTEGRATED ENVIRONMENTAL ASSESSMENT AND MANAGEMENT	English	Article	Data Envelopment Analysis; Modified eco-efficiency framework; Green infrastructure; Sustainability; Rainwater harvesting	RAINWATER HARVESTING SYSTEMS; DATA ENVELOPMENT ANALYSIS; LIFE-CYCLE ASSESSMENT; CLIMATE-CHANGE; IMPACT ASSESSMENT; WATER-RESOURCES; ABSOLUTE; LEVEL	We propose a modified eco-efficiency (EE) framework and novel sustainability analysis methodology for green infrastructure (GI) practices used in water resource management. Green infrastructure practices such as rainwater harvesting (RWH), rain gardens, porous pavements, and green roofs are emerging as viable strategies for climate change adaptation. The modified framework includes 4 economic, 11 environmental, and 3 social indicators. Using 6 indicators from the framework, at least 1 from each dimension of sustainability, we demonstrate the methodology to analyseRWHdesigns. Weuse life cycle assessment and life cycle cost assessment to calculate the sustainability indicators of 20 design configurations as Decision Management Objectives (DMOs). Five DMOs emerged as relatively more sustainable along the EE analysis Tradeoff Line, and we used Data Envelopment Analysis (DEA), a widely applied statistical approach, to quantify the modified EE measures asDMOsustainability scores. We also addressed the subjectivity and sensitivity analysis requirements of sustainability analysis, and we evaluated the performance of 10 weighting schemes that included classical DEA, equal weights, National Institute of Standards and Technology's stakeholder panel, Eco-Indicator 99, Sustainable Society Foundation's Sustainable Society Index, and 5 derived schemes. We improved upon classical DEA by applying the weighting schemes to identify sustainability scores that ranged from 0.18 to 1.0, avoiding the nonuniqueness problem and revealing the least to most sustainable DMOs. Our methodology provides a more comprehensive view of water resource management and is generally applicable to GI and industrial, environmental, and engineered systems to explore the sustainability space of alternative design configurations. Published 2017. This article is a US Government work and is in the public domain in the USA. Integrated Environmental Assessment and Management published by Wiley Periodicals, Inc. on behalf of Society of Environmental Toxicology & Chemistry (SETAC)	68	2017	10.1002/ieam.1928	
A Systematic Review of Civil and Environmental Infrastructures for Coastal Adaptation to Sea Level Rise	Nazarnia, H; Nazarnia, M; Sarmasti, H; Wills, WO	CIVIL ENGINEERING JOURNAL-TEHRAN	English	Review	Sea Level Rise; Coastal Communities; Infrastructure; Resilience	CLIMATE-CHANGE; SEAWATER INTRUSION; IMPACT; VULNERABILITY; RESILIENCE; TRANSPORT; INUNDATION; DRAINAGE; RETREAT; ZONE	Rising levels of seas and oceans due to global warming could drastically affect the daily lives of residents in coastal belts and lowland areas. Many of the most heavily populated regions in the world have been developed on the shorelines. Sea-level rise could directly affect the serviceability of urban structures and infrastructures of coastal regions; effects may include intrusion of salt water into drinking water resources, submergence of roads and railways, flowing of seawater into wastewater networks, and exacerbating land subsidence. These reasons have urged climate-change and infrastructure resilience researchers to focus on methods for prediction and prevention of SLR effects on urbanization systems. Most of the studies have concentrated on environmental aspects or modeling of flooding, however, there is a lack of research on behavior of urban lifelines for long-term planning. Hence, the resilience of coastal cities has become of more interest in recent years. This paper presents a meta- analysis and review of existing literatures on the impacts of SLR on civil infrastructure. We categorize these impacts based on different types of infrastructures (e.g. water, transportation, energy) and regions. The review provides i) an intensive coverage of the existing literature on adaptations ii) an exploration of current gaps and challenges in civil infrastructures in different regions of the world and iii) the engineering perspective of SLR besides managing directions to be useful for engineers, advisory committees, policy makers, and scholars for future studies.	68	2020	10.28991/cej-2020-03091555	
Pavement Infrastructure Sustainability Assessment: A Systematic Review	Acai, J; Amadi-Echendu, J	2018 PORTLAND INTERNATIONAL CONFERENCE ON MANAGEMENT OF ENGINEERING AND TECHNOLOGY (PICMET '18): MANAGING TECHNOLOGICAL ENTREPRENEURSHIP: THE ENGINE FOR ECONOMIC GROWTH	English	Proceedings Paper		LIFE-CYCLE ASSESSMENT; ULTRAFINE PARTICLES; SOCIAL SUSTAINABILITY; TRANSPORT INFRASTRUCTURES; WASTE MATERIALS; ADAPTATION; EXPOSURE; ASPHALT; GUIDE; PART	Road transport infrastructures are highly valuable assets designed for long period of use and play a major socioeconomic role. Conformity of road infrastructure development to the Triple Bottom Line (TBL) of sustainability requirements of social, economic and environmental has gained immense debate in the construction industry in recent years. The rapid population increase worldwide coupled with demand for services and widespread use of planet's finite resources has resulted to the generation of wastes associated with the construction, utilization, rehabilitation and reconstruction of pavement infrastructure raising great concern to stakeholders in the road transportation sub-sector because of the environmental impacts of the associated activities. However, attempts have been made to address sustainability considerations in the road infrastructure programs to meet both internal and external (environmental) sustainability, but most of this have been in Europe and America, leaving developing economies in Africa and Asia struggling with meeting the sustainability challenges. Tools and methodologies have been developed to evaluate sustainability of road infrastructures from the quantitative (life cycle assessments), qualitative (sustainability rating systems) and climate change perspective. Through a descriptive and exploratory approach, this paper delves into the documentary advancement in achieving sustainable development of road transport infrastructure.	68	2018		
Ecosystem services management: An evaluation of green adaptations for urban development in Dhaka, Bangladesh	Zinia, NJ; McShane, P	LANDSCAPE AND URBAN PLANNING	English	Article	Urban ecosystem services; Green adaptation; Climate change; Social acceptance; Economic feasibility; City		We evaluated green adaptation strategies (parks, gardens, green roof, rainwater harvest, green facades/wall, porous pavement, and green and blue belts) in the context of urban development and potential climate change impacts for the city of Dhaka, Bangladesh. Our review of relevant literature revealed substantial environmental (cooler and cleaner environment), economic (reduced energy demand, avoided cost of drainage maintenance, increased land values) and social (higher social interaction, improved mental and physical health) benefits arising from the maintenance and development of ecosystem services in major cities. Our evaluation of green adaptation strategies was undertaken with household surveys in three wards of Dhaka, expert interviews, and our personal experiences. Rooftop gardens/agriculture had very high social acceptance (85%) and economic feasibility and was commonly practiced in Dhaka, particularly among house owners. Pocket park, green roof, rainwater harvest, green facades/wall, porous pavement, and community garden were all considered to be highly feasible for implementation with collective efforts but had lower social acceptance. Many respondents were unwilling to pay for green adaptation strategies even knowing their benefits. Our research revealed that successful implementation of beneficial green adaptation will require public participation at all stages supported through awareness raising campaigns. Enforcement of laws and strong commitment from the government was also considered to be beneficial. However, more transparent cost-benefit analyses promoting the conservation of ecosystem services is required, particularly for resource-poor Dhaka. Green adaptations make cities more resilient to pressures from demographic change and climate change increasingly relevant in the developing world.	67	2018	10.1016/j.landurbplan.2018.01.008	
Integrated adaptive design for wildlife movement under climate change	Lister, NM; Brocki, M; Ament, R	FRONTIERS IN ECOLOGY AND THE ENVIRONMENT	English	Review		CHANGE ADAPTATION STRATEGIES; MITIGATION MEASURES; CROSSING STRUCTURES; RANGE SHIFTS; ROADS; MANAGEMENT; CONNECTIVITY; POPULATIONS; PERFORMANCE; RESPONSES	Climate change is anticipated to alter both wildlife movement and distributions. Despite mounting evidence that wildlife-crossing infrastructure offers a reliable, physical solution to the linked problems of wildlife road mortality and habitat fragmentation, pervasive barriers - from economic to governance structures - prevent the widespread introduction of an infrastructure network. To overcome these barriers, and to cope with the challenges posed by climate change, we argue that proactive, anticipatory planning and evidence-based, integrated highway-impact mitigation strategies are needed. Specifically, wildlife-crossing infrastructure should emphasize an integrated and adaptive approach to constructing innovative, modular, and potentially moveable structures that can be transferred from one location to another as monitoring of habitats and wildlife needs indicate. Continued investment in fixed, static structures, which are typically based on engineering standards designed for traffic loads rather than wildlife movement, may prove ineffectual as habitats change in composition and location, potentially leading to associated changes in the locations of wildlife-vehicle collisions.	67	2015	10.1890/150080	
Natural hazard experiences and adaptations: A study of winter climate-induced road closures in Norway	Jacobsen, JKS; Leiren, MD; Saarinen, J	NORSK GEOGRAFISK TIDSSKRIFT-NORWEGIAN JOURNAL OF GEOGRAPHY	English	Article	Kerstin Potthoff; Catriona Turner; accessibility; adaptation; community; lifeline; road closure	SOCIAL VULNERABILITY; ADAPTIVE CAPACITY; RISK; RESILIENCE; FRAMEWORK; WORRY	The effects of global climate change include more extreme weather events that harm lifeline infrastructure such as road access. The questionnaire-based study takes a novel natural experiment approach to subjective personal experiences and perceptions of lifeline vulnerability in two seaside communities in Norway that have been sporadically isolated due to avalanches, heavy snowfall, and/or snowdrifts. The enquiry aims at filling a research gap on sudden winter climate-induced disconnections and road travel hazards in advanced societies. The results show that weather-induced road closures lead to worries about road travel and practical problems, but also that many people are able to adjust to reduce their vulnerability. The authors concluded that community characteristics such as available services and social and human capital are important for understanding people's vulnerabilities, worries, and hazard preparedness.	67	2016	10.1080/00291951.2016.1238847	
Urban Green Infrastructure Impacts on Climate Regulation Services in Sydney, Australia	Lin, BB; Meyers, J; Beaty, RM; Barnett, GB	SUSTAINABILITY	English	Article	urban planning; land surface temperature; urban trees; remote sensing; climate change adaptation; urban cooling	EXTREME HEAT EVENTS; ECOSYSTEM SERVICES; RISK-FACTORS; SHADE TREES; CITIES; AREAS; ISLAND; SPACE; TEMPERATURE; GENERATION	In many parts of the world, urban planning has a renewed focus on addressing the multiple challenges associated with population growth and climate change. Focused on local needs and priorities, these planning processes are raising tensions between more compact and dense urban form to reduce energy use and associated emissions and the provision of urban green infrastructure for ecosystem services and climate adaptation. In this study, we investigated the spatial distribution of green infrastructure at the neighbourhood scale in Sydney, Australia and examined how a mix of landscape types (pavement, bare soil/dry grass, green grass, and tree cover) affect temperature variation in three important locations for urban residents-around the home, in the roads and footpaths where people walk, and in parkland areas. Considering that residential and parkland areas contribute to the majority of green space in Sydney, it is important to understand how changes in landscape mix within these three neighbourhood areas will affect local temperature for urban residents. For residential houses, it was found that the percentage of tree canopy cover around the house had a significant negative relationship ($p = 0.002$) with surface temperatures of rooftops where greater tree cover led to lower rooftop temperatures. In streetscapes, both the percentage of tree cover ($p < 0.0001$) and the percentage of green grass ($p < 0.0001$) within the road segment had a significant negative relationship with the surface temperature of the road pavement. In the parks, the percentage of pavement ($p < 0.0001$) and the percentage of bare soil/dry grass ($p < 0.0001$) showed a significantly positive trend with land surface temperatures where greater land cover in the form of pavement and bare soil/dry grass led to higher temperatures. Collectively, these findings highlight the importance of promoting or reducing certain landscape covers depending on the land use type in order to maximise the cooling potential of green infrastructure.	67	2016	10.3390/su8080788	
Incorporating Flood Hazards into Pavement Sustainability Assessment	Achebe, J; Oyedeji, O; Saari, RK; Tighe, S; Nasir, F	TRANSPORTATION RESEARCH RECORD	English	Article		CLIMATE-CHANGE; EMISSIONS; ADAPTATION; MITIGATION; BENEFITS; IMPACTS	The functional and structural performance of pavement infrastructures are at risk from climate change impacts. However, past sustainability assessment studies do not consider how the performance of infrastructure will be affected by a changing climate. The goal of this research is to investigate the impacts of flooding in a unified assessment of the resilience and sustainability of pavement. A case study of concrete pavement was evaluated for scenarios with and without flooding. The AASHTOWare Pavement ME design program was used to simulate the structural performance of typical jointed plain concrete pavement (JPCP) designs for collector roads in Canada. Predicted performance was used in the resilience and sustainability assessment under scenarios with and without flooding. The damage ratio and cost of damage were assessed to quantify the resilience of concrete pavement to floods. Life cycle costs and environmental impacts were compared across a climate change scenario with consideration of maintenance and rehabilitation activities. Results reveal that a typical Ontario JPCP design with structural slab thickness < 200 mm is less resilient than the Manitoba design for collector roads, but the 25 mm slab thickness difference in Manitoba design can lead to 50% change in damage ratio and damage cost. When estimating the social cost associated with greenhouse gas and air pollutant emissions, the additional environmental impact resulting from flooding for the Ontario road is almost seven times that of the Manitoba road. However, the life cycle economic cost and environmental impact do not yield an overal benefit with increased slab thickness.	66	2021	10.1177/03611981211015225	
Quantification of the environmental effectiveness of nature-based solutions for increasing the resilience of cities under climate change	Epelde, L; Mendizabal, M; Gutierrez, L; Artetxe, A; Garbisu, C; Feliu, E	URBAN FORESTRY & URBAN GREENING	English	Article	Adaptation; Biodiversity; Carbon capture; Flood control; Multi-benefit solutions; Thermal comfort	ECOLOGICAL NETWORKS; ECOSYSTEM SERVICES; GREEN; ADAPTATION; QUALITY; CONNECTIVITY; CONSERVATION; BIODIVERSITY; PERFORMANCE; PROTECTION	Nature-based solutions (NBSs) enhance the potential for mitigation and adaptation to climate change in cities. Among the environmental benefits offered by these measures, enhanced biodiversity, increased carbon storage, reduction of extreme temperatures, and pluvial flood control are crucial. The purpose of this study was to establish an integrated methodology for quantifying the benefits of NBSs and complementary measures and to apply it in a neighbourhood of Donostia-San Sebasti' an (Spain), where two alternative designs that incorporated NBSs and complementary measures were designed. Then, the individual effectiveness of the four variables was measured using both in-situ measurements and modelling approaches. For the integrated effectiveness, a multicriteria decision analysis was employed. Both the 'feasible' design and the 'ideal' one led to an increase in biodiversity (46 and 108 %, respectively) and carbon storage (50 and 130 %, respectively). When considering each measure independently, putting soil provided the highest benefits for carbon capture and biodiversity; meanwhile, planting woody species and installing light-coloured permeable pavements and water fountains reduced the mean radiant temperature by 26.5 K and the air temperature by 0.5 and 2.5 K, respectively, in specific places. Finally, the importance of quantifying the multiple environmental benefits of NBSs for the selection of climate-smart options in urban planning has been highlighted.	66	2022	10.1016/j.ufug.2021.127433	
Using Climate Models to Estimate Urban Vulnerability to Flash Floods	Kermanshah, A; Derrible, S; Berkelhammer, M	JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY	English	Article		UNITED-STATES; NETWORK; ROBUSTNESS; WEATHER; EVENTS; INFRASTRUCTURE; CENTRALITY; TRANSPORT; EXTREMES; IMPACTS	Climate change will impact urban infrastructure networks by changing precipitation patterns in a region. This study presents a novel vulnerability assessment framework for infrastructure networks against extreme rainfall-induced flash floods, with a specific application to transportation. The framework combines climate models, network science, geographical information systems (GIS), and stochastic modeling to compile a vulnerability surface (VS). Daily precipitation simulations for 2006-2100 from the Community Climate System Model, version 4 (CCSM4), are used to produce a stochastic simulation of extreme flash flood events in five U.S. cities-that is, Boston, Massachusetts; Houston, Texas; Miami, Florida; Oklahoma City, Oklahoma; and Philadelphia, Pennsylvania-under two different climate scenarios (RCP4.5 and RCP8.5). To assess the impact of these events, percentage drops in static (i.e., overall properties and robustness topological indicators) and dynamic (i.e., GIS accessibility and travel-demand metrics) network properties are measured before and after simulated extreme events. The results of these metrics are inputs on a radar chart to form a VS. Overall, the results show that changes in flash flood frequency due to climate change can have a significant impact on road networks, as was demonstrated recently in Houston, Texas. The magnitude of these impacts is chiefly associated with the geographic location of the cities and the size of the networks. The proposed framework can be reproduced in any city around the world, and researchers can use the results as guidelines for infrastructure design and planning purposes. Moreover, sensitivity analysis to varying greenhouse gas concentration trajectories can help local and national authorities to prioritize strategies for adaptation to climate change in more vulnerable regions.	66	2017	10.1175/JAMC-D-17-0083.1	
A review of the relation between climate variability and mass removal processes. Tunja-Paez case study	Barreto, LCL; Mesa, JKR	INGENIERIA SOLIDARIA	English	Review	Climate change; climate variability; mass removal; precipitation; roadway infrastructure; adaptation		This literature review paper is a product of the Research Project Relation Between Climate Variability with Mass Removal Processes. Tunja-Paez case study, developed in the Universidad PedagÓgica y TecnolÓgica de Colombia in the year 2020. Introduction: This paper focuses on the review of research studies and advances made during the last decade regarding the influence of climatic variability on the dynamics of slopes. Objective: To determine the influence of climatic variability in areas that present slope instability in the TunjaPaez road corridor located in the department of Boyaca. Methods: A systematic review of information from books, manuals, reports, guides, and scientific papers on climate change, climate variability, mass removal processes, meteorological variables, and their influence on the resilience and adaptation of infrastructure related to containment and slope drainage projects. Results: The studies indicate criteria that relate temperature, precipitation and seismic activity with the occurrence of mass movements. Conclusion: Climatic anomalies in terms of precipitation and temperature have allowed research methodologies using probabilistic models to be developed for estimating the occurrence of said phenomena in future scenarios. Originality: The presented literature indicates the influence of climatic variability in the resulting mass removal processes as evidenced in studies at the global and national level. Limitations: This paper's compiled scientific studies contrast the problems in the stability of slopes of the Tunja-Paez road corridor, without going into the details of these problems.	65	2021	10.16925/2357-6014.2021.01.03	
Assessing storm surge risk under future sea-level rise scenarios: a case study in the North Adriatic coast	Rizzi, J; Torresan, S; Zabeo, A; Critto, A; Tosoni, A; Tomasin, A; Marcomini, A	JOURNAL OF COASTAL CONSERVATION	English	Article	Storm surge; Climate change; Sea-level rise; Regional risk assessment; Joint probability method	CLIMATE-CHANGE; ASSESSMENT METHODOLOGY; NATURAL HAZARDS; FLOOD RISK; VULNERABILITY; SCALE; MAPS	Low-lying coastal areas are often prone to storm surge flooding that can render severe damages to properties, destruction of habitats, threat to human safety and the environment. The impacts of coastal flooding are also expected to increase in the future as a consequence of global climate change and sea-level rise. This paper presents a comprehensive assessment of the potential risks raised by storm surge and sea-level rise on multiple coastal targets (i.e., population, buildings, infrastructures, agriculture, natural and semi-natural environments and cultural heritage) in the Northern Adriatic coast in Italy. Through the assessment of hazard, exposure, vulnerability and risk, a Regional Risk Assessment (RRA) methodology allowed identifying and prioritizing hot-spot risk areas and targets requiring particular attention for the definition of adaptation strategies. Hazard scenarios were based on the analysis of tide gauge data (elaborated with the Joint Probability Method) and of different sea-level rise projections for the year 2100. Geographical-information analysis was then used to characterize vulnerability patterns of exposed natural and human systems and to make a spatial ranking of risks. Maps produced for the worst scenario showed that beaches are the target at higher risk (with more than 90% of the surface in the higher relative risk class) due to the low elevation and high proximity to the coastline. Also cultural heritage (i.e., villas, historical buildings and roads) and wetlands are highly threatened by storm surge flooding. The relative risks will be lower (i.e., between 25% and 40% of their surface/length in the higher relative risk class) for most of the other receptors (i.e., local roads, railways, natural and semi-natural environments and agricultural areas), including population and buildings that are mostly classified in lower risk classes. The overall results of the assessment, including maps and risk metrics, can be useful to rise the attention of coastal managers about the need to adapt to climate change, developing climate-proof policies and programs for the sustainable management of coastal zones.	65	2017	10.1007/s11852-017-0517-5	
Climate Mitigation and Adaptation Strategies for Roofs and Pavements: A Case Study at Sapienza University Campus	Battisti, A; Laureti, F; Zinzi, M; Volpicelli, G	SUSTAINABILITY	English	Article	permeable pavements; cool roofs; cool pavements; green roofs; urban heat island (UHI) mitigation; PET	URBAN HEAT-ISLAND; PHYSIOLOGICAL EQUIVALENT TEMPERATURE; OF-THE-ART; THERMAL COMFORT; GREEN ROOFS; BIOMETEOROLOGICAL ASSESSMENT; HIGH-ALBEDO; OUTDOOR; MICROCLIMATE; ENVIRONMENT	The progressively emerging concept of urban resilience to climate change highlights the importance of mitigation and adaptation measures, and the need to integrate urban climatology in the design process, in order to better understand the multiple effects of combined green and cool technologies for the transition to climate responsive and thermally comfortable urban open spaces. This study focuses the attention on selected mitigation and adaptation technologies; two renovation scenarios were designed and modeled according to the minimal intervention criterion. The study pays attention to the effect on surface temperature and physiological equivalent temperature (PET) of vegetation and high albedo materials characterizing the horizontal boundaries of the site. The Sapienza University campus, a historical site in Rome, is taken as a case study. These results highlight the importance of treed open spaces and the combination of permeable green pavements associated with cool roofs as the most effective strategy for the mitigation of summer heatwaves and the improvement of outdoor thermal comfort.	65	2018	10.3390/su10103788	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Evaluation of the health-risk reduction potential of countermeasures to urban heat islands	Buchin, O; Hoelscher, MT; Meier, F; Nehls, T; Ziegler, F	ENERGY AND BUILDINGS	English	Article; Proceedings Paper	Risk analysis; Heat wave; Heat-related risks; Heat stress; Cool roof; Cool pavement; Urban green; Passive building design; Air-conditioning	US CITIES; MITIGATION MEASURES; AIR-TEMPERATURE; COOL ROOFS; NEW-YORK; MORTALITY; IMPACTS; GREEN; VULNERABILITY; GERMANY	Traditional assessment of heat-related health risks neglects the influence of the building physics as outdoor conditions are used as predictor variables. Data on heat-related mortality from Berlin, Germany and from the US are evaluated with a risk concept which differentiates between outdoor and indoor hazards. Such, the influence of non-linear building physics on heat-related risks can be considered and the impact of adaptation strategies can be examined. The number of heat-related deaths in the age-group 65+ for Berlin is expected to double with each 1 K increase in ambient temperature. It can be reduced by 50% with a mean ambient air-temperature reduction of 0.8 K. Countermeasures to urban heat islands are evaluated according to their reduction potential on hazards, both indoors and outdoors. The analysis shows that classic UHI countermeasures, which are effective in reducing air-temperatures outdoors, do not necessarily reduce the indoor hazard. Regarding indoor heat-related hazards, trees, facade and roof greening, cool roofs and cool pavements have a low impact only. Measures at the building level, namely cool roofs and facade greening perform best, however, passive cooling and air-conditioning are most effective. To reduce the number of excess deaths in a changing climate, combined measures are necessary. (C) 2015 Elsevier B.V. All rights reserved.	65	2016	10.1016/j.enbuild.2015.06.038	
A Numerical Study on Mitigation Strategies of Urban Heat Islands in a Tropical Megacity: A Case Study in Kaohsiung City, Taiwan	Huang, JM; Chen, LC	SUSTAINABILITY	English	Article	urban heat island (UHI); permeable pavement; greening; Envi-met; block-scale	GREEN INFRASTRUCTURE; THERMAL ENVIRONMENT; CLIMATE; TEMPERATURE; VEGETATION; IMPACT; AIR; CONFIGURATION; MICROCLIMATE; ADAPTATION	In recent years, with the rapid increase in global warming and urbanization, urban heat island effects (UHI) have become an important environmental issue. Taiwan is no exception, with previous studies demonstrating serious UHIs in megacities. Although existing UHI research has utilized computer simulations to analyze improvement scenarios, there are few cooling strategy studies in actual blocks of Taiwan. Therefore, this study selected a block of a megacity in a tropical region of Taiwan as a case study by ENVI-met. Five improvement strategies were tested and compared to the current situation (B0): (1) Case C1 changed to permeable pavement, (2) Case C2 increased the green coverage ratio (GCR) of the street to 60%, (3) Case C3 changed to permeable pavement and increased the GCR in the street to 60%, (4) Case C4 changed to permeable pavement, increased the GCR in the street to 60%, and increased the GCR in the parks to 80%, and (5) Case C5 changed to permeable pavement, increased GCR in the street to 60% and parks to 80%, and set the GCR on the roof of public buildings to 100%. The results showed that the average temperature of the current thermal environment is 36.0 degrees C, with the comfort level described as very hot. Among the five improvement schemes, C5 had the greatest effect, cooling the area by an average of 2.00 degrees C. Further analysis of the relationship between the different GCRs of streets (SGCR) and the cooling effects revealed that for every 10% increase in the SGCR, the temperature of the pedestrian layer was reduced by 0.15 degrees C.	64	2020	10.3390/su12103952	
Forecasting riverine erosion hazards to electricity transmission towers under increasing flow magnitudes	[Anonymous]	CLIMATE RISK MANAGEMENT	English	Article	Erosion hazard; Critical infrastructure; River channel change; Electricity transmission towers; Flow magnitude scenarios	CRITICAL INFRASTRUCTURE; CELLULAR-MODEL; CLIMATE-CHANGE; UPLAND RIVER; VALIDATION; IMPACT; FLOODS	Flooding and erosion will pose increasing challenges to urban settlements and critical infrastructure, such as roads and power grids in the future. Improved projections on the impact of climate change to critical infrastructure are essential to assist future planning. This paper uses hydro-sedimentary modelling to predict river erosion threats to electricity transmission infrastructure in an urbanised river valley under multiple increasing flow magnitude scenarios. We use a coupled hydrodynamic and landscape evolution model, CAESAR-Lisflood, to simulate river channel changes along a reach of the River Mersey, UK from the present day to 2050. A range of synthetic flow scenarios, based on recent hydrological records, was used in the model ranging from 'no change' up to a flow with 50% higher magnitude. The results revealed: (1) riverbank erosion will pose significant threats to several transmission towers located along the river, requiring intervention to avoid destabilisation by the moving channel; (2) the total area of floodplain erosion and deposition >= 0.5 m deep was positively related to increasing projected flow magnitudes. However, through running a 'low' and 'high' erosion version of the model, the simulations revealed these threats were most sensitive to the calibration of the erosion component of the model, illustrating the challenges and uncertainty in forecasting long-term river channel change; and (3) how long-term simulations can assist in adaptation planning for electricity transmission towers. Further reach- and catchment-scale modelling will be necessary to determine the timings of large floods more accurately, which produce the most significant erosion and deposition events, and to evaluate the efficacy of protections to transmission towers.	63	2022	10.1016/j.crm.2022.100439	
Assessment of climate change adaptation costs for the U.S. road network	Chinowsky P.S., Price J.C., Neumann J.E.	Global Environmental Change	English	Article	Degradation; Economic impact; Infrastructure; Roads	climate change; economic impact; environmental economics; maintenance; road construction; temporal period; United States	The U.S. road network is one of the nation's most important capital assets and is vital to the functioning of the U.S. economy. Maintaining this asset involves approximately $134 billion of government funds annually from Federal, State, and local agencies. Climate change may represent a risk or an opportunity to this network, as changes in climate stress will affect the resources necessary for both road maintenance and construction projects. This paper develops an approach for estimating climate-related changes in road maintenance and construction costs such that the current level of service provided by roads is maintained over time. We estimate these costs under a baseline scenario in which annual mean global temperature increases by 1.5 °C in 2050 relative to the historical average and a mitigation scenario under which this increase in mean temperature is limited to 1.0 °C. Depending on the nature of the changes in climate that occur in a given area, our analysis suggests that climate change may lead to a reduction in road maintenance and/or construction costs or an increase in costs. Overall, however, our analysis shows that climate change, if unchecked, will increase the annual costs of keeping paved and unpaved roads in service by $785 million in present value terms by 2050. When not discounted, this figure increases to $2.8 billion. Policies to reduce greenhouse gas emissions are estimated to reduce these costs by approximately $280 million in present value terms and by $885 million when not discounted. These costs vary substantially by region and time period, information that should be important for transportation planners at the national, state, and local levels. © 2013 Elsevier Ltd.	62	2013	10.1016/j.gloenvcha.2013.03.004	
Climate change damages to Alaska public infrastructure and the economics of proactive adaptation	Melvin, AM; Larsen, P; Boehlert, B; Neumann, JE; Chinowsky, P; Espinet, X; Martinich, J; Baumann, MS; Rennels, L; Bothner, A; Nicolsky, DJ; Marchenko, SS	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	English	Article	Alaska; climate change; damages; adaptation; infrastructure	THAW SETTLEMENT; COASTAL-PLAIN; ACTIVE LAYER; FIRE REGIME; PERMAFROST; VULNERABILITY; ROADS; IMPACTS; HAZARD; COSTS	Climate change in the circumpolar region is causing dramatic environmental change that is increasing the vulnerability of infrastructure. We quantified the economic impacts of climate change on Alaska public infrastructure under relatively high and low climate forcing scenarios [representative concentration pathway 8.5 (RCP8.5) and RCP4.5] using an infrastructure model modified to account for unique climate impacts at northern latitudes, including near-surface permafrost thaw. Additionally, we evaluated how proactive adaptation influenced economic impacts on select infrastructure types and developed first-order estimates of potential land losses associated with coastal erosion and lengthening of the coastal ice-free season for 12 communities. Cumulative estimated expenses from climate-related damage to infrastructure without adaptation measures (hereafter damages) from 2015 to 2099 totaled $5.5 billion (2015 dollars, 3% discount) for RCP8.5 and $4.2 billion for RCP4.5, suggesting that reducing greenhouse gas emissions could lessen damages by $1.3 billion this century. The distribution of damages varied across the state, with the largest damages projected for the interior and southcentral Alaska. The largest source of damages was road flooding caused by increased precipitation followed by damages to buildings associated with near-surface permafrost thaw. Smaller damages were observed for airports, railroads, and pipelines. Proactive adaptation reduced total projected cumulative expenditures to $2.9 billion for RCP8.5 and $2.3 billion for RCP4.5. For road flooding, adaptation provided an annual savings of 80-100% across four study eras. For nearly all infrastructure types and time periods evaluated, damages and adaptation costs were larger for RCP8.5 than RCP4.5. Estimated coastal erosion losses were also larger for RCP8.5.	62	2017	10.1073/pnas.1611056113	
Flood probability quantification for road infrastructure: Data-driven spatial-statistical approach and case study applications	Kalantari, Z; Cavalli, M; Cantone, C; Crema, S; Destouni, G	SCIENCE OF THE TOTAL ENVIRONMENT	English	Article	Sediment connectivity; Climate change adaptation; GIS; Multivariate statistical model; Decision making	LEAST-SQUARES REGRESSION; SEDIMENT CONNECTIVITY; NATURAL HAZARDS; CATCHMENT-SCALE; AIRBORNE LIDAR; SOIL-EROSION; FRAMEWORK; SYSTEMS; MODEL; MORPHOLOGY	Climate-driven increase in the frequency of extreme hydrological events is expected to impose greater strain on the built environment and major transport infrastructure, such as roads and railways. This study develops a data driven spatial-statistical approach to quantifying and mapping the probability of flooding at critical road-stream intersection locations, where water flow and sediment transport may accumulate and cause serious road damage. The approach is based on novel integration of key watershed and road characteristics, including also measures of sediment connectivity. The approach is concretely applied to and quantified for two specific study case examples in southwest Sweden, with documented road flooding effects of recorded extreme rainfall. The novel contributions of this study in combining a sediment connectivity account with that of soil type, land use, spatial precipitation-runoff variability and road drainage in catchments, and in extending the connectivity measure use for different types of catchments, improve the accuracy of model results for road flood probability. (C) 2016 Elsevier B.V. All rights reserved.	62	2017	10.1016/j.scitotenv.2016.12.147	
Incorporating the impacts of climate change into infrastructure life cycle assessments: A case study of pavement service life performance	Guest, G; Zhang, JY; Maadani, O; Shirkhani, H	JOURNAL OF INDUSTRIAL ECOLOGY	English	Article	adaptation; climate change; flexible pavement; framework; industrial ecology; life cycle assessment	SCENARIOS; LCA; TEMPERATURE; CARBONATION; CONTEXT; BRIDGES; ALBEDO	Climate change is expected to impact both the operational and structural performance of infrastructures such as roads, bridges, and buildings. However, most past life cycle assessment (LCA) studies do not consider how the operational/structural performance of infrastructure will be affected by a changing climate. The goal of this research was to develop a framework for integrating climate change impacts into LCA of infrastructure systems. To illustrate this framework, a flexible pavement case study was considered where life-cycle environmental impacts were compared across a climate change scenario and several time horizons. The Mechanistic-Empirical Pavement Design Guide (MEPDG) was utilized to capture the structural performance of each pavement performance scenario and performance distresses were used as inputs into a pavement LCA model that considered construction and maintenance/rehabilitation materials and activities, change in relative surface albedo, and impacts due to traffic. The results from the case study suggest that climate change will likely alter the optimal design requirements in the latter half of this century but in the near-to-mid term, the international roughness index (IRI) and total rutting degradation profile was very close to the historical climate run. While the inclusion of mechanistic performance models with climate change data as input introduces new uncertainties to infrastructure-based LCA, sensitivity analyses runs were performed to better understand a comprehensive range of result outcomes. Through further infrastructure cases the framework could be streamlined to better suit specific infrastructures where only the infrastructure components with the greatest sensitivity to climate change are explicitly modeled using mechanistic-empirical modeling routines.	61	2020	10.1111/jiec.12915	
DO SOCIO ECONOMIC CHARACTERISTICS OF FARMING COMMUNITY REALLY MATTER FOR THE ADOPTION OF CLIMATE CHANGE STRATEGIES? A CASE STUDY OF CENTRAL PUNJAB, PAKISTAN	Shahbaz, P; Boz, I; ul Haq, S	FRESENIUS ENVIRONMENTAL BULLETIN	English	Article	Climate change; adoption; adaptation strategies; Perception; agriculture; Punjab	MANAGEMENT TECHNOLOGIES; SMALLHOLDER FARMERS; PROGRAMS EVIDENCE; ADAPTATION; DETERMINANTS; LEVEL; AREA; VULNERABILITY; AGRICULTURE; PERCEPTIONS	Agriculture sector is vital to ensure global food security and eradicate poverty in rural areas but climate change poses a great threat to this sector especially in developing countries due to lower adaptive capacity of farming community in these countries. Farming community can minimize the impact of climate change on agriculture by adopting climate change strategies at their farms. Therefore, this study analyzed how farmers perceive climate change, which strategies they adopt to minimize the impact of climate change at their farms, and the influential factors affecting the adoption of these strategies. For this purpose, cross sectional data of 195 farmers selected through multi stage purposive and random sampling techniques were collected in a face to face survey and multiple linear regression analysis was used to determine the factors affecting adoption of climate change strategies. Climate change is no more a mystery for the farmers and farming community perceive this variability very well. Majority of the farmers perceived an increase in both summer as well as winter temperatures. Farming community in the area was adopting conventional climate change strategies such as changing in crop cultivation dates, new crop varieties, crop diversification, mix farming, and intensified use of chemicals at their farms in order to minimize the climate changes. Adoption of climate change strategies at farm level was influenced by schooling years, age, machinery ownership, market distance, agricultural labor force, extension services and total land of the farmers. Therefore, extension services, and improving road infrastructure to enhance market access are essential to increase adoption of climate change strategies among farmers.	60	2021		
Energy infrastructure in India: Profile and risks under climate change	Garg, A; Naswa, P; Shukla, PR	ENERGY POLICY	English	Article	Energy infrastructure; Reverse impact; Vulnerability index	RESOLUTION; ECONOMICS; SECURITY	India has committed large investments to energy infrastructure assets-power plants, refineries, energy ports, pipelines, roads, railways, etc. The coastal infrastructure being developed to meet the rising energy imports is vulnerable to climate extremes. This paper provides an overview of climate risks to energy infrastructures in India and details two case studies - a crude oil importing port and a western coast railway transporting coal. The climate vulnerability of the port has been mapped using an index while that of the railway has been done through a damage function for RCP 4.5.0 and 8.5 scenarios. Our analysis shows that risk management through adaptation is likely to be very expensive. The system risks can be even greater and might adversely affect energy security and access objectives. Aligning, sustainable development and climate adaptation measures can deliver substantial co-benefits. The key policy recommendations include: i) mandatory vulnerability assessment to future climate risks for energy infrastructures; ii) project and systemic risks in the vulnerability index; iii) adaptation funds for unmitigated climate risks; iv) continuous monitoring of climatic parameters and implementation of adaptation measures, and iv) sustainability actions along energy infrastructures that enhance climate resilience and simultaneously deliver co-benefits to local agents. (C) 2014 Elsevier Ltd. All rights reserved.	60	2015	10.1016/j.enpol.2014.12.007	
Nature-Based Resilience: A Multi-Type Evaluation of Productive Green Infrastructure in Agricultural Settings in Ontario, Canada	Anderson, V; Gough, WA	ATMOSPHERE	English	Article	green roofs; urban agriculture; tree-based intercropping; agroforestry; food security	AIR-POLLUTION REMOVAL; CARBON SEQUESTRATION; SOUTHERN ONTARIO; URBAN VEGETATION; NITROGEN-DIOXIDE; CLIMATE-CHANGE; SURFACE OZONE; HEAT-WAVE; OPEN-ROAD; QUALITY	Nature-based solutions such as green infrastructure present an opportunity to reduce air pollutant concentrations and greenhouse gas emissions. This paper presents new findings from a controlled field study in Ontario, Canada, evaluating the impact of productive applications of green infrastructure on air pollution and carbon dioxide concentrations across different agricultural morphologies compared to other non-productive applications. This study demonstrates that productive green infrastructure applications are as beneficial as non-productive applications in reducing ozone, nitrogen dioxide, and carbon dioxide concentrations. Nature-based solutions present an opportunity to build climate resilience into agricultural systems through supply-side mitigation and adaptation. The implementation of productive green infrastructure could be a viable agricultural practice to address multiple climate change impacts.	60	2021	10.3390/atmos12091183	
Prediction of Flexible Pavement Deterioration in Relation to Climate Change Using Fuzzy Logic	Jeong, H; Kim, H; Kim, K; Kim, H	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Adaptation; Climate change; Flexible pavement; Fuzzy logic; Infrastructure	PERFORMANCE	An understanding of the impacts of climate change on infrastructure is important in the context of reducing future socioeconomic losses. Previous research has introduced models based on empirical and mechanical analyses to predict the behavior of infrastructure considering climate change. However, the uncertainty and unavailability of information regarding climate change prevent the widespread use of these previous models. This paper presents a method for developing a climate impact-assessment system using fuzzy inferences to predict the alteration of infrastructure service life. Fuzzy inferences enable an understanding of the impacts of climate on infrastructure, with expert knowledge reflecting the interactions between multiple environmental factors. Based on the proposed method, the impacts of climate change on infrastructure can be analyzed by obtaining an expected service life with respect to various climate scenarios. A case study was conducted on a flexible pavement road in Alabama to show the applicability and utility of the method. The proposed method is expected to improve infrastructure management and planning practices, establishing proactive adaptation strategies to minimize additional infrastructure expenditure and damage. (c) 2017 American Society of Civil Engineers.	60	2017	10.1061/(ASCE)IS.1943-555X.0000363	
The potential of green infrastructure application in urban runoff control for land use planning: A preliminary evaluation from a southern Italy case study	Pappalardo, V; La Rosa, D; Campisano, A; La Greca, P	ECOSYSTEM SERVICES	English	Article	Run-off control; Sustainable Urban drainage systems; Urban planning; Urban flooding	FLOOD RISK-MANAGEMENT; CLIMATE-CHANGE; HUMAN HEALTH; ADAPTATION; ECOSYSTEM; DRAINAGE; SYSTEMS; DESIGN; POLICY; AREAS	Among the approaches for run-off regulation, green infrastructure is identified as non-traditional measure to compensate the effects of soil sealing generated from urban development. It is recognized as a way to increase the provision of urban ecosystem services and is increasingly being used in research and practice on storm-water management through Sustainable Urban Drainage Systems (SUDS). The adoption of SUDS in urban planning might protect hydrological and ecological dimensions of landscapes while providing resilient options to face flood risk management. This paper shows the assessment of SUDS potential to increase the regulating service capacity in a dense urban catchment in southern Italy. A comparison between scenarios of pre-implementation and post-implementation of SUDS is performed through catchment simulations with a hydraulic model. Results showed different effectiveness of SUDS options, in terms of variations of the indicator chosen as proxy of the regulating service capacity. Results showed a better performance obtained by green roofs than permeable pavements, highlighting a limited capacity of run-off regulation achieved with SUDS deployment in public areas only. This suggests that innovative policies to encourage private land owners to adopt measures of SUDS could be fundamental for the retrofitting of urban settlements.	60	2017	10.1016/j.ecoser.2017.04.015	
Translating Uncertain Sea Level Projections Into Infrastructure Impacts Using a Bayesian Framework	Moftakhari, H; AghaKouchak, A; Sanders, BF; Matthew, RA; Mazdiyasni, O	GEOPHYSICAL RESEARCH LETTERS	English	Article		CLIMATE-CHANGE ADAPTATION; DISASTER RISK REDUCTION; FLOOD RISK; COASTAL; VULNERABILITY; 21ST-CENTURY; EXPOSURE; EXTREMES; PACIFIC; COMMUNICATION	Climate change may affect ocean-driven coastal flooding regimes by both raising the mean sea level (msl) and altering ocean-atmosphere interactions. For reliable projections of coastal flood risk, information provided by different climate models must be considered in addition to associated uncertainties. In this paper, we propose a framework to project future coastal water levels and quantify the resulting flooding hazard to infrastructure. We use Bayesian Model Averaging to generate a weighted ensemble of storm surge predictions from eight climate models for two coastal counties in California. The resulting ensembles combined with msl projections, and predicted astronomical tides are then used to quantify changes in the likelihood of road flooding under representative concentration pathways 4.5 and 8.5 in the near-future (1998-2063) and mid-future (2018-2083). The results show that road flooding rates will be significantly higher in the near-future and mid-future compared to the recent past (1950-2015) if adaptation measures are not implemented.	60	2017	10.1002/2017GL076116	
Adapting rail and road networks to weather extremes: case studies for southern Germany and Austria	Doll, C; Trinks, C; Sedlacek, N; Pelikan, V; Comes, T; Schultmann, F	NATURAL HAZARDS	English	Article	Road networks; Railway operations; Extreme weather events; Climate change; Adaptation; Weather information systems; Investments; Forecasts	CLIMATE-CHANGE; TRANSPORTATION; EVENTS	The assessment of the current impacts of extreme weather conditions on transport systems reveals high costs in specific locations. Prominent examples for Europe are the economic consequences of the harsh winter periods 2009/2010 and 2010/2011 and the floods in Austria, Eastern Europe, Germany and the United Kingdom in 2005 and 2007. Departing from the EC-funded project WEATHER, this paper delves into the subject of adaptation strategies by revisiting the project's general findings on adaptation strategies and by adding two specific cases: (1) advanced winter maintenance on roads in southwest Germany and (2) technical and organizational measures in Alpine rail transport. For these two cases, feasible adaptation strategies are elaborated and their potential is discussed in light of damage cost forecasts up to 2050. For the road sector, we find a high potential to mitigate weather-related costs, although damages here are expected to decline. In contrast, rail systems face strongly increasing damages and the mitigation options offered by improved information and communication systems seem to be largely exploited. Consequently, it is easier to justify expensive adaptation measures for high-cost rail infrastructures than for road transport. A generic analysis of 14 damage cases worldwide, however, revealed that generally awareness raising, cooperation and communication strategies are sufficient to mitigate the most severe damages by natural disasters.	59	2014	10.1007/s11069-013-0969-3	
Developing Green Infrastructure Strategies Based on the Analysis of Sewer System Critical Components	Shen, C; Xia, HS; Fu, X; Wang, XH; Wang, WP	WATER	English	Article	green infrastructure; grey infrastructure; sewer system behaviour; stormwater management; urban inundation	LOW IMPACT DEVELOPMENT; CLIMATE-CHANGE; RUNOFF; PERFORMANCE; MODEL; SIMULATION; MITIGATION	Flooding has presented a significant risk for urban areas around the world. Road inundation is one of the severe consequences leading to traffic issues and congestion. Green infrastructure (GI) offers further potential for stormwater management as an environmentally friendly and sustainable solution. However, sewer system behaviour has been overlooked in GI implementation. This study investigates sewer performance by measuring topological connectivity and hydraulic characteristics, and critical components are identified under different design storms. Three retrofit scenarios, including enlarged pipes (grey infrastructure, Grey I), rain gardens (GI), and the combination of enlarged pipes and increased rain gardens (GI + Grey I), are proposed according to the distribution of critical components. The results show that it is feasible to locate the vulnerable parts of the sewer system and GI site allocations based on the critical components that significantly impact the performance of the entire system. While all three scenarios can mitigate inundation, GI and GI + Grey I perform better than pipe enlargement, especially for runoff reduction during long-duration rainfall. Furthermore, the sewer behaviour and retrofit effect are dynamic under different rainfall patterns, leading to diverse combined effects. The discoveries reveal that the adaptation measures should combine with sewer behaviour and local rainfall characteristics to enhance stormwater management.	59	2021	10.3390/w13192694	
Understanding Interdependent Climate Change Risks Using a Serious Game	Undorf, S; Tett, SFB; Hagg, J; Metzger, MJ; Wilson, C; Edmond, G; Jacques-Turner, M; Forrest, S; Shoote, M	BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY	English	Article		ATTRIBUTION	Anthropogenic climate change calls for rapid and enormous cuts in emissions of CO2 and other greenhouse gases to mitigate future impacts. Even with these, however, many changes will continue to occur over the next 20-30 years adding to those already observed. Adaptation is crucial and urgent, but identifying strategies is complex and requires dialogue and cooperation among stakeholders, especially for infrastructure that exhibits interdependent risks in that failure in one type may impact others. A serious game was codeveloped with infrastructure operators to communicate climate projections and climate hazards to them; identify potential interdependencies, cascading impacts, cumulative effects, and vulnerability hot spots; and engage them to improve cooperation and enable a shared understanding of cross-cutting climate risks and interdependencies. In the game, players provide present-day infrastructure services in the Inverclyde district, Scotland, as they experience a plausible decade of 2050s weather characterized by a sequence of hazard events. This sequence was extracted from climate model projections to ensure scientific plausibility. The infrastructure operators were responsible for drinking water and gas supplies, road and rail transport, wastewater treatment, and civil infrastructure. When playing the game the participating U.K. infrastructure providers felt that although there were challenges, they could cope with 2050s climate change. None of the projected hazard events were anticipated to cause catastrophic impact cascades on infrastructure. The game was positively received, and the study suggests it is a useful tool to both communicate climate hazards and explore potential interdependent risks by bringing together stakeholders' individual expertise in an engaging way.	59	2020	10.1175/BAMS-D-19-0177.1	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed	Mei, C; Liu, JH; Wang, H; Yang, ZY; Ding, XY; Shao, WW	SCIENCE OF THE TOTAL ENVIRONMENT	English	Article	Urban flood; Storm water management model; Life cycle cost analysis; Cost-effectiveness; Low impact development; Urbanization	LOW IMPACT DEVELOPMENT; ASSESSING COST-EFFECTIVENESS; CLIMATE-CHANGE; LAND-USE; ADAPTATION PATHWAYS; MANAGEMENT; STORMWATER; INUNDATION; SYSTEM; BMPS	Green infrastructure (GI) has become increasingly important in urban stormwater management because of the effects of climate change and urbanization. To mitigate severe urban water-related problems, China is implementing GI at the national scale under its Sponge City Program(SCP). The SCP is currently in a pilot period, however, little attention has been paid to the cost-effectiveness of GI implementation in China. In this study, an evaluation framework based on the Storm Water Management Model (SWMM) and life cycle cost analysis (LCCA) was applied to undertake integrated assessments of the development of GI for flood mitigation, to support robust decision making regarding sponge city construction in urbanized watersheds. A baseline scenario and 15 GI scenarios under six design rainfall events with recurrence intervals ranging from 2-100 years were simulated and assessed. Model simulation results confirmed the effectiveness of GI for flood mitigation. Nevertheless, even under the most beneficial scenario, the results showed the hydrological performance of GI was incapable of eliminating flooding. Analysis indicated the bioretention cell (BC) plus vegetated swale (VS) scenario was the most cost-effective GI option for unit investment under all rainfall events. However, regarding the maximum potential of the implementation areas of all GI scenarios, the porous pavement plus BC + VS strategy was considered most reasonable for the study area. Although the optimal combinations are influenced by uncertainties in both the model and the GI parameters, the main trends and key insights derived remain unaffected; therefore, the conclusions are relevant regarding sponge city construction within the study area. (C) 2018 Elsevier B.V. All rights reserved.	58	2018	10.1016/j.scitotenv.2018.05.199	
Mapping Natural Hazard Impacts on Road Infrastructure-The Extreme Precipitation in Baden-Wurttemberg, Germany, June 2013	Keller, S; Atzl, A	INTERNATIONAL JOURNAL OF DISASTER RISK SCIENCE	English	Article	Extreme precipitation; Floods; Germany; Hazard patterns; Landslides; Road infrastructure	GEOMORPHOLOGY; GIS	Infrastructures in Europe have been affected by impacts of extreme natural events with increasing frequency over the past decades. One of the most recent examples is the flooding that affected parts of Germany in June 2013. Global warming is expected to change patterns of climate-related extreme events affecting infrastructure. This article presents an explanatory approach. Based on an observational design, causal connections between the occurrence and patterns of extreme events and related road infrastructure impacts are analyzed. The hazard mapping case study in the state of Baden-Wurttemberg combines traffic information and data on the June 2013 extreme precipitation in Germany. It examines the precipitation occurrence and road infrastructure impact characteristics in Baden-Wurttemberg and identifies spatiotemporal hazard patterns. The article suggests further research needs and fields of application for risk mapping in climate change adaptation research in Germany.	58	2014	10.1007/s13753-014-0026-1	
Water, Sanitation, and Hygiene Vulnerability among Rural Areas and Small Towns in South Africa: Exploring the Role of Climate Change, Marginalization, and Inequality	Abrams, AL; Carden, K; Teta, C; Wagsaether, K	WATER	English	Article	adaptation; developing countries; resilience; WASH; drainage; water quality; drought; vulnerability	ACCESS; KAROO	Access to water, sanitation, and hygiene (WASH)-including drainage-services-is essential for public health and socio-economic development, but access remains inadequate and inequitable in low- to middle-income countries such as South Africa. In South Africa, rural areas and small towns generally depend on a limited and climate-sensitive economic base (e.g., farming), and they have a limited capacity and are located in areas where transport challenges can increase WASH access risks. Climate change shifts hydrological cycles, which can worsen WASH access and increase susceptibility to the interlinked impacts of droughts and flooding in already vulnerable regions. We adopted a transdisciplinary approach to explore the needs, barriers, and vulnerabilities with respect to WASH in rural areas and small towns in South Africa-using two case studies to explore climate risk and vulnerability assessment (CRVA) in one rural village in the northern Limpopo province and a small town in the Western Cape province. This holistic approach considered natural (environment and climate) and socio-economic (economic, social, governance, and political) factors and how they interplay in hampering access to WASH. Extreme weather events characterized by frequent and intense droughts or floods aggravate surface and groundwater availability and damage water infrastructure while threatening agriculture-dependent livelihoods. The lack of reliable transport infrastructure increases risks posed by flooding as roads to vital supplies are prone to damage. High inequality linked to rising unemployment and the Apartheid legacy of a segregated service delivery system result in inequitable access to WASH services. The intertwined ways in which natural elements and historical, social, economic, governance, and policy aspects are changing in South Africa increase WASH vulnerability in rural areas and small towns.</p>	58	2021	10.3390/w13202810	
Effectiveness of cool walls on cooling load and urban temperature in a tropical climate	Nazarian, N; Dumas, N; Kleissl, J; Norford, L	ENERGY AND BUILDINGS	English	Article	Cool walls; Reflective surfaces; Building energy use; Urban heat island; Urban design	ENERGY-BALANCE MODEL; HEAT-ISLAND; REFLECTIVE MATERIALS; AIR-TEMPERATURE; IMPACTS; ROOF; PAVEMENTS; PERFORMANCE; BUILDINGS; COATINGS	The urban overheating, driven by the increasing expansion of our cities and the global climate change, is becoming one of the main environmental challenges of today. Consequently, cooling technologies are emerging as mitigation and adaptation strategies. Reflective roof and pavement surfaces have been widely studied for their potential benefits, but detailed evaluations of the effect of wall albedo on the urban microclimate are limited. This study addresses this gap by evaluating the effects of reflective walls on urban energy use and outdoor climate. The energy balance of an idealized neighborhood is represented using a 3D numerical model, Temperature of Urban Facets Indoor-Outdoor Building Energy Simulator (TUF-IOBES), which determines the cooling loads and outdoor air temperature. The study focuses on the tropical climate of Singapore, addressing the urban climate in highly-populated cities in low latitudes that are significantly affected by the UHI. Simulations are conducted for two neighborhoods representative of low-rise residential and high-rise commercial urban areas, spanning a range of urban density, canyon geometry, building construction, and occupant schedules. The building thermal load and outdoor temperature are then calculated for these two idealized neighborhoods, analyzing the effectiveness of cool walls while also considering the role of other design factors such as window-to-wall ratio (WWR) and glazing solar heat gain coefficient (SHGC) in modulating the impact. Unlike the analysis of cool roofs, we find that a universal conclusion regarding the impact of cool walls cannot be drawn. The role of wall albedo significantly depends on the collective design of urban areas as well as the use and occupancy of buildings. We find that urban density (in other words the local climate zone) followed by window properties are important factors in determining the impact of wall albedo on thermal loads and UHI, as they determine the radiative exchange between and into the buildings. Accordingly, contrary to the general expectation, for a high urban density (commercial neighborhood (CZ6) and high WWR and SHGC, we observe that cool (reflective) walls can increase the building energy use. Regarding UHI, increasing the reflectivity of walls decreases the canopy air temperature but the impact is marginal (similar to 0.1 degrees C) compared to other urban design parameters. (C) 2019 Elsevier B.V. All rights reserved.	57	2019	10.1016/j.enbuild.2019.01.022	
Modeling Cost Impacts and Adaptation of Freeze-Thaw Climate Change on a Porous Asphalt Road Network	Kwiatkowski, KP; Oslakovic, IS; ter Maat, H; Hartmann, A; Chinowsky, P; Dewulf, GPMR	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Climate change; Adaptation; Porous asphalt; Freeze-thaw; Roads; Planning	NETHERLANDS; CYCLES; BUDGET	Changes in weather patterns pose a threat to the serviceability and long-term performance of roads, and porous asphalt (PA) roads are particularly sensitive to the freezing-thawing (FT) phenomenon. The main objective of this research is to assess the impact of climate change, particularly freezing and thawing cycles, on PA. Climate models predict changes in air temperature, not pavement temperature. To predict the climate change impact on pavements performance, this requires first establishing a relationship between air and road temperature and a correlation between pavement performance and FT cycles. This project focuses on the Netherlands, where PA pavement use has become mandatory, and recent severe winters have increased the discussion about the cold weather performance of porous asphalt and the potential challenges of changing winter weather patterns. When considering long-term changes in climate, the cost impacts of freeze-thaw on PA pavement are predicted to vary regionally and in most areas reach a point in the middle of the century when a reactive wait-and-see approach is more advantageous than proactive adaptation. Further research is suggested to refine the relationship between observed damage and freeze-thaw impacts on PA pavement.	57	2020	10.1061/(ASCE)IS.1943-555X.0000559	
Role of watering practices in large-scale urban planning strategies to face the heat-wave risk in future climate	Daniel, M; Lemonsu, A; Viguie, V	URBAN CLIMATE	English	Article	Irrigation; Pavement watering; Urban heat island effect; Urban climate; Climate change; Adaptation	METROPOLITAN AREA; GREEN WALLS; TEB SCHEME; MODEL; IMPACT; SIMULATIONS; VEGETATION; INCLUSION; EUROPE; ISLAND	Increasing heat-wave risk due to regional climate evolutions, exacerbated by urban heat island (UHI) effects, is a major threat for the inhabitants of many cities. Adaptive policies such as greening the urban environment are often proposed to limit population vulnerability, as vegetation enables to regulate the microclimate by evapotranspiration. The efficiency of such strategies depends on water availability and raises the issues of water supply for irrigation and of vegetation efficiency. The vegetation watering alternatives and a scenario of pavement watering are studied and compared using Paris (France) urban area as a case study. With an evolution of the city based on business as usual trends, urban climate modeling enables to evaluate both UHI and heat stress under heat-wave conditions in 2100. Vegetation watering is efficient in reducing air temperature and thermal stress, but mostly in residential areas where vegetation density is important enough. Pavement watering is relevant in the densely built city center only where it improves the cooling efficiency and increases the water consumption by 2% only. The combination of both solutions provides the best performances with a reduction (compared to a non irrigated scenario) of the maximum temperature anomaly by 0.8 degrees C (2.6 degrees C) during the day (night). (c) 2016 Elsevier B.V. All rights reserved.	57	2018	10.1016/j.uclim.2016.11.001	
Status and determinants of small farming households' food security and role of market access in enhancing food security in rural Pakistan	Ahmed, UL; Ying, L; Bashir, MK; Abid, M; Zulfiqar, F	PLOS ONE	English	Article		LOGISTIC-REGRESSION; CLIMATE-CHANGE; PUNJAB; PERCEPTIONS; ADAPTATION; FARMERS; IMPACT; LEVEL	In most of the developing countries, lack of resources and little market accessibility are among the major factors that affect small farming household food security. This study aims to investigate the status of small farming households' food security, and its determinants including the role of market accessibility factors in enhancing food security at household level. In addition, this study also determines the households' perception about different kinds of livelihoods risks. This study is based on a household survey of 576 households conducted through face-to-face interviews using structured interviews in Punjab, Pakistan. Food security status is calculated using dietary intake method. The study findings show that one-fourth of the households are food insecure. The study findings reveal that farm households perceive increase in food prices, crop diseases, lack of irrigation water and increase in health expenses as major livelihood risks. Further, the results of logistic regression show that family size, monthly income, food prices, health expenses and debt are main factors influencing the food security status of rural households. Furthermore, the market accessibility factors (road distance and transportation cost) do significantly affect the small farming household food security. The results suggest that local food security can be enhanced by creating off-farm employment opportunities, improved transportation facilities and road infrastructure.	57	2017	10.1371/journal.pone.0185466	
A method for modelling coastal erosion risk: the example of Scotland	Fitton, JM; Hansom, JD; Rennie, AF	NATURAL HAZARDS	English	Article	Coastal erosion; Vulnerability; Geodemographic classification; Exposure; GIS	VULNERABILITY INDEX; MANAGEMENT; BEACHES	It is thought that 70% of beaches worldwide are experiencing erosion (Bird in Coastline changes: a global review, Wiley, Hoboken, 1985), and as global sea levels are rising and expected to accelerate, the management of coastal erosion is now a shared global issue. This paper aims to demonstrate a method to robustly model both the incidence of the coastal erosion hazard, the vulnerability of the population, and the exposure of coastal assets to determine coastal erosion risk, using Scotland as a case study. In Scotland, the 2017 Climate Change Risk Assessment for Scotland highlights the threat posed by coastal erosion to coastal assets and the Climate Change (Scotland) Act 2009 requires an Adaptation Programme to address the risks posed by climate change. Internationally, an understanding and adaption to coastal hazards is imperative to people, infrastructure and economies, with Scotland being no exception. This paper uses a Coastal Erosion Susceptibility Model (CESM) (Fitton et al. in Ocean Coast Manag 132:80-89.https://doi.org/10.1016/j.ocecoaman.2016.08.018, 2016) to establish the exposure to coastal erosion of residential dwellings, roads, and rail track in Scotland. In parallel, the vulnerability of the population to coastal erosion, using a suite of indicators and Experian Mosaic Scotland geodemographic classification, is also presented. The combined exposure and vulnerability data are then used to determine coastal erosion risk in Scotland. This paper identifies that 3310 dwellings (a value of A 524 pound m) are exposed to erosion, and the Coastal Erosion Vulnerability Index (CEVI) identifies 1273 of these are also considered to be highly vulnerable to coastal erosion, i.e. at high risk. Additionally, the CESM classified 179 km (A 1.2 pound bn worth) of road and 13 km of rail track (A 93 pound m to A 2 pound bn worth) to be exposed. Identifying locations and assets that are exposed and at risk from coastal erosion is crucial for effective management and enables proactive, rather that reactive, decisions to be made at the coast. Natural hazards and climate change are set to impact most on the vulnerable in society. It is therefore imperative that we begin to plan, manage, and support both people and the environment in a manner which is socially just and sustainable. We encourage a detailed vulnerability analysis, such as the CEVI demonstrated here for Scotland, to be included within future coastal erosion risk research. This approach would support a more sustainable and long-term approach to coastal management decisions.	56	2018	10.1007/s11069-017-3164-0	
A Statistical Approach to Mapping Flood Susceptibility in the Lower Connecticut River Valley Region	Giovannettone, J; Copenhaver, T; Burns, M; Choquette, S	WATER RESOURCES RESEARCH	English	Article		GROUPING GEOMORPHIC PARAMETERS; PRINCIPAL COMPONENT ANALYSIS; FREQUENCY RATIO; CLIMATE-CHANGE; WATER-QUALITY; SYSTEM; MODEL; URBANIZATION; VALIDATION; SIMULATION	Flood susceptibility in the Lower Connecticut River Valley Region attributable to nonclimatic flood risk factors is mapped using a quantitative method using logistic regression. Flood risk factors considered include elevation, slope, curvature (concave, convex, or flat), distance to water, land cover, vegetative density, surficial materials, soil drainage, and impervious surface. Values of factors at point locations were correlated to whether a location was located within or outside of the U.S. Federal Emergency Management Agency 100-year Special Flood Hazard Area (SFHA). The Lower Connecticut River Valley Region was divided into urban, rural, and coastal subregions to assess the differences in factor contributions to flood susceptibility between different region types; for each region flood risk factors were extracted from 4,000 points, of which an equal number were within or outside of the 100-year SFHA. Logistic regression coefficients were obtained. It was found that elevation and distance to water have the greatest contribution to flood susceptibility in the urban and coastal subregions, whereas distance to water and surficial materials dominate in the rural subregion. The contribution of land use to flood susceptibility increased by over 200% between the rural and urban regions. Probabilities of flooding were computed using each regional logistic regression equation. Several areas classified as very high risk (80-100%) and high risk (60-80%) were located outside of the SFHA and included several types of infrastructure critical for human health, safety, and education. This study demonstrates the utility of logistic regression as an efficient methodology to map regional flood susceptibility. Plain Language Summery Flooding is one of the most severe and potentially devastating natural disasters that can occur. Floods can come in many forms, including river, coastal, and flash flooding. Whenever and wherever any of these types of flooding occur, long-term planning and adaptation, preparedness, and response time are all critical factors in reducing the overall impacts. Awareness of areas that are currently prone and will remain prone to flooding in the future is essential to consider in both short-term and long-term planning. Such awareness comes from an understanding of a combination not only of regional climatic factors but also of nonclimate factors that relate to natural, physical, and development characteristics. The current study estimates the risk of flooding throughout the Lower Connecticut River Valley Region (LCRVR) based on site and regional characteristics. Several methods were considered to estimate flood risk; the method that was finally selected for this study involves a statistical approach in which a data set having one or more independent variables that produce a binary value of no or yes (0 or 1, respectively) for the dependent variable is analyzed. The independent variables in this case include several nonclimate factors related to flood risk that could potentially affect the region and for which sufficient data were available and are referred to as flood risk factors. Flood risk factors considered include elevation, land slope, land curvature (concave, convex, or flat), distance to water body, land cover, density of vegetation, surface geology, ability of the soil to drain water, and the percent of impervious surface (e.g., pavement). The objective is to link each of the flood risk factors to the dependent variables, which in this case is the occurrence of flooding for a flood event that is estimated to occur on average once in every 100 years. It was found that the overall quality of recent satellite images of the LCRVR during large flood events was not sufficient for the current analysis; therefore, it was decided to use the U.S. Federal Emergency Management Agency 100-year Special Flood Hazard Area (SFHA) to indicate areas where flood inundation would occur. The advantage of using the SFHA and the selected statistical modeling methodology is that they allow the contribution of each flood risk factor within the SFHA to be estimated and then applied to the entire study region to identify additional areas outside of the SFHA that have high flood risk. The LCRVR was divided into three subregions (urban, rural, and coastal) to accentuate the differences in the contributions of each flood risk factor to flood risk between an urban and a rural area and between inland and coastal areas; for each subregion 4,000 point locations were randomly chosen from which to extract data for each flood risk factor. An equal number of these points were selected in locations that were within and outside of the SFHA for each subregion. Site data for each flood risk factor were extracted and associated with a 1 if the location was within the SFHA and a 0 otherwise. The resulting relations between each flood risk factor and flood occurrence were analyzed so that regression coefficients could be estimated for each factor, the magnitude of which indicates the relative strength of each flood risk factor's influence on flooding in a subregion. It was found that elevation and distance to water have the most influence on flood risk in the urban and coastal subregions, whereas distance to water and surface geology dominate in the rural subregion. The contribution of elevation and land use were also found to increase the most between the rural and urban subregions. The coefficients for each subregion are then used to assign probabilities of flooding to all locations over a grid covering that subregion. The results for each subregion were combined to create an overall flood probability map of the LCRVR. Probabilities were classified very low risk (0-20%), low risk (20-40%), medium risk (40-60%), high risk (60-80%), and very high risk (80-100%). It was observed that several areas classified as very high risk and high risk were located outside of the SFHA. Several types of infrastructure critical for human health, safety, and education were finally overlaid on the flood risk map to identify those assets that are most vulnerable to the 100-year flood and may therefore require additional flood risk mitigation.	56	2018	10.1029/2018WR023018	
Evidence of climate change in the hyper-arid region of the southern coast of Peru, head of the Atacama Desert	Pino-Vargas, E; Chavarri-Velarde, E	TECNOLOGIA Y CIENCIAS DEL AGUA	English	Article	Climate change; droughts; floods; the most; hyper-arid region; Atacama Desert	LA YARADA; GROUNDWATER; AQUIFER; TACNA; MECHANISMS; DEPOSITS; AMERICA; BASIN; AGE	The effect of climate change in this region is considered as one of the driest in the world, according to the evidence found and recorded, may be favorable or unfavorable for water availability. In this work, we seek to evaluate and validate the evidence of climate change such as droughts and floods that are occurring in the southern region of Peru and northern Chile called the headwaters of the Atacama Desert. The analysis of the interrelationships and climate trends was carried out, to demonstrate conditions of climate change about the occurrence of alluviums. In recent years, extraordinary precipitation events have occurred that have generated surface storage, vegetation growth, and alluvial surface flows in areas where they were not normal. The return periods of said extraordinary events were calculated. Likewise, la mancha caliente (the hot blob) -detected by NOAA- brought with it, temperature anomalies between 4 and 6 degrees C, and has a high probability of being the agent causing local rainfall in the study area. We consider these events as evidence of climate change; the normal conditions have been altered and the damage is irrefutable, it must be specified, for example, that a large part of the road infrastructure, services, buildings, etc., are not designed to take these conditions into account current climate, therefore, it is necessary to establish the safety regulations and adaptation of buildings to these new conditions that are being presented.	56	2022	10.24850/j-tyca-2022-01-08	
Experimental Comparative Study between Conventional and Green Parking Lots: Analysis of Subsurface Thermal Behavior under Warm and Dry Summer Conditions	Bouzoudja, R; Leconte, F; Kiss, M; Pierret, M; Pruvot, C; Detriche, S; Louvel, B; Bertout, J; Akotsuaie, Z; Wu, TY; Goffon, R; Colin, B; Petrissans, A; Lagiere, P; Petrissans, M	ATMOSPHERE	English	Article	green infrastructure; green parking lot; in-situ measurement; nature-based solutions; pervious pavement; soil temperature	URBAN HEAT-ISLAND; SURFACE-TEMPERATURE; SEASONAL-VARIATIONS; AIR-TEMPERATURE; COOLING RATES; MITIGATION; PAVEMENTS; VEGETATION; UHI; CONDUCTIVITY	Green infrastructure has a role to play in climate change adaptation strategies in cities. Alternative urban spaces should be designed considering new requirements in terms of urban microclimate and thermal comfort. Pervious pavements such as green parking lots can contribute to this goal through solar evaporative cooling. However, the cooling benefits of such systems remain under debate during dry and warm periods. The aim of this study was to compare experimentally the thermal behavior of different parking lot types (PLTs) with vegetated urban soil. Four parking lots were instrumented, with temperature probes buried at different depths. Underground temperatures were measured during summer 2019, and the hottest days of the period were analyzed. Results show that the less mineral used in the surface coating, the less it warms up. The temperature difference at the upper layer can reach 10 degrees C between mineral and non-mineral PLTs. PLTs can be grouped into three types: (i) high surface temperature during daytime and nighttime, important heat transfer toward the sublayers, and low-time shift (asphalt system); (ii) high (resp. low) surface temperature during daytime (resp. nighttime), weak heat transfer toward the sublayers, and important time shift (paved stone system); and (iii) low surface temperature during daytime and nighttime, weak heat transfer toward the sublayers, and important time shift (vegetation and substrate system, wood chips system, vegetated urban soil). The results of this study underline that pervious pavements demonstrate thermal benefits under warm and dry summer conditions compared to conventional parking lot solutions. The results also indicate that the hygrothermal properties of urban materials are crucial for urban heat island mitigation.	56	2021	10.3390/atmos12080994	
Perspectives on the emerging role of the Asian Infrastructure Investment Bank	De Jonge, A	INTERNATIONAL AFFAIRS	English	Article		CHINA; POLICY	This article uses recursivity theory to examine the emerging nature and position of the Asian Infrastructure Investment Bank (AIIB) from four different perspectives. Part one describes important domestic drivers within China providing motives for the AIIB initiative. These include domestic overinvestment in infrastructure and construction, combined with environmental stresses compelling the shift towards a more sustainable economy. Part two examines regional networks and linkages that the AIIB is becoming part of. These include China's 'one belt, one road' initiative, and various collective initiatives based around ASEAN. In part three, this article explores the AIIB's appearance on the development finance scene as an example of 'contested multilateralism'-where a new multilateral institution emerges to challenge the rules and practices of existing institutions. The AIIB has entered into co-financing agreements with many of its multilateral development bank peers. Its standards and procedures are strongly influenced by existing ones, even while it begins to influence the practices of its partner multilateral development banks. Part four examines the potential influence of a future alliance between the AIIB and the UNCCC's Green Climate Fund. Such an alliance would require an even greater degree of compliance by the AIIB with global standards of transparency and good governance, as well as expanding the scope for the AIIB to influence regional climate change adaptation and mitigation infrastructure initiatives.	56	2017	10.1093/ia/iix156	
Social resilience and its scale effects along the historical Tea-Horse Road	Yang, LE; Chen, JX; Geng, J; Fang, YP; Yang, WB	ENVIRONMENTAL RESEARCH LETTERS	English	Article	social resilience; flood resilience; spatial-temporal dynamics; scale effect; flood adaptation; climate resilience; Tea-Horse Road	CLIMATE-CHANGE; ADAPTATION; CAPACITY; DISASTER	This study adopted an empirical analysis to explore social resilience to major natural disasters along the Tea-Horse Road (THR) in southwest China and to understand why and how the THR and its connected communities maintained and developed over a long period. A set of archive data, literature re-analysis, statistical data, monitoring data, and surveyed materials were collected and qualitatively and quantitatively analysed to support a holistic investigation of disaster impacts and social resilience. The results indicate that (a) natural disasters occurred frequently but were distributed over place and time and had various impacts, which left possibilities for maintaining social development with diverse and specific coping strategies; (b) strong central and local governance continually improved infrastructure and engineering technologies, and collaboration in social networks with local experience and disaster cultures were the major contributing factors that enhanced social resilience at various levels; (c) the THR area demonstrated various features of social resilience to natural disasters in terms of spatial-temporal scales, where the combination of multiple resilience measures enabled the resilience of the entire social system at various places over long time periods. Generally, larger social systems with diverse response capabilities were more resilient than small and individual entities over a long time scale. The study highlights that the THR region withstood frequent natural disasters but maintained a general development of social economy, transportation, and advanced technologies, and performed a positive transformation to a more resilient status. Overall, this paper describes the scale effects of multiple resilience measures along the THR and calls for specific studies on social resilience and transformation of diverse social entities over multiple spatial-temporal scales.	56	2021	10.1088/1748-9326/abea35	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
A Comparison of Neighborhood-Scale Interventions to Alleviate Urban Heat in Doha, Qatar	Ferwati, S; Skelhorn, C; Shandas, V; Makido, Y	SUSTAINABILITY	English	Article	urban climate; urban microclimate; microclimate modeling; urbanization; sustainable development; neighborhood adaptation; climate change	OUTDOOR THERMAL COMFORT; BUILT ENVIRONMENT; ISLAND; MITIGATION; SURFACE; HEALTH; GREEN; CITY; AIR; TEMPERATURES	Recent evidence suggests that many densely populated areas of the world will be uninhabitable in the coming century due to the depletion of resources, climate change, and increasing urbanization. This poses serious questions regarding the actions that require immediate attention, and opportunities to stave off massive losses of infrastructure, populations, and financial investments. The present study utilizes microclimate modeling to examine the role of landscape features as they affect ambient temperatures in one of the fastest growing regions of the world: Doha, Qatar. By modeling three study sites around Dohaone highly urbanized, one newly urbanizing, and one coastal low-density urbanizedthe research indicates that at the neighborhood scale, the most effective scenario was that of adding mature trees along the sides of roads. In the coastal study area, the model results estimated a maximum hourly air temperature reduction of 1.35 degrees C, and in the highly urbanized inland site, surface temperature reductions were up to 15 degrees C at 12:00. While other scenarios were effective at reducing air and surface temperatures, the mean radiant temperature was also increased or nearly neutral for most of the other scenarios. This result highlights the need to develop improved shading measures for pedestrian pathways and outdoor recreational areas, especially for highly urbanized inland areas in Doha and cities with similar climatic conditions.	55	2019	10.3390/su1030730	
Systematic Knowledge Sharing in a Natural Hazard Damage Context: How Organizational Borders Limit Lessons Learned	Nyman, MR; Johansson, M; Liljegren, E	RISK HAZARDS & CRISIS IN PUBLIC POLICY	English	Article	feedback loops; lessons learned; risk management; climate change adaptation; public-private partnership; road maintenance	RISK; MANAGEMENT; PROJECTS; SAFETY; COLLABORATIONS; CONSTRUCTION; PERFORMANCE; CHALLENGES; STRATEGIES; ACCIDENTS	The aim of this paper is to increase knowledge about systematic lessons learning in a public-private partnership. Empirically, it focuses on road maintenance in Sweden where the Swedish Transport Administration (STA) is responsible for the state-owned infrastructure and tendered contractors carry out all maintenance. The tendering process stipulates that the stakeholders should enable learning and the knowledge transfer that is, by necessity, required for preventive purposes. Semi-structured interviews with project leaders from the STA and respondents from two tendering contractors of maintenance were used to investigate attitudes to and the understanding of sharing experiences and knowledge about damage caused by weather extremes and the relevance of climate change adaptation in their field. The analysis suggests that most of the respondents' experiences stay within their own organization, which creates parallel feedback loops, rather than becomes shared knowledge that could be used as lessons learned enhancing preventive work against future damage and loss. The analysis indicates imbalance in feedback of knowledge concerning weather extremes and their effects.	55	2017	10.1002/hfm3.12119	
Warming threat compounds habitat degradation impacts on a tropical butterfly community in Vietnam	Bonebrake, TC; Pickett, EJ; Tsang, TPN; Tak, CY; Vu, MQ; Vu, LV	GLOBAL ECOLOGY AND CONSERVATION	English	Article	Biodiversity; Climate change; Degradation; Lepidoptera; Roads	CLIMATE-CHANGE; BIODIVERSITY; VULNERABILITY; RESPONSES; CONSERVATION; ASSEMBLAGES; ADAPTATION; FORESTS; SHIFTS; RISK	Species are threatened globally by multiple and often synergistic environmental changes including habitat loss, fragmentation and climate change. However, how these changes act in concert is poorly understood, especially in the tropics where the vast majority of biodiversity resides. Here, using a unique dataset covering 10 years of butterfly surveys (2003-2013) at Tam Dao National Park in northern Vietnam, we examined the combined impacts of habitat degradation (following intensive infrastructure development in 2005) and the possible threat of warming (extrapolating upon the relationship between natural climatic variation and community indices) for tropical butterfly communities. We found that both habitat degradation and warmer temperatures led to fewer narrow-range and forest-associated species comprising the sampled communities. Under projected climate change scenarios, the impact of warming was comparable to habitat degradation with respect to community change, and degraded forest communities were projected to shift towards cosmopolitan and non-forest species even more. The tropics have been heavily deforested world-wide and also suffer from heavy impacts of degradation and fragmentation, especially road construction. Warming will compound habitat degradation impacts such that the conservation of tropical biodiversity will require addressing these multiple global changes simultaneously. (C) 2016 The Authors. Published by Elsevier B.V.	55	2016	10.1016/j.gecco.2016.09.003	
Assessing Riverbank Erosion and Livelihood Resilience Using Traditional Approaches in Northern Bangladesh	Mamun, AA; Islam, AMT; Alam, E; Pal, SC; Alam, GMM	SUSTAINABILITY	English	Article	riverbank erosion; impacts; traditional erosion control approach; livelihoods; resilience; Bangladesh	INDUCED DISPLACEES; RURAL HOUSEHOLDS; CLIMATE-CHANGE; ADAPTATION; VULNERABILITY; RESETTLEMENT; HAZARD	Bangladesh is a riverine country that is the most climate-change-vulnerable country in the world. Riverbank erosion adversely affects people and their livelihoods by damaging their homesteads, agricultural land, and causing economic, social, and psychological distress over time. Under these criteria, erosion control measures/approaches are vital for protecting erosion and crating livelihoods resilient. This study intends to assess riverbank erosion and livelihood resilience using traditional erosion control approaches by observing and surveying 118 riverine households in Rowmari, northern Bangladesh. The results show that riverbank erosion enormously damages household lands, socio-economic conditions, livelihoods, and resources, resulting in increased vulnerability. About 54.2% of the households utilize traditional approaches known as bundlings and 33.1% use both bundlings + bank vegetation that helps them resist erosion. Traditional erosion management approaches enhance resilience by safeguarding agricultural land, crop fields, production, and homesteads rapidly and sustainably, and by reducing damage to infrastructure, roads, embankments and transportation in the region. A probit model was also employed to explore factors that have influenced traditional erosion approaches. The factors such as age, education, family size, erosion experience, occupation, earning members, and farm size were meaningfully related to taking traditional erosion approaches. It is expected that the outcomes of the present research will help guide governmental agencies and policymakers and contribute to the construction of a sustainable riverbank erosion action framework in Bangladesh and other regions with similar problems.	54	2022	10.3390/su14042348	
Phenological advance of blossoming over the past century in one of the world's largest urban forests, Gauteng City-Region, South Africa	Fitchett, JM; Raik, K	URBAN FORESTRY & URBAN GREENING	English	Article	Jacaranda; Flowering; Phenology; Climate; Gauteng; South Africa	CLIMATE-CHANGE; FLOWERING PHENOLOGY; PLANT PHENOLOGY; NORTHERN-HEMISPHERE; PATTERNS; RAINFALL	The Gauteng City-Region in the northern interior of South Africa hosts one of the world's largest and most densely vegetated urban forests. The tree species, distributed across pavements, parks and suburban gardens, comprise a range of indigenous and alien species. The most aesthetically distinct of these is Jacaranda mimosifolia (Bignoniaceae), a purple-blossoming tree introduced from Brazil in the 1800s to beautify the cities. The distinct appearance during flowering and their abundance in the Gauteng City-Region has resulting in reporting of peak flowering events in local newspapers throughout the past century. This provides a valuable phenological record, particularly in southern Africa where phenology is seldom recorded. Analysing these reports of Jacaranda mimosifolia flowering, an advance of 2.1 days per decade is calculated for the period 1927-2019. This occurs against a backdrop of statistically significant annual and monthly temperature increases of -0.1-0.2 degrees C/decade for Tmax and -0.2-0.4 degrees C/decade for Tmin, and non-uniform change in rainfall. This phenological advance is most significantly related to winter climatic conditions, including Tmax, rainfall and frost occurrence. The strongest phenological driver is June Tmax, at a rate of 4.3-5.3d/degrees C across the City-Region. This advance reflects the response of the tree to regional climate warming, which poses threats to the species and the urban forest in the long term when thresholds for adaptation are surpassed.	54	2021	10.1016/j.ufug.2021.127238	
Simulated climate adaptation in storm-water systems: Evaluating the efficiency of within-system flexibility	McCurdy, AD; Travis, WR	CLIMATE RISK MANAGEMENT	English	Article	Climate adaptation; Stormwater management; Adaptation pathways	ADAPTIVE POLICY PATHWAYS; FLOOD RISK-MANAGEMENT; REAL OPTIONS; PRECIPITATION; UNCERTAINTY; DESIGN	Changes in regional temperature and precipitation patterns resulting from global climate change may adversely affect the performance of long-lived infrastructure. Adaptation may be necessary to ensure that infrastructure offers consistent service and remains cost effective. But long service times and deep uncertainty associated with future climate projections make adaptation decisions especially challenging for managers. Incorporating flexibility into systems can increase their effectiveness across different climate futures but can also add significant costs. In this paper we review existing work on flexibility in climate change adaptation of infrastructure, such as robust decision-making and dynamic adaptive pathways, apply a basic typology of flexibility, and test alternative strategies for flexibility in distributed infrastructure systems comprised of multiple emplacements of a common, long-lived element: roadway culverts. Rather than treating a system of dispersed infrastructure elements as monolithic, we simulate options flexibility in which inherent differences in individual elements is incorporated into adaptation decisions. We use a virtual testbed of highway drainage crossing structures to examine the performance under different climate scenarios of policies that allow for multiple adaptation strategies with varying timing based on individual emplacement characteristics. Results indicate that a strategy with options flexibility informed by crossing characteristics offers a more efficient method of adaptation than do monolithic policies. In some cases this results in more cost-effective adaptation for agencies building long-lived, climate-sensitive infrastructure, even where detailed system data and analytical capacity is limited.	54	2018	10.1016/j.crm.2017.12.002	
Analysis of the heat budget of standard, cool and watered pavements under lab heat-wave conditions	Parison, S; Hendel, M; Grados, A; Royon, L	ENERGY AND BUILDINGS	English	Article	Cool pavements; Pavement-watering; Evaporative cooling; Surface heat budget; Energy partitioning; Urban heat island; Climate change adaptation; Heat mitigation	ISLAND; IMPACTS; ENERGY; SCALE; BUILDINGS; STRATEGY; COATINGS; SUMMER; FLUXES; RISK	The thermal behavior of 12 standard and cool pavement structures (asphalt, granite, stabilized sand, cobblestones, reflective paints, pervious concretes, dry grass, etc.) coupled with pavement-watering is studied in the lab under heat-wave-like conditions. Watering is fine-tuned for each structure to maximize cooling and minimize water consumption using two linear cooling regimes, before deployment in the field. The surface heat budget is closely studied and the partitioning of irradiance and net radiation into conductive, convective, radiative and cooling flux at surface is analyzed for each structure. Energy partitioning, surface temperature increase and optimal watering rates all exhibit good correlation with overall surface absorptivity. The transmitted flux at varying depths is also characterized using a transmission index that includes surface absorptivity and apparent conductivity of the traversed layers. Results of this study intend to improve our understanding of the energy balance of cool pavements compared to traditional ones under given weather conditions, as well as that of processes involved in the optimization of their evaporative cooling versus watering rate. Benefits of each pavement, efficiency of the method, limitations of the protocol and its potential transposition to the field are all discussed in this contribution. (C) 2020 Elsevier B.V. All rights reserved.	53	2020	10.1016/j.enbuild.2020.110455	
Priority analysis of port investment along the 21st-Century Maritime Silk Road region: the case of Southeast Asia	Zheng, JF; Yang, LX; Li, W; Fu, XW; Li, DQ	MARITIME POLICY & MANAGEMENT	English	Article; Early Access	Maritime Silk Road; port investment; random walk; Southeast Asia	BELT-ONE ROAD; COMPLEX NETWORKS; LINK PREDICTION; CLIMATE-CHANGE; RANDOM-WALK; CONSTRUCTION; COMPETITION; LOGISTICS; ADAPTATION; MARKET	Most of the Southeast Asian countries are developing economies that have large demand for maritime infrastructures. Some but not all the ports in this region could significantly benefit from and contribute to the Belt and Road Initiative (BRI) proposed by the Chinese government. This paper models the port investment priority in the Southeast Asian region, so that efficient and sustainable investments can be made under the BRI. Based on the link prediction theory, a random walk method is proposed to assess the priorities of port construction projects at different sites. The proposed method explicitly considers important economic and political factors, especially those linking Southeast Asian countries with China. Our model is calibrated and verified with numerical experiments, so that policy and managerial recommendations can be obtained for this region. Results consistent with industry reality also provide supports to the validity of the model. This study introduces a new dimension of investment planning for multiple ports taking into account the resultant impacts on shipping networks, and recommends selected port construction sites with good potential in Southeast Asia.	53	2021	10.1080/03088839.2021.1937741	
Adapting transportation to climate change on federal lands in Washington State, USA	Strauch, RL; Raymond, CL; Rochefort, RM; Hamlet, AF; Lauver, C	CLIMATIC CHANGE	English	Article		VARIABILITY; FORESTS; FUTURE	Research scientists collaborated with federal land managers of two national parks and two national forests to conduct a climate change vulnerability assessment and to identify adaptation strategies for a transportation network covering 28,900 km of roads and trails in north-central Washington, U.S.A. The assessment employed observations of sensitivity and response to climatic variability, downscaled climate projections, literature reviews, current management policies and practices, expert knowledge, and stakeholder engagement. Primary pathways for climate impacts focused on projected increases in extreme high flows and flooding, elevated winter soil moisture and landslide hazards, and loss of snowpack. The biggest impacts to roads and trails are expected from temperature-induced changes in hydrologic regimes that enhance autumn flooding and reduce spring snowpack. Projected higher winter soil moisture caused by changes in seasonal precipitation and snow accumulation could reduce slope stability. Earlier snowmelt may lengthen the snow-free season for visitor use and agency operations. Infrastructure age, design, maintenance, location, use, and limited redundancy along with funding policies and management, influence the sensitivities of the transportation system. Vulnerabilities were identified based on when and where these sensitivities to changes in climate may emerge. Adaptation strategies and tactics identified to address these vulnerabilities included: upgrading stream crossing and drainage design, changing use and maintenance, relocating or closing roads and trails, modifying funding policies, and expanding pubic engagement. Many adaptation options are no regrets approaches to changes in climate projected for the 2040s and 2080s that can be applied to other resource sectors and mountainous regions.	52	2015	10.1007/s10584-015-1357-7	
Climate change adaptation strategies for transportation infrastructure in Prince George, Canada	Picketts, IM; Andrey, J; Matthews, L; Dery, SJ; Tighe, S	REGIONAL ENVIRONMENTAL CHANGE	English	Article	Adaptation; Local government; Transportation; Road safety; Road maintenance; British Columbia	BARRIERS; FRAMEWORK; DIALOGUE; WEATHER	Transport infrastructure is particularly vulnerable to climate impacts as it is designed for long operational lives, and both episodic and seasonal conditions contribute to deterioration, disruption and unsafe incidents. There are some examples of adaptation in transportation design, but many communities do not have the capacity to incorporate climate change considerations into infrastructure planning and management. Researchers worked closely with the City of Prince George, in Central British Columbia, Canada, to build on existing work and explore how the City could plan, design, and maintain roads and other structures to account for climate change. A local steering committee was formed, and created and evaluated 23 potential research topics. Two focus areas were selected for further investigation and explored during a workshop with practitioners, researchers, consultants and other representatives. The workshop precipitated an investigation of projected impacts of climate change on road maintenance and road safety, and plans to explore alternative paving techniques. Outcomes of the case study provide insights regarding climate change and local transportation infrastructure, including: how researchers can engage with local experts to explore adaptation; issues local governments perceive as important; and barriers communities face as they attempt to address vulnerabilities.	52	2016	10.1007/s10113-015-0828-8	
Quantifying the Influence of Climate Change to Priorities for Infrastructure Projects	You, HW; Lambert, JH; Clarens, AF; McFarlane, BJ	IEEE TRANSACTIONS ON SYSTEMS MAN CYBERNETICS SYSTEMS	English	Article	Deep uncertainty; infrastructure systems; risk analysis; robust decision making; transportation planning	DEEP UNCERTAINTIES; ADAPTATION	Uncertainties of climate change and other nonprobabilistic and structural uncertainties need to be addressed in strategic planning and priority setting for infrastructure systems. Traditional economic analysis and risk analysis of particular uncertainties can be prohibitive due to sparse data, complex models, and unforeseen interactions of climate change with other stressors. Nevertheless, planners need to proceed in the near term and may be asked to allocate resources to these deep uncertainties. This paper identifies and quantifies the influence of climate change combining with other sources of uncertainty to the priority order of projects in a portfolio of infrastructure investments. A demonstration for the Hampton Roads region of Virginia proceeds as follows. First, we apply traditional multicriteria analysis to generate a baseline prioritization of over 93 transportation projects. Next, we identify the following scenarios: climate conditions combined with economic conditions, wear and tear, ecological conditions, and traffic-demand conditions, and climate conditions alone. Next, we adjust a multicriteria value function for each scenario. We then quantify the sensitivity of the priority order of projects to the scenarios. Last, we identify the scenarios that are disruptive to the baseline prioritization. This approach is widely applicable to strategic planning for infrastructure systems that are subject to uncertainties of emergent and future conditions.	52	2014	10.1109/TSMC.2013.2248709	
Reduction of urban heat island and associated greenhouse gas emissions	Chen, RN; You, XY	MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE	English	Article	Green space; Heat island; Numerical simulation; Orthogonal experimental design; Residential community	THERMAL COMFORT; MITIGATION STRATEGIES; ENERGY; TEMPERATURE; IMPACT; DESIGN; MORTALITY; SCALE; MICROCLIMATE; TECHNOLOGIES	The reduction of urban heat island (UHI) and carbon emission is of great importance for thermal environment of urban residential areas. This paper aimed to establish a method to analyze the effect of different underlying surface layouts on the reduction of heat island intensity and carbon emission. Taking Tianjin, China, as a case study area, a computational fluid dynamics (CFD) model, satellite-based remote sensing retrieval technique, and orthogonal experimental design were performed to investigate and quantify the performance of mitigation strategies (i.e., urban green space or water body, cool/high reflectivity pavement, and reflective roofs and facades) on UHI. The results indicated that urban green space is the most natural and effective mitigation strategy, while the widespread application of cool/high reflectivity materials is suggested as a mitigation strategy for building height more than 10 m above the ground. Application of urban water body is the next preferred strategy for air at 1.5 m pedestrian level. Green roofs, rainwater gardens, and permeable brick pavements are also more feasible in high-density cities for mitigating the UHI effect. The above mitigation and adaptation strategies of community scale can be acted on UHI and as a global urban climate change response.	52	2020	10.1007/s11027-019-09886-1	
Vulnerability of Transport Networks to Multi-Scenario Flooding and Optimum Location of Emergency Management Centers	Perez-Morales, A; Gomariz-Castillo, F; Pardo-Zaragoza, P	WATER	English	Article	flood risk assessments; vulnerability of networks; emergency management; geographic information systems; open source	IMPACT; DAMAGE; LINKS; GIS	Floods are the climatic factors that cause more significant impacts on transportation infrastructures. This circumstance could get worse, taking into account climate change effects. The literature points out different adaptation measures to minimize the possible increasing effects caused by climate change. Among them is the improvement of the vulnerability of a transport network and Emergency Management Systems. The effective management of emergencies is of vital importance to minimize the potential damage resulting from a catastrophe. Given such circumstances, analysis of the vulnerability of networks is a technique whose results highlight deficiencies and serve as support for future decisions concerning the transformation of the network or the installation of new emergency centers. The main objective of this research is to highlight the vulnerability of the road network in a variety of multi-contingency scenarios related to flooding and to identify the optimal location for a new emergency management center based on that analysis. The results obtained could be used in urban planning tasks to improve the resilience of urban areas in the face of an increase in flood episodes caused by climate change.	52	2019	10.3390/w11061197	
Adaptation Becoming Business as Usual: A Framework for Climate-Change-Ready Transport Infrastructure	Quinn, AD; Ferranti, EJS; Hodgkinson, SP; Jack, ACR; Beckford, J; Dora, JM	INFRASTRUCTURES	English	Article	climate change adaptation; extreme weather; adaptation framework; adaptation pathways; resilience; risk management; sustainability	RAILWAY NETWORK; HEAT-RISK; EVENTS; RESILIENCE; PATHWAYS; SYSTEMS; IMPACT; FLOOD	Extreme weather damages and disrupts transport infrastructure in a multitude of ways. Heavy rainfall and ensuing landslides or flooding may lead to road or rail closures; extreme heat can damage road surfaces, or cause tracks, signalling or electronic equipment to overheat, or thermal discomfort for passengers. As extreme weather is expected to occur more frequently in the future, transport infrastructure owners and operators must increase their preparedness in order to reduce weather-related service disruption and the associated financial costs. This article presents a two-sided framework for use by any organization to develop climate-change-ready transport infrastructure, regardless of their current level of knowledge or preparedness for climate change. The framework is composed of an adaptation strategy and an implementation plan, and has the overarching ambition to embed climate change adaptation within organisational procedures so it becomes a normal function of business. It advocates adaptation pathways, i.e., sequential adaptive actions that do not compromise future actions. The circular, iterative structure ensures new knowledge, or socio-economic changes may be incorporated, and that previous adaptations are evaluated. Moreover, the framework aligns with existing asset management procedures (e.g., ISO standards) or governmental or organisational approaches to climate change adaptation. By adopting this framework, organisations can self-identify their own level of adaptation readiness and seek to enhance it.	49	2018	10.3390/infrastructures3020010	
Adaptive capacity to manage permafrost degradation in Northwest Greenland	Jungsberg, L; Herslund, LB; Nilsson, K; Wang, SN; Tomaskovicova, S; Madsen, K; Scheer, J; Ingeman-Nielsen, T	POLAR GEOGRAPHY	English	Article	Adaptive capacity; permafrost degradation; community action; long-term planning; Northwest Greenland	CLIMATE-CHANGE ADAPTATION; GOVERNANCE; INFRASTRUCTURE	Global warming has reduced the extent of permafrost, increased permafrost temperatures, and deepened the active layer across the Arctic. Permafrost degradation has detrimental effects on infrastructure and negative impacts on ecosystem services for many Arctic communities. This study examines the adaptive capacity for managing permafrost degradation in Northwest Greenland. The methods are based on questionnaire and interview data from fieldwork, frozen ground temperature records and published data forecasting the deepening of the active layer. Results illustrate the impact of permafrost degradation on the physical environment, hunting and harvesting, housing, and the economy in Northwest Greenland. House owners are mending damage caused by ground movement, and local institutions are concerned with the maintenance of roads and other public infrastructure impacted by permafrost. The scientific knowledge needed to inform decision-making is useful for identifying overall changes, but existing data sources are scarce, and more detailed permafrost maps are needed for long-term town planning. The study concludes that many individuals and institutions engage in autonomous adaptation on an ad hoc basis, rather than pursuing an overall strategy to increase the adaptive capacity in advance of future permafrost degradation in Northwest Greenland.	49	2022	10.1080/1088937X.2021.1995067	
Identifying interactions between policy, accountability and outcomes for adaptation of urban roads	Herrera, JSC; MacAskill, K; Haigh, S	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Adaptation; Adaptation planning; Urban road infrastructure; Climate change; Bogota	CLIMATE-CHANGE; TRANSFORMATIONAL ADAPTATION; INFRASTRUCTURES	Several decision-making frameworks are available to foster climate adaptation of road infrastructure, but these focus mainly on the adaptation of national or regional roads. Urban road infrastructure is equally important for the efficient functioning of society and it is imperative to understand the peculiarities of adapting these types of roads, however, existing frameworks may not be appropriate for this purpose. This paper presents a conceptual framework called the Expanded Adaptation Action Cycles (EAAC) that conceptualizes in a simple, yet comprehensive manner the adaptation planning processes of urban road infrastructure. A case study of the decision-making processes for the development and maintenance of the road network of Bogota, Colombia was conducted to demonstrate the practical utility of this framework as a diagnostic tool. Analysing the evidence collected using the EAAC framework indicates that the city is currently at the early stages of its adaptation planning and that the adaptation measures being considered suggest that, at most, the city is aiming to implement incremental adaptation. This demonstrates how the EAAC framework provides the ability to understand the relative position of a city's approach to adaptation planning within a wider spectrum of possibilities, providing insight into the potential impact of possible planning interventions.	49	2020	10.1016/j.trd.2020.102595	
Environmental and economic impacts of rising sea levels: A case study in Kuwait's coastal zone	Al-Mutairi, N; Alsahli, M; El-Gammal, M; Ibrahim, M; Abou Samra, R	OCEAN & COASTAL MANAGEMENT	English	Article	Sea level rise; Inundation; Coastal erosion; Adaptation; Climate change	DECISION-SUPPORT-SYSTEM; SHORELINE RETREAT; RISE; VULNERABILITY; CLIMATE	From an environmental and economic perspective, Kuwait?s coastal zone is highly vulnerable to sea level rise (SLR). This paper aims to assess SLR?s impact on Kuwait?s coastal zone at both the local and national level. The economic and environmental assessments focused on inundation of land, the population at risk, residential sector losses, and affected infrastructure under four SLR scenarios (0.5, 1, 1.5, and 2 m sea rise). Several spatial datasets comprising a digital elevation model, satellite images, and land use map were processed using ArcGIS 10. In addition, the rate of beach erosion from SLR was calculated by applying the Bruun rule. The results revealed that the governorates expected to be the most severely impacted were Hawalli and Kuwait Capital, in terms of both the number of affected people and the residential sector?s economic losses. Although the Ahmadi governorate would experience a lower risk of inundation, its coastal area is home to the oil industry, including refineries, harbors, and several power and desalination plants. On a national scale, applying the Bruun rule revealed that the beaches investigated would be eroded entirely by a 1 m increase in sea level. Furthermore, if sea levels rose from 0.5 m to 2 m, 1.4%?4.8% of Kuwait?s coastal zone would be inundated, forcing 0.28%?1% of residents to abandon their homes, causing residential losses of $3,463 to $11,142 million. In the same scenarios, the transportation sector would suffer damage to around 1.5%?5% of its road network. The impact of SLR would also extend to the natural environment of Kuwait Bay and caused damage to its ecosystems. The predicted consequences of SLR would vary from one area to another based on natural barriers, shoreline type, coastal structures, and the type of urban development. Therefore, national and local governments? response should consider the long-term consequences of SLR and initiate a proactive adaptation strategy.	48	2021	10.1016/j.ocecoaman.2021.105572	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Expanding infrastructure and growing anthropogenic impacts along Arctic coasts	Bartsch, A; Pointner, G; Nitze, I; Efimova, A; Jakober, D; Ley, S; Hogstrom, E; Grosse, G; Schweitzer, P	ENVIRONMENTAL RESEARCH LETTERS	English	Article	Arctic; permafrost; settlements; infrastructure; remote sensing; machine learning; Sentinel	CLIMATE-CHANGE; PERMAFROST; VULNERABILITY; COMMUNITIES; ADAPTATION; DYNAMICS; FIELD; ICE; OIL; MAP	The accelerating climatic changes and new infrastructure development across the Arctic require more robust risk and environmental assessment, but thus far there is no consistent record of human impact. We provide a first panarctic satellite-based record of expanding infrastructure and anthropogenic impacts along all permafrost affected coasts (100 km buffer, approximate to 6.2 Mio km(2)), named the Sentinel-1/2 derived Arctic Coastal Human Impact (SACHI) dataset. The completeness and thematic content goes beyond traditional satellite based approaches as well as other publicly accessible data sources. Three classes are considered: linear transport infrastructure (roads and railways), buildings, and other impacted area. C-band synthetic aperture radar and multi-spectral information (2016-2020) is exploited within a machine learning framework (gradient boosting machines and deep learning) and combined for retrieval with 10 m nominal resolution. In total, an area of 1243 km(2) constitutes human-built infrastructure as of 2016-2020. Depending on region, SACHI contains 8%-48% more information (human presence) than in OpenStreetMap. 221 (78%) more settlements are identified than in a recently published dataset for this region. 47% is not covered in a global night-time light dataset from 2016. At least 15% (180 km(2)) correspond to new or increased detectable human impact since 2000 according to a Landsat-based normalized difference vegetation index trend comparison within the analysis extent. Most of the expanded presence occurred in Russia, but also some in Canada and US. 31% and 5% of impacted area associated predominantly with oil/gas and mining industry respectively has appeared after 2000. 55% of the identified human impacted area will be shifting to above 0 C-circle ground temperature at two meter depth by 2050 if current permafrost warming trends continue at the pace of the last two decades, highlighting the critical importance to better understand how much and where Arctic infrastructure may become threatened by permafrost thaw.	48	2021	10.1088/1748-9326/ac3176	
Integrating blue-green and grey infrastructure through an adaptation pathways approach to surface water flooding	Kapetas, L; Fenner, R	PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES	English	Article	flooding; sustainable drainage systems; adaptative planning; adaptation pathways; multiple benefits	CLIMATE-CHANGE ADAPTATION; RISK-MANAGEMENT; ROBUST; UNCERTAINTY; VALUATION; POINTS; COST	A range of solutions to future flood risk are available ranging from blue-green infrastructure (BGI) as commonly incorporated in sustainable drainage systems (SuDS) to traditional grey infrastructure (e.g. pipe networks, storage tanks, flood walls). Each offers a different profile with respect to costs, flexibility of implementation and the ability to deliver a range of wider benefits beyond their flood protection function. An important question that must be addressed when considering these approaches is what is the most suitable mix of grey and blue-green solutions to urban flooding at any location and at any future time? This paper uses an adaptation pathways approach to compare a range of alternative options to deal with current and expected future flood risk in part of a London borough. Solutions considered separately and in combination include grey pipe expansion, bioretention cells, permeable pavements and storage ponds. A methodological framework combines a range of existing tools to develop, assess and characterize each pathway, including a storm water management model (SWMM), a SuDs opportunity selection tool, an adaptation pathway generator and the CIRIA B ST pound tool for monetizing multiple benefits. Climate change is represented by the UK Water Industry Research method for establishing future rainfall intensities for sewer and BGI design. The results showed that by extending the way in which adaptation pathways are compared and evaluated through the wider consideration of multiple benefits there is a trade-off between deferring interventions until they are needed for flood risk mitigation and delivering the multiple benefits associated with interventions so that performance thresholds do not need to be met before introducing new options. The relative contribution of each option's capital and operation and maintenance costs has implications on when the option is implemented as well as the rate of implementation. The monetization of the multiple benefits associated with each pathway shows that their economic co-evaluation alongside infrastructure costs can change the preference for one pathway over another. This article is part of the theme issue 'Urban flood resilience'.	48	2020	10.1098/rsta.2019.0204	
Seasonal and Long-Term Changes to Pavement Life Caused by Rising Temperatures from Climate Change	Knott, JF; Sias, JE; Dave, EV; Jacobs, JM	TRANSPORTATION RESEARCH RECORD	English	Article		PERFORMANCE; ADAPTATION; DESIGN	Pavements are vulnerable to reduced life with climate-change-induced temperature rise. Greenhouse gas emissions have caused an increase in global temperatures since the mid-20th century and the warming is projected to accelerate. Many studies have characterized this risk with a top-down approach in which climate-change scenarios are chosen and applied to predict pavement-life reduction. This approach is useful in identifying possible pavement futures but may miss short-term or seasonal pavement-response trends that are essential for adaptation planning. A bottom-up approach focuses on a pavement's response to incremental temperature change resulting in a more complete understanding of temperature-induced pavement damage. In this study, a hybrid bottom-up/top-down approach was used to quantify the impact of changing pavement seasons and temperatures on pavement life with incremental temperature rise from 0 to 5 degrees C at a site in coastal New Hampshire. Changes in season length, seasonal average temperatures, and temperature-dependent resilient modulus were used in layered-elastic analysis to simulate the pavement's response to temperature rise. Projected temperature rise from downscaled global climate models was then superimposed on the results to determine the timing of the effects. The winter pavement season is projected to end by mid-century, replaced by a lengthening fall season. Seasonal pavement damage, currently dominated by the late spring and summer seasons, is projected to be distributed more evenly throughout the year as temperatures rise. A 7% to 32% increase in the asphalt-layer thickness is recommended to protect the base and subgrade with rising temperatures from early century to late-mid-century.	48	2019	10.1177/0361198198442 49	
The infrastructure planning support system: Analyzing the impact of climate change on road infrastructure and development	Schweikert, A; Chinowsky, P; Kwiatkowski, K; Espinet, X	TRANSPORT POLICY	English	Article	Climate change adaptation; Development; Infrastructure; Roads; Measuring impact; Policy		This paper details the Infrastructure Planning Support System (IPSS), a software tool that incorporates five areas of analysis, including climate change, environment, and social impact, to provide a holistic, longer-term approach to the management and planning of road infrastructure. The system combines quantitative and qualitative analysis methods to develop an estimated fiscal cost, in addition to estimates of GHG emissions, transportation time and cost savings, and a prioritization metric focusing on social impact of road construction. The IPSS system has been applied in several case studies, including South Africa, Mozambique, Vietnam, a pan-African analysis, and several Asian countries including China, South Korea, Mongolia, and Japan. This paper serves as the first comprehensive explanation of the IPSS system, including the literature review, background, and methodology. The results section focuses on the costs of climate change in an illustrative case study of the State of Colorado in the United States, due to specific data and outputs required for the other analysis components. This paper focuses on the need for a holistic systems approach, its relevance to transportation planning and investment, and one example of how climate change considerations can be quantified and applied at the policy level. (C) 2014 Elsevier Ltd. All rights reserved.	48	2014	10.1016/j.tranpol.2014.05.019	
Climate change and infrastructure impacts: comparing the impact on roads in ten countries through 2100	Schweikert, A; Chinowsky, P; Espinet, X; Tarbert, M	HUMANITARIAN TECHNOLOGY: SCIENCE, SYSTEMS AND GLOBAL IMPACT 2014, (HUMTECH2014)	English	Proceedings Paper	Road infrastructure; climate change; adaptation; risk; developing countries; developed countries	SOCIAL VULNERABILITY	Climate change poses a critical threat to future development, particularly in areas where poverty is widespread and key assets such as infrastructure are underdeveloped for even current needs. The focus of this study includes ten geographically and economically diverse countries and the impact of 54 distinct AR4 Global Circulation Model (GCM) scenarios of future climate change on their existing road networks. The analysis is completed using a software tool which uses engineering and materialsbased stressor-response functions to determine the impact of climate on maintenance, repair and construction. This study represents an update to a previous study conducted by the authors in 2011. The key updates include methodological advances, policy-oriented results presentation and the use of a new software tool developed by the authors. For nine out of ten countries in the study, pro-active adaptation measures result in lower fiscal costs and higher connectivity rates as early as 2025. The results through 2100 are presented and the costs of climate change present clear findings for these countries in terms of road maintenance, construction, and adaptation policy. In rural areas, particularly those in low-income countries, roads represent a lifeline for economic and agricultural livelihood, as well as a number of indirect benefits including access to healthcare, education, credit, political participation, and more. Roads may be sparse through geographic locations, making each road critical. Extreme events pose a costly hazard to roads in terms of degradation, necessary maintenance, and potential decrease in lifespan due to climatic impacts. Climate change poses costly impacts in terms of maintenance, repairs and lost connectivity; yet many of these impacts can be mitigated and avoided by pro-active adaptation measures. It is a crucial consideration for protecting current and future infrastructure investments and the economic, social, and other functions they serve. The Infrastructure Planning Support System (IPSS) is a software tool designed to quantify the impacts of both extreme events and incremental climatic changes on road infrastructure in any geographic location throughout the world. The system identifies the financial cost on a yearly basis through 2100 and allows users to compare proactive adaptation measures and reactive nonadaptation measures. IPSS compares a ` no climate change' scenario as a baseline to provide information on the ` regret' that may occur if a predicted outcome of climate change model does not manifest as projected. Infrastructure impacts are determined based on civil engineering materials research, field studies of actual impacts on roads and buildings, and additional data. These resources are combined into stressor-response equations which are implemented to provide specific cost estimates. Additionally, the program can be customized to a specific location where data is available on stressor-response impacts on the infrastructure elements being analyzed. This paper focuses on the methodology and application of the IPSS tool to countries representing a range of incomes including low-income, middle, and upper income countries. The IPSS tool is used to compare costs of adaptation and opportunity cost for each country. The results indicate that higher income countries face significant dollar costs due to the extensive road networks, with very high costs in Japan and Italy, in particular. Bolivia, Ethiopia, and Cameroon all show extremely high advantages to adaptation, yet the costs required to simply maintain existing networks are equivalent to funding equal to doubling or tripling the existing paved road inventory. These results can help policy makers at the national and international levels decide where and how to invest; and show that climate change represents a significant and urgent threat to transportation throughout the world. (C) 2014 Elsevier Ltd.	47	2014	10.1016/j.proeng.2014.07.072	
Beyond agriculture: A review of the Thornthwaite Moisture Index with respect to road pavements and other infrastructure applications	Taylor, MAP; Philp, ML	INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION	English	Review	Climate change; infrastructure; moisture index; pavement	CLASSIFICATION; CLIMATES	In 1948, the Thornthwaite Moisture Index was introduced as a new global climate classification system. Since its advent, the use of the index has moved beyond climate classification for agricultural systems. This review article identifies cases where the Thornthwaite Moisture Index has been applied in the design and maintenance of infrastructure, with an emphasis on its application in the transport arena. Furthermore, the article investigates the possible application of the Thornthwaite Moisture Index in providing an environmental indicator in the design of infrastructure to allow future adaptation to changing climate conditions. An adapted road degradation model for Australia is presented illustrating the effects on pavement degradation under changing climate conditions using the Thornthwaite Moisture Index.	46	2016	10.1080/15568318.2014.997408	
Green Infrastructure Financing as an Imperative to Achieve Green Goals	Zimmerman, R; Brenner, R; Abella, JL	CLIMATE	English	Article	green infrastructure finance; green infrastructure project costs; financial sources; public finance; private finance; stormwater management; climate mitigation and adaptation; co-benefits	FUTURE	Green infrastructure (GI) has increasingly gained popularity for achieving adaptation and mitigation goals associated with climate change and extreme weather events. To continue implementing GI, financial tools are needed for upfront project capital or development costs and later for maintenance. This study's purpose is to evaluate financing tools used in a selected GI dataset and to assess how those tools are linked to various GI technologies and other GI project characteristics like cost and size. The dataset includes over 400 GI U.S. projects, comprising a convenience sample, from the American Society of Landscape Architects (ASLA). GI project characteristics were organized to answer a number of research questions using descriptive statistics. Results indicated that the number of projects and overall cost shares were mostly located in a few states. Grants were the most common financial tool with about two-thirds of the projects reporting information on financial tools receiving grant funding. Most projects reported financing from only one tool with a maximum of three tools. Projects primarily included multiple GI technologies averaging three and a maximum of nine. The most common GI technologies were bioswales, retention, rain gardens, and porous pavements. These findings are useful for decision-makers evaluating funding support for GI.	46	2019	10.3390/cli7030039	
Links between environment and stomatal size through evolutionary time in Proteaceae	Jordan, GJ; Carpenter, RJ; Holland, BR; Beeton, NJ; Woodhams, MD; Brodribb, TJ	PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES	English	Article	CO2; Cenozoic; fossil; guard cell; plant evolution	ATMOSPHERIC CO2; LEAF; CLIMATE; ADAPTATION; EXTINCTION; FRAMEWORK; GREEN; PARTS; WORLD	The size of plant stomata (adjustable pores that determine the uptake of CO2 and loss of water from leaves) is considered to be evolutionarily important. This study uses fossils from the major Southern Hemisphere family Proteaceae to test whether stomatal cell size responded to Cenozoic climate change. We measured the length and abundance of guard cells (the cells forming stomata), the area of epidermal pavement cells, stomatal index and maximum stomatal conductance from a comprehensive sample of fossil cuticles of Proteaceae, and extracted published estimates of past temperature and atmospheric CO2. We developed a novel test based on stochastic modelling of trait evolution to test correlations among traits. Guard cell length increased, and stomatal density decreased significantly with decreasing palaeotemperature. However, contrary to expectations, stomata tended to be smaller and more densely packed at higher atmospheric CO2. Thus, associations between stomatal traits and palaeoclimate over the last 70 million years in Proteaceae suggest that stomatal size is significantly affected by environmental factors other than atmospheric CO2. Guard cell length, pavement cell area, stomatal density and stomatal index covaried in ways consistent with coordinated development of leaf tissues.	46	2020	10.1098/rspb.2019.2876	
Planning green infrastructure to mitigate urban surface water flooding risk - A methodology to identify priority areas applied in the city of Ghent	Li, LY; Uyttenhove, P; Vaneetvelde, V	LANDSCAPE AND URBAN PLANNING	English	Article	Flood resilient city; Greening strategy; Climate change adaptation; Geography information System (GIS); Multi-criteria evaluation (MCE); Analytic Hierarchy Process (AHP)	CLIMATE; RESILIENCE; VULNERABILITY; MANAGEMENT; EUROPE; IMPACT; DAMAGE	Urban surface water floods pose growing threats in urban areas, which cause not only massive physical water disturbance, but also loss of human lives, destruction of social and economic infrastructures and disorder of society. The number and scale of flood damage in urban areas will continue to increase in the next several decades due to global trend in urbanization and climate change. Despite the extensive construction of grey infrastructures, many cities in the world remain vulnerable to surface water flooding, especially during the extremely weather events. Since the 1990s, green infrastructure has developed as an alternative and sustainable approach to mitigate flood hazard in urban areas. Despite the great effectiveness of urban green infrastructures in alleviating storm water runoff, there is comparatively little research for planners and designers to determine an appropriate strategy for green infrastructure planning. To address this gap, we propose a GIS-based multi-criteria evaluation method to identify the priority areas to site green infrastructure, based on five criteria: 1) storm-water runoff mitigation; 2) social flood vulnerable group protection; 3) flood sensitive area road infrastructures protection; 4) flood sensitive area buildings protection and 5) environmental justice. The weights of the five criteria are defined by the Analytic Hierarchy Process. We focus particularly on mitigating urban surface water flooding risk and demonstrate how the method can be applied using a case study of Ghent.	46	2020	10.1016/j.landurbplan.2019.103703	
Large and small numbers: options for quantifying the costs of extremes on transport now and in 40 years	Doll, C; Klug, S; Enei, R	NATURAL HAZARDS	English	Article	Transport; Weather extremes; Climate change; Cost assessment; Risk; Forecast		The past 15 years has been characterized by a high density of record-breaking weather extremes in Europe. These include the extratropical cyclones Lothar, Kyrill and Xynthia across western and mid Europe; the major floods in the UK, Germany and eastern Europe; the heat waves in 2003 and 2007 and, after a long period of mild winters, the heavy winter seasons in 2009/2010 and 2010/2011. Inspired by the rising trends in weather-related damages worldwide and the studies on the topic carried out in overseas, the EC funded the sister projects such as Weather Extremes-Assessing the Impacts on Transport and Hazards for European Regions (WEATHER), EWENT and ECONET to determine the magnitude of current and future risks to the European transport sector and to assess suitable adaptation strategies. This paper presents the assessment framework of the WEATHER project and the results of weather-inflicted damage costs now and in 2040-2050. Total annual damages are found to be around a,not sign2.5 billion, which largely attribute to road traffic. However, broken down to passenger and ton kilometers the highest risk is borne by rail traffic due to its expensive infrastructures and its comparably complex operating structure. This indication even amplifies when looking four decades ahead: while average road transport costs will only raise by 7 % due to milder winters, rail traffic costs may increase by up to 80 % due to more floods and less predictable winter periods. A comparison with the results of the EWENT study uncovers a high range of uncertainty concerning methodological approaches and data treatment. Thus, the final figures might even be much higher.	45	2014	10.1007/s11069-013-0821-9	
The role of green roofs in mitigating Urban Heat Island effects in the metropolitan area of Adelaide, South Australia	Razzaghmanesh, M; Beecham, S; Salemi, T	URBAN FORESTRY & URBAN GREENING	English	Article	Green roofs; Urban heat island; Climate change adaptation	EXTENSIVE LIVING ROOF; DRY CLIMATE; VEGETATION; QUALITY; ENVIRONMENTS; TEMPERATURES; PERFORMANCE; SURVIVAL; BENEFITS; COMFORT	Changing an urban environment and replacing vegetated surfaces with low albedo materials is one of the reasons for increasing temperatures in an urban environment and consequently also one of the key causes of urban heat island effects. In this study, an experimental investigation at the micro-scale and also a numerical simulation at the macro-scale of a typical urban environment in Adelaide were conducted to estimate the potential for mitigating the UHI effect. The results showed that existing low albedo materials such as asphalt, metal roofs and brick pavements contribute to the heat island potential. Also, urban development and a lack of natural vegetation contribute to increased temperatures in cities. The ability of two types of extensive and intensive green roofs to reduce the surrounding micro-climate temperatures were monitored. The results showed that they have significant cooling effects in summer time and could behave as an insulation layer to keep buildings warmer in the winter. Furthermore, different scenarios of adding green roofs to the Adelaide urban environment were investigated using the Envi-MET model. The scenario modelling of adding green roofs in a typical urban area in Adelaide, Australia, supported the hypothesis that this can lead to reductions in energy consumption in the Adelaide urban environment. Also an increased use of other water sensitive urban design technologies such as green walls and street trees together with the adoption of high albedo materials is recommended for achieving the optimum efficiency in terms of reducing urban temperatures and mitigating urban heat island effects. (C) 2015 Elsevier GmbH. All rights reserved.	45	2016	10.1016/j.ufug.2015.11.013	
Assessing risks from climate variability and change for disaster-prone zones in Bangladesh	Toufique, KA; Islam, A	INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION	English	Article	Bangladesh; Disaster; Vulnerability; Climate change; Adaptation	COASTAL BANGLADESH; VULNERABILITY; REDUCTION; FLOOD	We have measured livelihoods vulnerability indices for four disaster prone zones in Bangladesh, namely saline, flood, flash flood and drought. A total of 2558 households were surveyed to collect data on socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and climate variability. The data were aggregated using a composite index and vulnerabilities across the four disaster prone areas were compared. Our results show that the flash flood zone is the most vulnerable zone followed by the saline, drought and flood zones respectively. The flash flood zone is mainly a mono-rice crop area and local livelihood opportunities are uncertain and limited. Road infrastructure is poor as a large part of this zone remains under water in the wet season. Public health services are underprovided and the hospitals are understaffed, sanitary conditions are poor and the households suffer a longer period of food insecurity. The poor households living in the saline zone have to depend more on social networks and local authorities to withstand livelihood shocks brought about by natural disasters such as tidal surges, cyclones and increasing salinity. The drought and saline zones are highly vulnerable to water. Water in these zones is not only scarce but also unsafe for drinking. The saline zone also suffers from salinity in water used for irrigation which has already affected productivity of land. We suggest an increase in public spending on sanitation and drinking water, health and rural infrastructure particularly in the disaster prone areas where incidence of poverty is high. (C) 2014 Elsevier Ltd. All rights reserved.	44	2014	10.1016/j.ijdrr.2014.08.008	
Evaluating the atmospheric drivers leading to the December 2014 flood in Schleswig-Holstein, Germany	Schade, NH	EARTH SYSTEM DYNAMICS	English	Article		EXTREMES INDEXES; NORTH-SEA; CLIMATE; PRECIPITATION; MOISTURE; WEATHER; SURGE; BASIN	Regional analyses of atmospheric conditions that may cause flooding of important transport infrastructure (railway tracks, highways/roads, rivers/channels) and subsequent adaptation measures are part of topic 1 of the network of experts initiated by the German Federal Ministry of Transport and Digital Infrastructure (BMVI). As an example case study, the December 2014 flood in Schleswig-Holstein, Germany, was investigated. Atmospheric conditions at the onset of the flood event are described and evaluated with respect to the general weather circulation, initial wetness, and event precipitation. Persistent, proportionately westerly general weather circulations (GWCs) directed several low-pressure systems over the North Sea to Schleswig-Holstein during December 2014, accompanied by prolonged rainfall and finally a strong precipitation event in southern Schleswig-Holstein, causing several inland gauges to exceed their, by then maximum, water levels. Results show that the antecedent precipitation index (API) is able to reflect the soil moisture conditions and, in combination with the maximum 3-day precipitation sum (R3d), to capture the two main drivers finally leading to the flood: (1) the initial wetness of north-western Schleswig-Holstein and (2) strong event precipitation in southern and eastern Schleswig-Holstein from 21 to 23 December; at the same time, both indices exceeded their respective 5-year return periods. Further, trend analyses show that both API and R3d have been increasing during recent years, while regional patterns match the north-eastward shift of cyclone pathways, leading to a higher risk of flooding in Schleswig-Holstein. Within the network of experts, investigations of these and further indices/drivers for earth system changes (e.g. wind surge and sea level rise) derived from observations, reanalyses, and regional climate model data are planned for all German coastal areas. Results can be expected to lead to improved adaptation measures to floods under climate change conditions wherever catchments have to be drained and infrastructures and ecosystems may be harmed.	44	2017	10.5194/esd-8-405-2017	
Improving climate change adaptation in least developed Asia	Sovacool, BK; D'Agostino, AL; Rawlani, A; Meenawat, H	ENVIRONMENTAL SCIENCE & POLICY	English	Article	Adaptation; Adaptive capacity; Resilience; Least developed countries; Asia	RESILIENCE	This article investigates the climate vulnerabilities of four least developed Asian countries Bangladesh, Bhutan, Cambodia, and the Maldives-before discussing how efforts are underway to strengthen infrastructural, organizational, and community-based adaptation. Infrastructural adaptation refers to the assets, technologies, or hardware that can withstand climate change impacts, such as climate-proofed irrigation systems, roads, or electricity networks. Organizational adaptation refers to the endurance of an effective institution or set of institutions, usually government ministries or departments, in charge of planning and policy, as well as its capacity to develop and revise climate policies. Social adaptation refers to the cohesion of communities and the livelihoods of the people that compose them. We argue that resilient adaptation infrastructures can recover quickly from climate disruptions, resilient organizations can cope with new stresses and changes and still function, resilient communities have assets such as education or wealth that enable them to survive or even thrive in the face of climate-related challenges. Ongoing adaptation efforts in Bangladesh, Bhutan, Cambodia, and the Maldives are examples of projects that simultaneously attempt to enhance all three dimensions of adaptation. Data for these cases comes primarily from a review of country National Adaptation Programs of Action (NAPAs) supplemented with research interviews and site visits. (C) 2012 Elsevier Ltd. All rights reserved.	44	2012	10.1016/j.envsci.2012.04.009	
Measuring the effects of urban heat island mitigation techniques in the field: Application to the case of pavement-watering in Paris	Hendel M., Gutierrez P., Colombert M., Diab Y., Royon L.	Urban Climate	English	Article	Climate change adaptation; Evaporative cooling; Pavement-watering; Urban field measurements; Urban heat island; Urban heat island countermeasure		Urban heat island (UHI) countermeasures are of growing interest for cities. Field studies of their micro-climatic effects are scarce, yet are essential to properly evaluate their effectiveness and that of anti-UHI policies. The standard approach to determining their micro-climatic effects is to study the difference in measurements made at case and control stations. However, measurements conducted during a pavement-watering experiment in Paris, France reveal that this method mistakes preexisting differences for pavement-watering effects. An alternative approach based on a two-sample t-test was therefore developed and tested with the pavement-watering field trial as a case study. The proposed method proved able to determine the effects of pavement-watering, without misinterpreting preexisting differences. In the process of the case study, watering was found to reduce maximum daily heat stress, while having smaller statistically significant UHI-reducing effects. The greatest effects were reached during the day for all parameters with maximum reductions of 0.79 °C, 1.76 °C and 1.03 °C for air, mean radiant and UTCI-equivalent temperatures and a 4.1% increase in relative humidity, while UHI-mitigation reached up to -0.22 °C. The methodology developed is not specific to pavement-watering and recommendations for its improvement and its application to the field-evaluation of other UHI countermeasures are made. © 2016 Elsevier B.V.	44	2016	10.1016/j.uclim.2016.02.003	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Perceptions of visual and in situ representations of sea level rise and tidal flooding: the blue line project, Norfolk, Virginia	Hutton, NS; Allen, TR	GEOJOURNAL	English	Article	Sea level rise; Visualization; Community resilience; Coastal management	CLIMATE-CHANGE; HAMPTON ROADS; GREEN INFRASTRUCTURE; NATURAL HAZARDS; PUBLIC-HEALTH; RESILIENCE; VULNERABILITY; JUSTICE; FUTURE; DESIGN	Future maps and visualizations of sea level rise struggle to convey the salience of evolving coastal hazards on the ground. This study engaged three Norfolk, Virginia communities in the Blue Line project to identify the appealing components of various types of visualizations and determine which images increase risk perceptions, contribute to the selection of adaptation or mitigation strategies, and elicit protective actions. Participants viewed models of future high tide shorelines for 2050, 2080, and 2100 as digitized maps and photographs of the lines marked on the ground with tape, spray chalk, and flags at three different communities: a residential neighborhood and park; a downtown museum and open space; and a working waterfront. Results indicate that while the combination of maps and photographs were preferred for the realism conveyed, maps were better able to show a larger area and photographs were more personal. Photographs balanced the reactions to maps, which were preferred, and increased the perception of sea level rise, but also elicited built solutions. Citizens expressed greater immediacy for action in residential areas even if the perceived risk was higher in heritage areas. These results can inform the balance of visualization types utilized by planners and community organizations to create a comprehensive plan through participatory processes.	44	2022	10.1007/s10708-020-10356-4	
Residence and Job Location Change Choice Behavior under Flooding and Cyclone Impacts in Bangladesh	Lu, LJ; Lu, QC; Rahman, ABMS	SUSTAINABILITY	English	Article	choice behavior; residence and job location change; flooding; cyclone; climate change	SEA-LEVEL RISE; CLIMATE-CHANGE; WEATHER CONDITIONS; TRAVEL BEHAVIOR; VULNERABILITY ANALYSIS; ADAPTATION STRATEGIES; HUMAN MIGRATION; TRANSPORTATION; LINKS; ROBUSTNESS	Climate change enters significantly into and is shown to be a direct determinant of residence and job location change decisions. Understanding of how people's residence and job location change choice behavior is affected and thus responds to the impacts of climate change is essential for transportation planners and adaptation decision makers. As an addition to the current literature, the main purposes of this paper are to investigate people's residence and job location change choice behavior affected by factors at origin and look into the behavioral differences between coastal and inland people under flooding and cyclone scenarios in Bangladesh. Questionnaire data were surveyed in 14 coastal and inland cities of Bangladesh with an orthogonal design of three flooding/cyclone scenarios. The multinomial Logit model and cross-nested Logit model are proposed to address the above purposes. Results of this study indicate that flooding/cyclone factors and income, land owned, and number of family members significantly affects people's location change choice. In addition, coastal people are also significantly affected by previous experience factors. Furthermore, road connection plays an important role when people choose to change residence locations in coastal areas. It is also found that if there are changes in flooding impacts, the inland people will first consider to change their job locations, while the coastal people would consider both job and residence location changes. Results of this work provide policy suggestions on transportation infrastructure investment, shelter planning and construction, and population migration under flood and cyclone impacts as a result of climate change.	44	2015	10.3390/su70911612	
Road Drainage in Sweden: Current Practice and Suggestions for Adaptation to Climate Change	Kalantari, Z; Folkeson, L	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Infrastructure; Road transportation system; Adaptation; Operation and maintenance	OREGON; IMPACT; STEEP	This paper describes current practice in road surface and subsurface drainage in Sweden and analyzes the necessity for adaptation of the planning, construction, operation, maintenance and monitoring of road drainage measures to climate change. Based on a survey of professionals working with various aspects of road drainage, the study sought to identify: (1) problems experienced concerning road drainage, focusing on the current Swedish climate; (2) future problems regarding climate change impacts such as flooding and high flows; and (3) suggestions for adaptation measures concerning road drainage systems, taking future climate change into account. Suggested improvements concerning management and planning included clarification of responsibility for drainage issues, better overview of the location and condition of drainage facilities, inclusion of drainage system maintenance in procurement of operation contracts, maintenance plans for drainage facilities, and monitoring and inspection of drainage measures. Suggestions concerning drainage system construction, operation and maintenance included increasing the capacity of drainage facilities, stabilizing ditch slopes and various measures to prevent clogging of culverts. (C) 2013 American Society of Civil Engineers.	44	2013	10.1061/(ASCE)IS.1943-555X.0000119	
Consortium for Atlantic Regional Assessment: Information tools for community adaptation to changes in climate or land use	Dempsey, R; Fisher, A	RISK ANALYSIS	English	Article	climate change; climate projections; community decisionmaking; decision support; land-use change; local case studies; stakeholder participation	PEOPLE KNOW; VULNERABILITY; PERCEPTIONS; COUNTY	To inform local and regional decisions about protecting short-term and long-term quality of life, the Consortium for Atlantic Regional Assessment (CARA) provides data and tools (for the northeastern United States) that can help decisionmakers understand how outcomes of their decisions could be affected by potential changes in both climate and land use. On an interactive, user-friendly website, CARA has amassed data on climate (historical records and future projections for seven global climate models), land cover, and socioeconomic and environmental variables, along with tools to help decisionmakers tailor the data for their own decision types and locations. CARA Advisory Council stakeholders help identify what information and tools stakeholders would find most useful and how to present these: they also provide in-depth feedback for subregion case studies. General lessons include: (1) decisionmakers want detailed local projections for periods short enough to account for extreme events, in contrast to the broader spatial and temporal observations and projections that are available or consistent at a regional level; (2) stakeholders will not use such a website unless it is visually appealing and easy to find the information they want; (3) some stakeholders need background while others want to go immediately to data, and some want maps while others want text or tables. This article also compares what has been learned across case studies of Cape May County, New Jersey, Cape Cod, Massachusetts, and Hampton Roads, Virginia, relating specifically to sea-level rise. Lessons include: (1) groups can be affected differently by physical dangers compared with economic dangers; (2) decisions will differ according to decision makers' preferences about waiting and risk tolerance; (3) future scenarios and maps can help assess the impacts of dangers to emergency evacuation routes, homes, and infrastructure, and the natural environment; (4) residents' and decisionmakers' perceptions are affected by information about potential local impacts from global climate change.	43	2005	10.1111/j.1539-6924.2005.00695.x	
Resilience Versus Risk Assessing Cost of Climate Change Adaptation to California's Transportation System and the City of Sacramento, California	Schweikert, A; Espinet, X; Goldstein, S; Chinowsky, P	TRANSPORTATION RESEARCH RECORD	English	Article		IMPACT	Quantitative assessment of the vulnerability and adaptation options of road infrastructure and economic impacts of climate change is essential to building a more robust and resilient transportation network. To date, most research has focused on qualitative statements and broad findings or on location-specific case studies. This study details a quantitative, engineering-based analysis of the impacts of specific climate stressors on types of road infrastructure. The results are designed to be utilized by transportation planners to understand the vulnerability, risk, and adaptation options for creating a climate-resilient road network by providing specific design changes and fiscal cost analysis. The current study aims to build on previous work and addresses several gaps: use of all climate models approved by the Intergovernmental Panel on Climate Change to provide guidance despite uncertainty, provision of results similar to existing risk and vulnerability analyses to allow for implementation in existing planning processes, and introduction of a methodology requiring only routinely available road network information to allow for replicability across the United States. California is used as an illustrative case study that helps identify the existing vulnerabilities of the road network to climate change and the fiscal savings possible through pro-active adaptation strategies. Findings show that for the higher-impact model (95th percentile), California could save $1.9 billion between 2015 and 2050 by proactive adaptation. The contribution of this research is to move beyond the identification of vulnerabilities to a quantitative assessment of specific adaptation options that reduce a community's or region's vulnerability to climate change.	43	2015	10.3141/2532-02	
A framework for assessing the risks and impacts of rural access roads to a changing climate	le Roux, A; Khuluse-Makhanya, S; Arnold, K; Engelbrechet, F; Paige-Green, P; Verhaeghe, B	INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION	English	Article		TRANSPORT	African communities are worst affected by climate-related natural disasters, in part due to high socio-economic vulnerability, natural resource dependency and low adaptive capacity. Climate resilient road infrastructure in rural areas is critical for improving quality of live. For this reason, a geospatial risk and vulnerability assessment method was developed as a tool for determining where access roads, and the communities they serve, are most at risk to the effects of a changing climate. This is intended to help guide, through prioritisation, the identification of high-risk areas where appropriate climate adaptation measures would be most effective in reducing the impacts of climate variability and change. The research methodology relies on using GIS processes and spatial data to calculate a composite climate risk index, the combined output of a hazard exposure index as well as a road criticality index. The analysis methodology was applied to Mozambique, where large parts of the country were found to be at very high risk to change in terms of rural accessibility given the countries high and recurrent exposure to extreme floods. Downscaled climate simulations for a 2050 future under a low mitigation scenario indicated that pronounced increases in rainfall and cyclone activity are plausible in northern Mozambique, whilst the southern region may become hotter and drier. Prioritisation is thus crucial for more effective and efficient asset management. The methodology was found to be an efficient and effective way of identifying high-risk regions in terms of community access and the physical impact of climate on road infrastructure.	42	2019	10.1016/j.ijdrr.2019.101175	
Developing a GIS tool for emergency urban cooling in case of heat-waves	Hendel, M; Bobee, C; Karam, G; Parison, S; Berthe, A; Bordin, P	URBAN CLIMATE	English	Article	Climate change adaptation; Heat waves; Urban cooling; Emergency heat wave response; Decision support tool	VULNERABILITY INDEX; PAVEMENT; TEMPERATURE; LONDON; SCALE; RISK	Many cities are expected to face a strong increase in the frequency and intensity of heat-waves by the end of the 21st Century due to climate change. In Paris, the frequency of heat-waves could rise from an average of one day per year to 14-26 days per year, with temperatures reaching up to 50 degrees C. Since 2012, pavement-watering is viewed as a potential tool for emergency cooling by the city while scientific work on the technique has found its application to be best suited to densely built urban areas, compared for example to urban greening whose impact may be hindered by lack of available planting space. This paper proposes an interdisciplinary approach combining urban physics with social sciences to develop such a GIS model for pavement-watering as an emergency response to heat-waves in Paris. It is built on performance criteria derived from previous work are input into a Geographic Information System to identify urban areas where pavement-watering would be most effective. In addition, a heat-related health risk assessment is conducted, using microclimatic, urban and socio-economic layers, to single out areas where heat-wave risk is highest in public spaces, combining high temperatures, pedestrian traffic and local population vulnerability. The microclimatic hazard dataset includes a physical model of park and water body cool islands assuming they are driven by thermal diffusion. The resulting tool has significant flexibility in defining the thresholds of the different indicators. The mapping scheme identified a total of 50 to 200 km of high priority areas for pavement-watering, requiring between 1400 and 5800 m3)/day of non-potable water, equivalent to 0.6 to 2.6 L/day per capita. Limitations due to data quality or resolution are discussed as well as paths for further improvement.	42	2020	10.1016/j.uclim.2020.100646	
Multimodal transportation system protection against sea level rise	Sun, JY; Chow, ACH; Madanat, SM	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Sea level rise; Transportation infrastructure; Inundation; Operational landscape units; Public transit; Multimodal	CLIMATE-CHANGE; LAND-USE; ADAPTATION; VULNERABILITY; IMPACTS; BOSTON	Transportation infrastructure resilience is an important component of a region's ability to recover from natural disasters. While Sea Level Rise (SLR) is becoming inevitable with climate change, little is known of the impact of protection strategies on multiple modes of transport. The present paper proposes a framework where a range of coastal protection strategies are undertaken in the case of one meter of SLR (expected by the year 2100). The methodology incorporates high-resolution hydrodynamic simulations using the Coastal Storm Modeling System (CoSMoS) and traffic simulations using the Multi-Agent Transport Simulation (MATSim) to quantify the potential impact of SLR and protection strategies on both the highway and public transit systems in the San Francisco Bay Area. The results of the traffic simulations are analyzed at the regional and Transportation Analysis Zone (TAZ) levels. Modeling results show that coastal protection of one area will affect the transportation system (sometimes negatively) in areas beyond its vicinity. The improved spatial resolution, and the integration of highway and transit networks in a unified model, reveal transportation phenomena that were not identified in previous studies. By quantifying the impacts on commuters' mobility in different TAZs, the methodology can be used to develop effective and inclusive strategies against SLR for a given region of interest.	42	2020	10.1016/j.trd.2020.102568	
The Sustainability of Post-crisis Management on Flooding Prevention	Lauesen, LM	Proceedings Paper	English	Proceedings Paper	Flooding; Finance; Politics; Security; Stormwater management Sustainability	LOW IMPACT DEVELOPMENT; CLIMATE ADAPTATION; INFRASTRUCTURE; CITIES	The climate change has in the past decades given more extreme rain events, both in terms of intensity and duration, and recurring storm related sea-level rises happen these years almost annually according to different weather cycles around the World. The public policies and management of these events and the initiatives taken to prevent the damages from them have changed during these few decades mainly because of the recession following the financial crisis in 2007/2008. Before the financial crisis, municipalities and their water companies built large capacity basins in order to store stormwater masses in the sewer systems. After the crisis, on-ground rainwater management has become the new best management practice trying to prevent extreme water masses from the sewer system. The new use of the landscape; the green spaces as well as the city roads and parking lots for rainwater storage and transportation is claimed to be less costly than sewer/basin solutions. At the same time, costs for coastal security is rising, and small communities are lacking funds for building floodgates and -walls to protect the coastal cities from the sea-level rises. This turn in BMP is happening worldwide in countries and states struggling with extreme water events. Seemingly, it is all initiated from political pressure on minimizing public expenditure in general, and therefore also on infrastructure and security. This chapter reviews the international literature on flooding prevention and its relation to public policies and management and as an example shows the history of climate adaptation in Denmark. With cases from Denmark, the chapter shows that on-ground flooding prevention risk being even costlier than earlier, because the new ex-sewer solutions are not (necessarily) cheaper than traditional sewer systems especially in the highly paved cities, where the problem is most urgent. These findings supports the UNEP 2014 forecasts of tripling the costs for flooding prevention by 2050 compared to earlier estimates from 2010.	42	2019	10.1007/978-981-13-1047-8_7	
Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development	Neumann, JE; Chinowsky, P; Helman, J; Black, M; Fant, C; Strzepek, K; Martinich, J	CLIMATIC CHANGE	English	Article	Rail; Roads; Coastal development; Infrastructure; Proactive adaptation	COSTS	Changes in temperature, precipitation, sea level, and coastal storms will likely increase the vulnerability of infrastructure across the USA. Using models that analyze vulnerability, impacts, and adaptation, this paper estimates impacts to railroad, roads, and coastal properties under three infrastructure management response scenarios: No Adaptation; Reactive Adaptation, and Proactive Adaptation. Comparing damages under each of these potential responses provides strong support for facilitating effective adaptation in these three sectors. Under a high greenhouse gas emissions scenario and without adaptation, overall costs are projected to range in the $100s of billions annually by the end of this century. The first (reactive) tier of adaptation action, however, reduces costs by a factor of 10, and the second (proactive) tier reduces total costs across all three sectors to the low $10s of billions annually. For the rail and road sectors, estimated costs for Reactive and Proactive Adaptation scenarios capture a broader share of potential impacts, including selected indirect costs to rail and road users, and so are consistently about a factor of 2 higher than prior estimates. The results highlight the importance of considering climate risks in infrastructure planning and management.	41	2021	10.1007/s10584-021-03179-w	
Assessing real options in urban surface water flood risk management under climate change	Liu, HX; Wang, YT; Zhang, C; Chen, AS; Fu, GT	NATURAL HAZARDS	English	Article	Real options; Flood risk; Climate change; Adaptation measures; NPV; SuDS	INVESTMENT OPPORTUNITY; DECISION-MAKING; ADAPTATION; INFRASTRUCTURE; FRAMEWORK; BENEFITS; CHINA; MODEL	Developing an adaptation option is challenging for long-term engineering decisions due to uncertain future climatic conditions; this is especially true for urban flood risk management. This study develops a real options approach to assess adaptation options in urban surface water flood risk management under climate change. This approach is demonstrated using a case study of Waterloo in London, UK, in which three Sustainable Drainage System (SuDS) measures for surface water flood management, i.e., green roof, bio-retention and permeable pavement, are assessed. A trinomial tree model is used to represent the change in rainfall intensity over future horizons (2050s and 2080s) with the climate change data from UK Climate Projections 2009. A two-dimensional Cellular Automata-based model CADDIES is used to simulate surface water flooding. The results from the case study indicate that the real options approach is more cost-effective than the fixed adaptation approach. The benefit of real options adaptations is found to be higher with an increasing cost of SuDS measures compared to fixed adaptation. This study provides new evidence on the benefits of real options analysis in urban surface water flood risk management given the uncertainty associated with climate change.	40	2018	10.1007/s11069-018-3349-1	
Assessment of vulnerability and adaptation to sea-level rise for the coastal zone of Germany	Sterr, H	JOURNAL OF COASTAL RESEARCH	English	Article	storm floods; coastal risks; assessment scales; North Sea; Baltic Sea	CLIMATE-CHANGE	Germany's coast extends over 3700 km on both the North and Baltic Seas and is shared by five coastal states. Major seaport cities, Hamburg and Bremen, form two of these states, whereas rural areas and small and medium-size coastal towns comprise the other three coastal states. Along the coast large low-lying areas are already threatened by recurring storm flood events and erosion. Accelerated sea-level rise therefore exacerbates a high-risk situation. It is estimated that under a 1-m accelerated sea-level rise scenario the recurrence of devastating storm floods that presently have a probability of I in 100 will decrease to a 1 in 10 or even 1 in I probability. Vulnerability assessments have been carried out in Germany at three scales: (i) the national level, i.e., for all coastal areas lying below 5 m (Baltic Sea Coast) and 10 m (North Sea Coast), (ii) the regional level for the coastal state of Schleswig-Holstein, and (iii) the local level for selected communities within this state. When comparing findings from these analyses, the results show that the economic risks of flooding and erosion are highest when detailed studies covering the full range of infrastructure assets are used. However, the actual risk areas in detailed studies may be more confined when considering local topography and infrastructure such as road dams. Nationally, an accelerated sea-level rise of 1 m would put more than 300,000 people at risk in the coastal cities and communities, and economic values endangered by flooding and erosion would amount to more than 300 billion US$ (based on 1995 values). This is why German coastal states are following a strategy based on hard coastal protection measures against flooding, although authorities realize that maintaining and/or improving these defence structures might become rather costly in the long-term. Although additional investment in flood and erosion protection will be considerable (estimated at more than 500 million US$) this seems manageable for the national and regional economies. On the other hand, hard coastline defence and accelerated sea-level rise will increase coastal squeeze on the seaward side, endangering important coastal ecosystems such as tidal flats (Wadden Sea), saltmarshes, and dunes. Currently there is no strategy to remedy this increasing ecological vulnerability.	40	2008	10.2112/07A-0011.1	
Sustainable urban mobility plans: Bridging climate change and equity targets?	Arsenio, E; Martens, K; Di Ciommo, F	RESEARCH IN TRANSPORTATION ECONOMICS	English	Article; Proceedings Paper	Climate change; Sustainable urban mobility plans; Equity in transport; Urban transport policy	ISSUES	The European Commission (EC) introduced the concept of Sustainable Urban Mobility Plans (SUMPs) as a new planning paradigm with a focus on people's needs Planning for people. This represents a change from traditional planning approaches centred on motorized road traffic/infrastructure provision and a shift towards more sustainable transport options. SUMPs require a long-term and sustainable vision for cities and these are to pay special attention to the participation of citizens and stakeholders and to coordination of policies across sectors (transport, land use, health, energy, and so on). The EC guidelines on developing and implementing SUMPs (EC, 2013) establish the following primary objectives of this new way of planning urban mobility: accessibility and quality of life, as well as sustainability, economic viability, social equity, health and environment quality. Since urban areas in Europe account for 23%-25% of CO2 emissions from transport (EC, 2013b; EEA, 2014), SUMPs are expected to contribute to meet longterm climate change policy goals. However, it is less clear how SUMPs can contribute to address key societal challenges such as equity issues in accessibility. According to the EC guidelines SUMPs are still non-existing concepts in most European member states. However, several cities in Europe and beyond have already formulated and adopted SUMPs. This paper is built on a review of former voluntary SUMPs developed in Portugal. A sample of forty case studies is considered in the analysis. It aims: a) to understand how climate change goals and equity issues in accessibility have been addressed through the first generation of SUMPs; b) to reflect on the role of SUMPs as tools to answer climate change goals without putting at risk social equity issues, and c) to outline further research needs in the SUMP approach. The research results are expected to give insights into social equity needs in urban transport and climate change adaptation policies in Europe. (C) 2016 Elsevier Ltd. All rights reserved.	40	2016	10.1016/j.retrec.2016.04.008	
Adoption of Road Water Harvesting Practices and Their Impacts: Evidence from a Semi-Arid Region of Ethiopia	Gebru, KM; Woldearegay, K; van Steenbergen, F; Beyene, A; Vera, LF; Gebreegziabher, KT; Alemayhu, T	SUSTAINABILITY	English	Article	adoption; farmyard manure; fertilizer; income; Northern Ethiopia; road water harvesting; yield	TECHNOLOGIES; IRRIGATION; MANAGEMENT; POVERTY; AREAS	In the drylands of Ethiopia, several road water harvesting practices (RWHP) have been used to supplement rain-fed agriculture. However, factors affecting adoption of RWHP and their impacts were not studied systematically. Understanding the factors influencing the adoption of RWHP for sustainable agricultural intensification and climate resilience is critical to promoting such technologies. This paper investigates the impacts of using rural roads to harvest rainwater runoff and the factors causing farmers to adopt the practice. Road water harvesting is considered a possible mechanism for transformative climate change adaptation. By systematically capturing rainfall with rural road infrastructure, rain-related road damage is reduced, erosion and landscape degradation due to road development is lessened, and farm incomes increase due to the beneficial use of harvested water, resulting in an increased climate change resilience. This paper uses a binary probit model and propensity score matching methods based on a household survey of 159 households and 603 plots. The results of the probit model show that the education level of the household, family labor, access to markets, and distance of the farming plot from the farmer's dwelling are statistically significant in explaining farmers' adoption of RWHP in the study area. The casual impact estimation from the propensity score matching suggests that RWHP has positive and significant impacts on input uses (farmyard manure and fertilizer), crop yield, and farm income among the sample households.	39	2020	10.3390/su12218914	
Assessing impacts of climate change on flexible pavement service life based on Falling Weight Deflectometer measurements	Qiao, YN; Zhang, Y; Zhu, YF; Lemkus, T; Stoner, AMK; Zhang, JZ; Cui, YL	PHYSICS AND CHEMISTRY OF THE EARTH	English	Article	Flexible pavements; Resilience; Stiffness; CMIP5; Artificial neural networks	INFRASTRUCTURE; TEMPERATURE; PERFORMANCE; COSTS	Flexible pavements are typically designed using historical climate but are challenged by future climate change. Quantifying impacts of climate change on pavement service life can assist road authorities in planning for climate adaptation and, eventually, build climate resilience into road infrastructure design and management. In this study, a novel data-driven methodology is developed in order to quantify impacts of climate change on pavement service life in locations where Falling Weight Deflectometer (FWD) data are continuously measured, by means of: 1) training a supervised model (linear regression or Artificial Neural Networks, ANN) using historical climate data, maintenance, and traffic data as the candidate inputs and pavement layer stiffness back calculated from FWD testing as the outputs; 2) predicting layer stiffness using statistically downscaled future climate projections for three Coupled Model Intercomparison Project Phase 5 global climate models and three greenhouse gas concentration scenarios for four future 20-year periods; and 3) estimating changes in pavement stiffness and service lives due to climate change. A case study performed on a pavement section in Minnesota has shown that pavement layer stiffness will have a long-term reduction under future climate and the investigated pavement will lose up to 22.5% service life at the end of the century (2080-2099) from the 20 years' service life compared to the baseline climate (1979-1998).	39	2020	10.1016/j.pce.2020.102908	
Enhancing future resilience in urban drainage system: Green versus grey infrastructure	Dong, X; Guo, H; Zeng, SY	WATER RESEARCH	English	Article	Urban drainage system; Resilience; Grey infrastructure; Green infrastructure; Climate change	CLIMATE-CHANGE; EXTREME PRECIPITATION; URBANIZATION; FRAMEWORK; IMPACTS	In recent years, the concept transition from fail-safe to safe-to-fail makes the application of resilience analysis popular in urban drainage systems (UDSs) with various implications and quantifications. However, most existing definitions of UDSs resilience are confined to the severity of flooding, while uncertainties from climate change and urbanization are not considered. In this research, we take into account the functional variety, topological complexity, and disturbance randomness of UDSs and define a new formula of resilience based on three parts of system severity, i.e. social severity affected by urban flooding, environmental severity caused by sewer overflow, and technological severity considering the safe operation of downstream facilities. A case study in Kunming, China is designed to compare the effect of green and grey infrastructure strategies on the enhancement of system resilience together with their costs. Different system configurations with green roofs, permeable pavement and storage tanks are compared by scenario analysis with full consideration of future uncertainties induced by urbanization and climate change. The research contributes to the development of sustainability assessment of urban drainage system with consideration of the resilience of green and grey infrastructure under future change. Finding the response measures with high adaptation across a variety of future scenarios is crucial to establish sustainable urban drainage system in a long term. (C) 2017 Published by Elsevier Ltd.	39	2017	10.1016/j.watres.2017.07.038	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Extreme weather disasters challenges for sustainable development: Innovating a science and policy framework for disaster-resilient and sustainable Quezon City, Philippines	Raza, T; Liwag, CREU; Andres, AVL; Castro, JT; Cuna, AC; Vinarao, VG; Raza, TKS; Marasigan, KME; Espinosa, RIM; Rentoy, FC; Perez, BD; Ahmed, N	PROGRESS IN DISASTER SCIENCE	English	Article	Disaster risk reduction; Adaptive capacity; Hazard threat level; Relative vulnerability; Sustainable development	CLIMATE-CHANGE; RISK REDUCTION	The cities in Southeast Asian and Small Island Developing States have distorted the natural environment by haphazardly constructing roads, buildings, and other infrastructures. Such massive changes in the environment are altering the ecology, creating sustainable development challenges such as climate-related extreme weather events. Super Typhoon Haiyan devastated portions of Southeast Asia, particularly the Philippines, on November 8, 2013, that caused physical and psychological illnesses to the affected. To prevent these impacts and make cities sustainably develop and Climate Change (CC) resilient, a Science and Policy Framework (SPF) piloting Quezon City Local Government (QCLG) is developed. The application of SPF revealed, among others, the QCLG institutional and personnel adaptive capacities, threat level of CC-related hazards on development growth sectors and institutional and personnel relative vulnerabilities. These findings allowed QCLG to develop sectoral Local Climate Change Action Plan (LCCAP) 2017-2027 to mainstream CC Adaptation (CCA) at the very early stages of development planning. The SPF and LCCAP are flexible and fashioned toward enhancing key development sectors in creating sustainable and CCA-resilient Cities. They can be globally-effective tools for achieving the Paris Agreement, Sustainable Development Goals, and targets of the Sendai Framework.	39	2020	10.1016/j.pdisas.2020.100066	
Impact Assessment and Management Challenges of Key Rural Human Health Infrastructure Under Sea Level Rise	Mitchell, M; Isdell, RE; Herman, J; Tomlinson, C	FRONTIERS IN MARINE SCIENCE	English	Article	sea level rise; human health; risk assessment; adaptation; climate change; septic; resilience		Accelerating sea level rise in Virginia, United States, will significantly increase the flooding threat to low-lying roads, residences, and critical infrastructure as well as raise the water table, allowing saltwater intrusion into well water and threatening the function of septic fields. Although most of the adaptation work in Virginia has focused on urban economic centers, the majority of the coastline is rural and faces different threats and opportunities to address them compared to urban areas due to their reduced economic assets and their reliance on private infrastructure. In this case study, we assess the potential for geospatially quantifying impact to septic systems and adjacent water ways due to sea level rise. The case study found that the data necessary to reliably quantify these impacts on a state-wide scale are lacking and collection of that information needs to be prioritized given the potential for extensive sea level impacts.	39	2021	10.3389/fmars.2021.631757	
Incorporating the Effects of Climate Change into Bridge Deterioration Modeling: The Case of Slab-on-Girder Highway Bridge Deck Designs across Canada	Guest, G; Zhang, JY; Atadero, R; Shirkhani, H	JOURNAL OF MATERIALS IN CIVIL ENGINEERING	English	Article	Climate change; Adaptation; Bridge deck; Corrosion; Concrete	CONCRETE STRUCTURES; RC STRUCTURES; CORROSION; REINFORCEMENT; DURABILITY; DIFFUSION; CRACKING; COVER	Climate change is expected to impact both the operational and structural performance of infrastructure such as buildings, roads, and bridges. However, infrastructure design guides widely rely on historical climate data, if any, for informing design requirements. The goal of this research was to explore a methodology for modeling bridge deck design against corrosion attack in a changing climate. Three deterioration stages were simulated to understand the time to deck failure. Corrosion initiation of reinforcing steel was considered by utilizing a deterministic diffusion-based model predicting the time to reinforcement corrosion initiation. Crack initiation and crack growth were also simulated using mechanistic approaches to illustrate the sensitivity of bridge deck deterioration and design service life to changes in bridge deck design and a changing climate across major cities in Canada. The findings indicate that a changing climate has the potential to significantly alter the service life of a bridge deck, but the effect is strongly dependent on the durability design of the bridge deck. It is recommended that bridge designers strive to utilize mechanistic-empirical models that incorporate high-resolution climate data as inputs for better understanding chanaes in deterioration as a consequence of a nonstationary climate.	39	2020	10.1061/(ASCE)MT.1943-5533.0003245	
Let's hit the road! Environmental hazards, materialities, and mobility justice: insights from Tajikistan's Pamirs	Blondin, S	JOURNAL OF ETHNIC AND MIGRATION STUDIES	English	Article; Early Access	Material mobilities; climate mobilities; infrastructure; mobility justice; Tajikistan	CLIMATE MIGRATION; ADAPTATION; IMMOBILITY; DISASTER; IMPACT; GOJAL	This article draws from the expanding field of climate mobilities, which explores the nexus between climate change, environmental conditions and (im)mobility based on the 'mobilities paradigm'. Environmental hazards collide with transportation infrastructures, for instance through the adverse effects of floods, heat waves, and ice thawing on roads, and may for instance disrupt or hamper everyday mobility. Frequent disaster-induced mobility impairments may render individuals unable to commute between places and decrease their socioeconomic opportunities. Emphasising the material aspects of mobilities, this paper argues that an analysis of mobility systems helps to develop a deeper understanding of (im)mobility inequalities and injustices in the context of environmental risk and climate change. Sheller's mobility justice perspective is taken as a way to critically address mobility disruptions and to reflect on the interconnection of different (im)mobility patterns. Empirically, the paper draws on a case-study of Tajikistan's Bartang Valley, where disaster-induced mobility impairments reduce the residents' capacities to circulate and access food markets, healthcare facilities, and job opportunities. Overall, the paper is an invitation for the fields of environmental and climate mobilities to consider the impacts of environmental conditions on infrastructures, matter, and things that enable or hamper human (im)mobility.	39	2022	10.1080/1369183X.2022.2066261	
Stakeholder collaboration as a pathway to climate adaptation at coastal ports	Morris, LL	MARITIME POLICY & MANAGEMENT	English	Article	Ports; climate change; climate adaptation; Hampton Roads; Virginia; stakeholder collaboration	RESILIENCE	In coastal regions of the U.S. maritime transportation system, compelling reasons exist for implementing measures for climate change adaptation. As the effects of climate change amplify the impacts of natural hazards, a critical aspect of the nation's overall resiliency includes the ability of the maritime and coastal sectors to recover effectively from external shocks and to adapt to changing environmental conditions in order to continue to provide the services the nation relies upon for economic viability and homeland security. This requires adaptation for physical infrastructure as well as organizational, operational, and community elements throughout the maritime transportation system. This paper provides a literature review of port climate adaptation approaches, which highlights the established need and opportunities for collaboration among coastal stakeholders to implement climate adaptation in port communities. The current lack of federal support in the United States for climate adaptation in the maritime sector emphasizes the need for novel methods and approaches to facilitate adaptation at individual port and regional levels. A case study from the port community of Hampton Roads, Virginia provides an example of the time and effort dedicated to stakeholder collaboration to encourage local understanding of climate risks in order to facilitate successful adaptation.	39	2020	10.1080/03088839.2020.1729435	
The Economic Impact of Climate Change on Road Infrastructure in Ghana	Twerefou, DK; Chinowsky, P; Adjei-Mantey, K; Strzepek, NL	SUSTAINABILITY	English	Article	climate change; stressor-response; roads; temperature		This paper estimates the economic impact of climate change on road infrastructure using the stressor-response methodology. Our analysis indicates that it could cumulatively (2020-2100) cost Ghana $473 million to maintain and repair damages caused to existing roads as a result of climate change (no adapt scenario). However, if the country adapts the design and construction of new road infrastructure, expected to occur over the asset's lifespan (adapt scenario), the total cumulative cost could increase to $678.47 million due to the initial costs of adaptation. This investment provides lower costs on a decadal basis later in the infrastructure lifespan. This creates the planning question of whether lower decadal costs in the future are a priority or if minimizing initial costs is a priority. The paper addresses this question through decadal and average annual costs up to the year 2100 for the ten regions, using the potential impacts of 54 distinct potential climate scenarios.	39	2015	10.3390/su70911949	
On the utilization of hydrological modelling for road drainage design under climate and land use change	Kalantari, Z; Briel, A; Lyon, SW; Olofsson, B; Folkeson, L	SCIENCE OF THE TOTAL ENVIRONMENT	English	Article	Clear-cutting; Extreme storm events; Runoff; Road infrastructure dimensioning; MIKE SHE	ADAPTATION; IMPACT	Road drainage structures are often designed using methods that do not consider process-based representations of a landscape's hydrological response. This may create inadequately sized structures as coupled land cover and climate changes can lead to an amplified hydrological response. This study aims to quantify potential increases of runoff in response to future extreme rain events in a 61 km(2) catchment (40% forested) in southwest Sweden using a physically-based hydrological modelling approach. We simulate peak discharge and water level (stage) at two types of pipe bridges and one culvert, both of which are commonly used at Swedish road/stream intersections, under combined forest clear-cutting and future climate scenarios for 2050 and 2100. The frequency of changes in peak flow and water level varies with time (seasonality) and storm size. These changes indicate that the magnitude of peak flow is highly correlated to specific storm rather than storm size. In all scenarios considered, the dimensions of the current culvert are insufficient to handle the increase in water level estimated using a physically-based modelling approach. It also appears that the water level at the pipe bridges changes differently depending on the size and timing of the storm events. The findings of the present study and the approach put forward should be considered when planning investigations on and maintenance for areas at risk of high water flows. In addition, the research highlights the utility of physically-based hydrological models to identify the appropriateness of road drainage structure dimensioning. (C) 2014 Elsevier B.V. All rights reserved.	38	2014	10.1016/j.scitotenv.2013.12.114	
Weakening mechanisms imposed on California's levees under multiyear extreme drought	Robinson J.D., Vahedifard F.	Climatic Change	English	Article		Bridges; Climate change; Drought; Levees; Organic carbon; Potable water; Soils; Building foundations; Drought conditions; Hydro-mechanical; Land subsidence; Microbial oxidation; Mitigation strategy; Soil desiccations; Soil organic carbon; Embankments; climate change; cracking; desiccation; drought; extreme event; infrastructure; levee; oxidation; resilience; risk assessment; soil erosion; thermohydromechanics; California; United States	California is currently suffering from a multiyear extreme drought and the impacts of the drought are anticipated to worsen with climate change. The resilience of California's critical infrastructure such as earthen levees under drought conditions is a major concern that is poorly understood. California maintains more than 21,000 km of urban and nonurban levees which protect dry land from floods and deliver two-thirds of the state's drinking water. Many of these levees are currently operating under a high failure risk condition. This essay argues that California's protracted drought can further threaten the integrity of these already at -risk levee systems through the imposition of several thermo-hydro-mechanical weakening processes. Pertinent facts and statistics regarding California's drought and current status of its levees are presented. Lessons from previous catastrophic levee failures and major damages which occurred under similar events are discussed. Weakening processes such as soil-strength reduction, soil desiccation cracking, land subsidence and surface erosion, and microbial oxidation of soil organic carbon are comprehensively evaluated to illustrate the adverse impacts that the ongoing California drought can have on levees. This essay calls for further research in light of these potential drought-induced weakening mechanisms to support adaptation and mitigation strategies to possibly avert future levee failures. These weakening processes can threaten any drought-stricken infrastructure interfacing with soil, including embankments, roads, bridges, building foundations, and pipelines. © 2016, Springer Science+Business Media Dordrecht.	38	2016	10.1007/s10584-016-1649-6	
A methodological approach to assess the territorial vulnerability in terms of people and road characteristics	Maletta, R; Mendicino, G	GEORISK-ASSESSMENT AND MANAGEMENT OF RISK FOR ENGINEERED SYSTEMS AND GEOHAZARDS	English	Review	Vulnerability; risk; disaster; emergency plan; road network; people	CLIMATE-CHANGE; ADAPTATION; RISK	The objective of this paper is to develop an assessment model for territorial vulnerability by measuring the spatial heterogeneity of proper indicators that amplify the natural and manmade hazards. The proposed study was carried out through an evaluation of the following components: people characteristics, emergency plan elements, operational structures of civil protection, and road infrastructure. A methodological approach was implemented to analyse the inhabitants, workers and other users' vulnerabilities, combining these with road network vulnerability. The application of a GIS-based model was used to capture, analyse, and manage the spatial data recorded on different scales and to visualise vulnerability results. A case study was proposed regarding a municipal area in Southern Italy that is frequently affected by floods and landslides which cause damage to the road network, limiting access to structures and resources. Results show how strategies and responses to emergency management will be different in each community and need to be reviewed as part of regular planning and prevention activities. The proposed study aims to create a tool that can be adjusted to user-specific needs to support decision-making, to reduce risk, and for disaster management at the local levels.	37	2022	10.1080/17499518.2020.1815214	
Adaptation strategies of transport infrastructures to global climate change	Rattanachot, W; Wang, YH; Chong, D; Suwansawas, S	TRANSPORT POLICY	English	Article	Climate change; Rural roads; Adaptation strategies; Policy development; Life-cycle cost analysis	GREENHOUSE-GAS EMISSIONS; REDUCTION; PAVEMENT	Scientific records provide clear evidence of rising atmospheric greenhouse gases (GHG) concentrations. Global warming and rising extreme weather events are believed to be a result. Besides proactively combating global climate change, transport agencies may need to develop strategies for better preparedness of the impacts of climate change. This is particularly important for certain regions that are more vulnerable to the potential damages caused by climate change. A methodological framework for developing such strategies is presented in the paper. The framework is illustrated through two examples: the management of rural roads in Thailand where the vast road network is being threatened by increasing floods and rising sea levels and the improvement of pavement design strategies for expressways along the coast of Hong Kong. Adaption measures are proposed for the highway agencies to address the challenges caused by climate change. (C) 2015 Elsevier Ltd. All rights reserved.	37	2015	10.1016/j.tranpol.2015.03.001	
Addressing Climate Change Resilience in Pavements: Major Vulnerability Issues and Adaptation Measures	Saleh, M; Hashemian, L	SUSTAINABILITY	English	Article	climate change resilience; adaptation strategies; mitigation measures; robust materials; mix design; uncertainty; pavement design		Climate change is the one of the greatest challenges of our time, and it poses a threat to the surrounding built and natural environments. This review paper addresses climate change resilience in pavements by considering major vulnerability issues and adaptation measures. First, a review on foundational information of climate change related to transportation infrastructure is provided to bring all transportation professionals and practitioners to the same knowledge base on climate change terminology. Such information includes sources of climate information, climate scenarios, downscaling climate data, and uncertainty in climate projection information. Relevant climate stressors to pavements are discussed in some depth, including the most significant ones, which are increases in temperature and precipitation intensity. Thus, the proposed different engineering-informed adaptation measures relevant to the climate stressors of interest were evidence-based with reference to published peer-reviewed articles and case studies. Such adaptation solutions are related to monitoring pavement key performance parameters and pavement adaptations in structural design, robust materials and mix design, along with adaptation in maintenance, regulation, and construction. Efforts to adapt pavement systems to climate change are ongoing. In addition to such research works, this study concludes that impacts of adaptation measures on pavement and environment should be incorporated in the decision-making process in planning and design. This makes it important to integrate practical adaptation strategies in design and construction standards and guides, and implement awareness and education of climate change adaptation among engineers and practitioners.	37	2022	10.3390/su14042410	
Stimulating flood damage mitigation through insurance: An assessment of the french catnat system	Poussin J.K., Botzen W.J.W., Aerts J.C.J.H.	Environmental Hazards	English	Article	Climate change adaptation; Damage mitigation; Floods; France; Insurance; Natural disasters	cause of death; climate change; database; flood damage; flooding; infrastructure; inventory; mitigation; road; Greece	Flood risk has increased in France in the last 20 years and is projected to increase further in the future due to climate change and increase in exposure. Since 1982, France has had a natural disasters insurance system ('CatNat') in place that covers flood damage. This insurance system has been combined with what are called 'Risk Prevention Plans' (PPRs) in order to stimulate the undertaking of flood risk mitigation measures by communities and households. However, these schemes do not provide optimal incentives for flood damage reduction. This is confirmed by the results from a survey about flood preparedness of 885 households who live in flood-prone areas in France, which are presented in this paper. Moreover, this study provides suggestions for improvement, which are assessed on their potential economic, social and political implications. Among these suggestions are increasing the effectiveness of PPRs and increasing the incentives to apply and implement PPRs; improving the monitoring of the implementation of damage mitigation measures; and the possibility to differentiate premiums and deductibles according to flood risk. © 2013 Taylor & Francis.	37	2013	10.1080/17477891.2013.832650	
Adaptation strategies for port infrastructure and facilities under climate change at the Kaohsiung port	Yang, YC; Ge, YE	TRANSPORT POLICY	English	Article	Sea port; Vulnerability analysis; Adaptation strategy; Climate change	IMPACT; RISK	The growing impact of climate change on port infrastructure and facilities currently may lead to a rising frequency of such serious natural disasters or accidents as rising sea level, increasing extreme weather, increasing intensity of tropical storms and typhoons, rising wave height surmounting breakwater design levels, heavy rain exceeding quay well drainage capacity, rising ocean temperatures, and deteriorating harbor water quality. The paper aims to apply a risk management matrix approach to vulnerability assessment and identification of desirable adaptation strategies. The data for this investigation is first collected by means of questionnaire survey of experts in shipping companies or port management offices at the Kaohsiung port. Then, a vulnerability analysis of port infrastructure and facilities is carried out under the impact of severe typhoons. Subsequently, adaptation strategies are identified for infrastructure and facilities at the Kaohsiung port to address the adverse impacts of climate change. One intellectual merit of this paper is that ten vulnerability assessment criteria are proposed for addressing the impacts of climate change on port infrastructure and facilities. Second, both ground and access roads in the port area, and drainage facilities in flooding-prone areas are shown to be damaged in the moderate risk areas potentially impacted by typhoons. The third merit is that a set of adaptation strategies has been identified for the moderate risk areas impacted by serious typhoons.	36	2020	10.1016/j.tranpol.2020.06.019	
Adapting to climate change: an integrated biophysical and economic assessment for Mozambique	Arndt, C; Strzepeck, K; Tarp, F; Thurlow, J; Fant, C; Wright, L	SUSTAINABILITY SCIENCE	English	Article	Climate change; Biophysical and economic outcomes; General equilibrium modelling; Mozambique		Mozambique, like many African countries, is already highly susceptible to climate variability and extreme weather events. Climate change threatens to heighten this vulnerability. In order to evaluate potential impacts and adaptation options for Mozambique, we develop an integrated modelling framework that translates atmospheric changes from general circulation model projections into biophysical outcomes via detailed hydrologic, crop, hydropower and infrastructure models. These sector models simulate a historical baseline and four extreme climate change scenarios. Sector results are then passed down to a dynamic computable general equilibrium model, which is used to estimate economy-wide impacts on national welfare, as well as the total cost of damages caused by climate change. Potential damages without changes in policy are significant; our discounted estimates range from US$ 2.3 to US $7.4 billion during 2003-2050. Our analysis identifies improved road design and agricultural sector investments as key 'no-regret' adaptation measures, alongside intensified efforts to develop a more flexible and resilient society. Our findings also support the need for cooperative river basin management and the regional coordination of adaptation strategies.	36	2011	10.1007/s11625-010-0118-9	
Best Management Practices for the Transition to a Water-Sensitive City in the South of Portugal	Rodrigues, M; Antunes, C	SUSTAINABILITY	English	Article	water-sensitive city; water-sensitive urban design; urban water cycle; resilience; best management practices; Quarteira		The uncertainty that arises from future environmental and climatic challenges requires new approaches towards urban water management in Mediterranean cities. In this work, an urban water cycle (UWC) strategy based on the best management practices (BMPs) of water-sensitive urban design (WSUD) is proposed for the transition of a coastal city in the south of Portugal into a water-sensitive city (WSC), in line with the Municipal Strategy for Climate Change Adaptation of Loulé (EMAAC of Loulé). The city's watershed was identified using the ArcMap Hydrology toolset with geospatial data provided by Loulé's Municipal Council Operational Unit for Adaptation to Climate Change and Circular Economy (UOACEC). A broad characterization of the study area was conducted, identifying existing resources to further develop a SWOT (strengths, weaknesses, opportunities, threats) analysis. The Hydrology toolset outputs, precipitation events records, and survey results were used to identify flood-prone areas. The opportunities and threats identified were further used to develop the transition strategy, which is focused on critical areas identified and supported by BMPs, including source control, attenuation, treatment and infiltration measures, permeable pavements, rainwater harvesting systems, and bioretention basins. The approach is designed to increase the city's resilience to climate extremes, as well as community engagement towards UWC management.	36	2021	10.3390/su13052983	
Climate Change and Economic Growth Prospects for Malawi: An Uncertainty Approach	Arndt, C; Schlosser, A; Strzepek, K; Thurlow, J	JOURNAL OF AFRICAN ECONOMIES	English	Article	CGE model; climate change; economic impact; Malawi; probabilistic analysis	AGRICULTURE; INVESTMENT; ADAPTATION; EMISSIONS; POVERTY; IMPACTS; ROADS	Malawi confronts a growth and development imperative that it must meet in a context characterised by rising temperatures and deep uncertainty about trends in precipitation. This article evaluates the potential implications of climate change for overall growth and development prospects in Malawi. We combine climate, biophysical and economic models to develop a structural analysis focused on three primary impact channels: agriculture, road infrastructure and hydropower generation. We account explicitly for the uncertainty in climate forecasts by exploiting the best available information on the likely distribution of climate outcomes. We find that climate change is unlikely to substantially slow overall economic growth over the next couple of decades. However, assuming that global emissions remain effectively unconstrained, climate change implications become more pronounced over time. Reduced agricultural yields and increased damage to road infrastructure due to increased frequency and intensity of extreme events are the principal impact channels. Owing to the potential for positive impacts in the near term, the net present value of climate impacts from 2007 to 2050 (using a 5% discount rate) can be positive or negative with an average loss of about USD 610 million. The main implication of our findings is that Malawian policy makers should look to exploit the coming decade or two as these represent a window of opportunity to develop smart and forward looking adaptation policies. As many of these policies take time to develop, implement, and then execute, there is little cause for complacency.	36	2014	10.1093/jae/eju013	
Climate change in asset management of infrastructure: A risk-based methodology applied to disruption of traffic on road networks due to the flooding of tunnels	Hulbregtse, E; Napoles, OM; Hellebrandt, L; Paprotny, D; de Wit, S	EUROPEAN JOURNAL OF TRANSPORT AND INFRASTRUCTURE RESEARCH	English	Article	climate change; infrastructure; asset management; risk-based design; probabilistic modelling; structured expert judgement	EXPERT JUDGMENT ASSESSMENT; INTERCONNECTED INFRASTRUCTURES; ADAPTIVE MANAGEMENT; EURO-CORDEX; ADAPTATION; IMPACT; UNCERTAINTY; FRAMEWORK	This paper presents a risk-based method to quantify climate change effects on road infrastructure, as a support for decision-making on interventions. This can be implemented in climate adaptation plans as an element of asset management. The method is illustrated by a specific case in which traffic on a road network is disrupted by the flooding of a tunnel due to extreme rainfall. Novel techniques to describe both probability of occurrence and consequences of an event are integrated into the proposed risk-based approach. To model a typical climate-change related phenomenon, i.e. rainfall intensity-duration, a model using copulas is proposed as well as a method to account for uncertainty using structured expert judgement. To quantify the consequences, an existing quick scan tool is adopted. The method calculates the risk of flooding of a tunnel, expressed in both probability of occurrence and subsequent additional travel duration on the road network. By comparison of this evolving risk to a societally acceptable threshold, the remaining resilience of the tunnel is evaluated. Furthermore, the method assesses the development of the resilience over time as a result of projected climate change. The maximum time-to-intervention is defined as the period up until the moment when the resilience is depleted. By application of the method to a tunnel in two different contexts, i.e. in a regional road network and a highway network, it is shown that the consequences of tunnel flooding may differ by an order of magnitude (25-fold for the example). Using a risk-based decision-making perspective leads to significant differences in the maximum time-to-intervention. In the example case the year of intervention is determined at 2020 for a tunnel in a highway network, while interventions can be postponed until 2140 in a regional road network.	36	2016		

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Implications of climate change for agricultural sector performance in Africa: Policy challenges and research agenda	Hassan R.M.	Journal of African Economies	English	Article		adaptive management; agricultural development; agricultural economics; agricultural policy; arid region; capital market; climate change; crop production; economic development; economic planning; farming system; green revolution; irrigation; livestock farming; policy development; semiarid region; Africa; Animalia	The paper analysed how climate change (CC) has shaped African agriculture in the past and how it might impact on African farm economies in the future and what adaptation strategies African farmers have adopted to cope with these changes. The analyses covered all key farming systems and agro-climates of Africa in 11 countries in which data were collected from over 10,000 farm household surveys. Results provided evidence that African agriculture and the welfare of its rural population are vulnerable to CC. The highest risk of future CC damages is associated with specialised crop and livestock farming (mono systems) particularly under dryland conditions in arid and semi-arid regions. This indicates how difficult it is to achieve an African green revolution under the current high reliance on dryland systems (more than 95% of the land) given predicted harsh future climates (warmer and dryer projections) for most of the dryland areas in Africa. It will require substantial public and private investments in expanding irrigation and development of crop var-ieties and animal breeds that are tolerant to heat, water and low fertility stress-ses, and in building roads and marketing infrastructures that will improve access to critical inputs (e.g., fertiliser) and output trade. This essentially requires mainstreaming climate sensitivity as an integral component of all agricultural and broader economic development planning and policy design. Although the expected damages are large, many farming systems and communities in Africa face serious limiting conditions which reduce their ability to adapt and hence increase their vulnerability. Among the key factors found to constrain African farmers' ability to adopt effective adaptation measures are poor access to information, capital, technology and markets. Policies aimed at promoting farm-level adaptation need to emphasise the critical role of farmers' education; provision of improved climate, production and market information and the means to implement adaptations through affordable credit facilities. Other needed public interventions to help promote adaptation measures and reduce vulnerability include insurance against climate risks to farmers and provision of safety nets. © The author 2010. Published by Oxford University Press on behalf of the Centre for the Study of African Economies. All rights reserved.	36	2010	10.1093/jae/ejp026	
A global economic assessment of city policies to reduce climate change impacts	Estrada, F; Botzen, WJW; Tol, RSJ	NATURE CLIMATE CHANGE	English	Article		URBAN HEAT-ISLAND; STRATEGIES; CITIES; VULNERABILITY	Climate change impacts can be especially large in cities[1,2]. Several large cities are taking climate change into account in long-term strategies[3,4], for which it is important to have information on the costs and benefits of adaptation[5]. Studies on climate change impacts in cities mostly focus on a limited set of countries and risks, for example sea-level rise, health and water resources[6]. Most of these studies are qualitative, except for the costs of sea-level rise in cities[7,8]. These impact estimates do not take into account that large cities will experience additional warming due to the urban heat island effect[9,10], that is, the change of local climate patterns caused by urbanization. Here we provide a quantitative assessment of the economic costs of the joint impacts of local and global climate change for all main cities around the world. Cost-benefit analyses are presented of urban heat island mitigation options, including green and cool roofs and cool pavements. It is shown that local actions can be a climate risk-reduction instrument. Furthermore, limiting the urban heat island through city adaptation plans can significantly amplify the benefits of international mitigation efforts.	35	2017	10.1038/NCLIMATE3301	
Designing resilient regions by applying Blue- Green Infrastructure concepts	Ghofrani, Z; Sposito, V; Faggian, R	SUSTAINABLE CITY XI	English	Proceedings Paper	sustainable region; climate change adaptation; Blue-Green Infrastructure; disaster management	MANAGEMENT; RETROFITS; AREAS	In Australia, weather extremes (droughts and floods) are an accepted component of coupled human-environment systems. Australia is the driest inhabited continent on earth and also has the greatest annual rainfall and run-off variability. Competition for water between the environment, agriculture and domestic uses is intense and the cause of much public debate. It is not unusual for parts of Australia to transition quickly from a state of extreme water scarcity to one of severe flooding. In fact, floods cause more damage in Australia than any other natural disaster. Climate change will exacerbate the situation through increased frequency and intensity of heavy rainfall events and also more intense and longer-lasting droughts. The combination of drought followed by intense rainfall increases the risk of severe flooding, with impacts on civil infrastructure (road and bridge washouts, damage to houses), and impacts on agriculture (soil erosion and destruction of crops and livestock). Structural flood mitigation activities in Australia, such as the construction of levees, was initially driven by private landholders. These measures were often not well planned or integrated at larger scales and therefore have been viewed with some suspicion. More recently, non-structural (land planning, emergency management) approaches have become the key flood mitigation measure. In contrast, The Netherlands takes a structural approach through concepts like Blue-Green Infrastructure (BGI), with the aim of giving the flood a pathway. In this context, structural interventions in the landscape provide alternative pathways for flood water, slowing the waters progress such that flood damage is mitigated. Our research focuses on the feasibility of implementing BGI in Australia, considering the costs and benefits in terms of the biophysical environment, infrastructure and socioeconomic systems, in order to increase the resilience of rural and regional communities. The research will inform strategic and statutory planning at the regional level.	35	2016	10.2495/SC160421	
Effects of sea level rise induced land use changes on traffic congestion	Papakonstantinou, I; Siwo, AT; Madanat, SM	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	English	Article	Sea-level rise; Highway infrastructure protection; Transportation networks; Land use changes	CLIMATE-CHANGE; INFRASTRUCTURE; IMPACTS	This research investigates how land use changes due to sea level rise (SLR) may affect traffic network congestion and how preventive protection measures against SLR can significantly improve transportation network performance and possibly be cost effective. We use the San Francisco Bay Area shoreline, under a one-meter SLR, as a case study, and evaluate the results with different metrics: the number of commuters that are not able to execute their trip, and the Vehicle Hours Traveled increase. Our model considers both hydrodynamic and traffic effects. The results show that the relocation of commercial and residential buildings from inundated to dry areas will increase congestion levels, while preventive protection of the shoreline leads to lower levels of traffic congestion. Finally, we discuss other possible costs related to the absence of levee protection that should be evaluated by policy makers before developing SLR adaptation strategies.	35	2020	10.1016/j.trd.2020.102515	
Disruption and adaptation of urban transport networks from flooding	Pregnolato, M; Ford, A; Dawson, R	3RD EUROPEAN CONFERENCE ON FLOOD RISK MANAGEMENT (FLOODRISK 2016)	English	Proceedings Paper		CLIMATE-CHANGE; IMPACT; PERFORMANCE; WEATHER	Transport infrastructure networks are increasingly vulnerable to disruption from extreme rainfall events due to increasing surface water runoff from urbanization and changes in climate. Impacts from such disruptions typically extend far beyond the flood footprint, because of the interconnection and spatial extent of modern infrastructure. An integrated flood risk assessment couples high-resolution information on depth and velocity from the CityCAT urban flood model with empirical analysis of vehicle speeds in different depths of flood water, to perturb a transport accessibility model and determine the impact of a given event on journey times across the urban area. A case study in Newcastle-upon-Tyne (UK) shows that even minor flooding associate with a 1 in 10 year event can cause traffic disruptions of nearly half an hour. Two adaptation scenarios are subsequently tested (i) hardening (i.e. flood protection) a single major junction, (ii) introduction of green roofs across all buildings. Both options have benefits in terms of reduced disruption, but for a 1 in 200 year event greening all roofs in the city provided only three times the benefit of protecting one critical road junction, highlighting the importance of understanding network attributes such as capacity and flows.	34	2016	10.1051/e3sconf/20160707006	
Inter-city travel behaviour adaptation to extreme weather events	Lu, QC; Zhang, JY; Peng, ZR; Rahman, ABMS	JOURNAL OF TRANSPORT GEOGRAPHY	English	Article	Travel behaviour adaptation; Inter-city travel; Flooding; Coastal; Inland	SEA-LEVEL RISE; CLIMATE-CHANGE; TRANSPORTATION NETWORKS; VULNERABILITY ANALYSIS; ROAD NETWORKS; IMPACT; LINKS; PERSPECTIVE; PERFORMANCE; ROBUSTNESS	Increased attention has been paid to travel behaviour in circumstances of extreme weather conditions that are expected with climate change, and the analyses usually address intra-city travel. There is lack of assessments on inter-city travel which has less redundancy and is more exposed to extreme weather threats. In addition, much of the research has been carried out in developed countries. This paper provides new perspectives by investigating how people adapt their inter-city travel behaviour to flooding impacts in Bangladesh. With an orthogonal design of three flooding scenarios, questionnaire data were collected in 14 coastal and inland areas. Results of the statistical analyses identify the significant impacts of flooding on people's inter-city travel and reveal significant differences in attitudes and responses to flooding and extreme weather in coastal compared to inland locations. The main factors significantly affecting travel behaviour choice are road disruption, isolation by flood water, and flood frequency. These factors are felt differently in coastal and inland locations. The most common responses are cancelling trips or changing destinations. It is recommended that when making flooding adaptation decisions, it is important to protect road infrastructure and guarantee accessible routes in coastal areas, while offering more flood adaptation education to the inland people. (C) 2014 Elsevier Ltd. All rights reserved.	34	2014	10.1016/j.jtrangeo.2014.08.016	
Using green infrastructure to add value and assist place-making in public realm developments	Donaldson, GH; Joao, EM	IMPACT ASSESSMENT AND PROJECT APPRAISAL	English	Article	Green infrastructure; place-making; community engagement; public realm developments; maintenance of GI	ENVIRONMENTAL JUSTICE; ECOSYSTEM SERVICES; URBAN; ADAPTATION; SPACE	Green Infrastructure (GI), such as rain gardens, trees or permeable pavement, can provide several ecosystem services, protect biodiversity and mitigate the impacts of climate change in urban settings. Using a combination of public surveys and interviews with experts, this research evaluates opportunities and constraints for GI to add value and assist place-making in public realm developments, which is of relevance to impact assessment. The research uses the unique Woodside area in Glasgow as a case study. The project, 'Connecting Woodside', is a first of its kind in Scotland and lessons learned can be applied elsewhere. The study found that, to effectively utilise GI to assist place-making and add value in public realm developments, community engagement is a key aspect in developing public spaces. One of the main reasons identified for this was that GI was highly location specific. Therefore, it is important to understand the needs and wants of a place and its communities. The study demonstrated that community ownership of certain project aspects relative to GI could be beneficial for all stakeholders.	34	2020	10.1080/14615517.2019.1648731	
Integrating travel demand modeling and flood hazard risk analysis for evacuation and sheltering	Kim, K; Pant, P; Yamashita, E	INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION	English	Article	Hazard sciences; Flooding; Travel demand model (TDM); GIS; Honolulu	EMERGENCY MANAGEMENT	In this paper, the risks of flooding hazards to the transportation system in urban Honolulu are assessed using a regional travel demand model (TDM). The approach serves to support understanding of evacuation and sheltering needs. Coastal and inland flooding hazard scenarios were modeled with four different hazard conditions. The inundation defined by the Maximum Envelope of High Water (MEOW) based on a hurricane that struck Hawaii and a tsunami run-up generated by historical earthquake events combined with a one-meter rise in sea level provided the worst possible coastal flooding scenario. A 500-year return period riverine flooding scenario was also included. The critical flooding hazard was transformed into a uniform 100 by 100 meter GIS based grid system. The Oahu Metropolitan Planning Organization (OMPO) TransCAD model for 2035 provided the origin and destination trips for eleven trip types including motorized and non-motorized travel modes. The OMPO model includes personal travel, travel to the airport, commercial vehicle travel and visitor travel sub-models. Origin and destination trip matrices for Traffic Analysis Zones (TAZ) and highway and transit assignment details were extracted from the model. The O-D trips and road segment traffic details were transformed to the spatial grid system and overlaid on the flooding hazard layer. The spatial categorization of the flooding along with the trip and travel data from the TDM provided a robust method to quantify and visualize risks to travelers and the transportation system. The analysis shows that flooding hazard scenarios have serious risks in Honolulu. First, a large portion of the study area is susceptible to flooding, threatening the population, economy, and infrastructure. Second, in addition to areas susceptible to flooding, a larger percentage of origins, destinations, trips and vehicle miles of travel (VMT) are affected because of the need to travel through the at-risk areas. Third, commercial, transit and non-motorized trips are disproportionately affected compared to auto travel. This paper demonstrates how hazard data and risk models can be integrated with travel demand models for purposes of evacuation planning and sheltering as well as emergency planning and hazard mitigation and adaptation of the transportation system to climate change.	33	2018	10.1016/j.ijdrr.2017.10.025	
Interlinking Bristol Based Models to Build Resilience to Climate Change	Stevens, J; Henderson, R; Webber, J; Evans, B; Chen, A; Djordjevic, S; Sanchez-Munoz, D; Dominguez-Garcia, J	SUSTAINABILITY	English	Article	fluvial; pluvial; tidal; sewer; flood; risk; climate change; modelling; cascading effects	STABILITY; IMPACTS	Expanding populations and increased urbanisation are causing a strain on cities worldwide as they become more frequently and more severely affected by extreme weather conditions. Critical services and infrastructure are feeling increasing pressure to be maintained in a sustainable way under these combined stresses. Methods to better cope with these demanding factors are greatly needed now, and with the predicted impacts of climate change, further adaptation will become essential for the future. All cities comprise a complex of interdependent systems representing critical operations that cannot function properly independently, or be fully understood in isolation of one another. The consequences of localised flooding can become much more widespread due to the inter-relation of these connected systems. Due to reliance upon one another and this connectedness, an all-encompassing assessment is appropriate. Different model representations are available for different services and integrating these enables consideration of these cascading effects. In the case study city of Bristol, 1D and 2D hydraulic modelling predicting the location and severity of flooding has been used in conjunction with modelling of road traffic and energy supply by linking models established for these respective sectors. This enables identification of key vulnerabilities to prioritise resources and enhance city resilience against future sea-level rise and the more intense rainfall conditions anticipated.	33	2020	10.3390/su12083233	
Potential impacts of increased coastal flooding in California due to sea-level rise	Heberger, M; Cooley, H; Herrera, P; Gleick, PH; Moore, E	CLIMATIC CHANGE	English	Article		ECONOMIC COST	California is likely to experience increased coastal flooding and erosion caused by sea-level rise over the next century, affecting the state's population, infrastructure, and environment. As part of a set of studies on climate change impacts to California, this paper analyzes the potential impacts from projected sea-level rise if no actions are taken to protect the coast (a no-adaptation scenario), focusing on impacts to the state's population and infrastructure. Heberger et al. (2009) also covered effects on wetlands, costs of coastal defenses, and social and environmental justice related to sea-level rise. We analyzed the impact of a medium-high greenhouse gas emissions scenario (Special Report on Emissions Scenarios A2 in IPCC 2000) and included updated projections of sea-level rise based on work by Rahmstorf (Science 315(5810): 368, 2007). Under this scenario, sea levels rise by 1.4 m by the year 2100, far exceeding historical observed water level increases. By the end of this century, coastal flooding would, under this scenario, threaten regions that currently are home to approximately 480,000 people and $100 billion worth of property. Among those especially vulnerable are large numbers of low-income people and communities of color. A wide range of critical infrastructure, such as roads, hospitals, schools, emergency facilities, wastewater treatment plants, and power plants will also be at risk. Sea-level rise will inevitably change the character of California's coast; practices and policies should be put in place to mitigate the potentially costly and life-threatening impacts of sea-level rise.	33	2011	10.1007/s10584-011-0308-1	
A statistical method for quantifying the field effects of urban heat island mitigation techniques	Parison, S; Hendel, M; Royon, L	URBAN CLIMATE	English	Article	UHI countermeasure; Pavement-watering; Climate change adaptation; Linear mixed model; Before-after-control-impact (BACI) design	PSEUDOREPLICATION; DESIGN; GUIDE	The Lowry approach (1977) sets the framework for evaluating the meteorological effects of the urban heat island (UHI), by describing it as the superposition of background, local and urban climates. In this paper, by adapting this framework to the study of UHI countermeasures, we propose a statistical method suited for assessing their effects in the field. The framework demonstrates that direct comparisons between case and control sites cannot isolate the impacts of UHI countermeasure. It also shows that the interstation differences before and after countermeasure implementation cannot be considered as statistically independent. Consequently, statistical procedures suited for handling dependent observations are necessary such as a linear mixed or fixed effects model. As a case study, experimental data from pavement-watering experiments conducted in Paris since 2013 are used, with the goal of assessing its cooling effects for two different watering strategies. With the fixed effects model, long-lasting statistically-significant effects are found. Results indicate beneficial thermal effects for pedestrians with reductions of UTCI-equivalent temperature up to 2 degrees C, and duration of statistically-significant effects directly linked to the watered surface area. The method is limited by the number of measurements that must be gathered both before and after the UHI countermeasure implementation.	32	2020	10.1016/j.uclim.2020.100651	
Advancing index-based climate risk assessment to facilitate adaptation planning: Application in Shanghai and Shenzhen, China	Tian, Z; Lyu, XY; Zou, H; Yang, HL; Sun, LX; Pinya, MS; Chao, QC; Feng, AQ; Smith, B	ADVANCES IN CLIMATE CHANGE RESEARCH	English	Article	Climate risk assessment; Megacities; Resilient urban infrastructures; Subsystem; Knowledge co-creation process; China	KNOWLEDGE; IMPACTS	One of the key issues in climate risk management is to develop climate resilient infrastructure so as to ensure safety and sustainability of urban functioning systems as well as mitigate the adverse impacts associated with increasing climate hazards. However, conventional methods of assessing risks do not fully address the interaction of various subsystems within the city system and are unable to consolidate diverse opinions of various stakeholders on their assessments of sector-specific risks posed by climate change. To address this gap, this study advances an integrated-systems-analysis tool - Climate Risk Assessment of Infrastructure Tool (CRAIT), and applies it to analyze and compare the extent of risk factor exposure and vulnerability over time across five critical urban infrastructure sectors in Shanghai and Shenzhen, two cities that have distinctive geo-climate profiles and histories of infrastructure development. The results show significantly higher level of variation between the two cities in terms of vulnerability levels than that of exposure. More specifically, the sectors of critical buildings, water, energy, and information & communication in Shenzhen have significantly higher vulnerability levels than Shanghai in both the 2000s and the 2050s. We further discussed the vulnerability levels of subsystems in each sector and proposed twelve potential adaptation options for the roads system based on four sets of criteria: technical feasibility, flexibility, co-benefits, and policy compatibility. The application of CRAIT is bound to be a knowledge co-production process with the local experts and stakeholders. This knowledge co-production process highlights the importance of management advancements and nature-based green solutions in managing climate change risk in the future though differences are observed across the efficacy categories due to the geographical and meteorological conditions in the two cities. This study demonstrates that this knowledge co-creation process is valuable in facilitating policymakers' decision-making and their feedback to scientific understanding in climate risk assessment, and that this approach has general applicability for cities in other regions and countries.	32	2022	10.1016/j.accre.2022.02.003	
Assessing the Effects of Rising Groundwater from Sea Level Rise on the Service Life of Pavements in Coastal Road Infrastructure	Knott, JF; Elshaer, M; Daniel, JS; Jacobs, JM; Kirshen, P	TRANSPORTATION RESEARCH RECORD	English	Article			Coastal communities with road infrastructure close to the shoreline are vulnerable to the effects of sea level rise caused by climate change. The sea level in coastal New Hampshire is projected to rise by 3.9 to 6.6 ft (1.2 to 2.0 m) by 2100. Climate change vulnerability and adaptation studies have focused on surface water flooding caused by sea level rise; however, little attention has been given to the effects of climate change on groundwater. Groundwater is expected to rise with sea level rise and will intersect the unbound layers of coastal road infrastructure, thus reducing the service life of pavement. Vulnerability studies are an essential part of adaptation planning, and pavement engineers are looking for methods to identify roads that may experience premature failure. In this study, a regional groundwater model of coastal New Hampshire was used to identify road infrastructure for which rising groundwater will move into the unbound materials during the design life of the pavement. Multilayer elastic theory was used to analyze typical pavement profiles in several functional classifications of roadway to determine the magnitude of fatigue and rutting life reduction expected from four scenarios of sea level rise. All the evaluation sites experienced service life reduction, the magnitude and timing of which depended on the current depth to groundwater, the pavement structure, and the subgrade. The use of this methodology will enable pavement engineers to target coastal road adaptation projects effectively and will result in significant cost savings compared with implementation of broad adaptation projects or the costs of no action.	32	2017	10.3141/2639-01	
Economics of Making Roadway Pavements Resilient to Climate Change: Use of Discounted Cash Flow and Real Options Analysis	Kottayi, NM; Mallick, RB; Jacobs, JM; Daniel, JS	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Climate change; Real option; Net present value; Resilient; Adaptation; Pavements		An increase in the number of extreme weather events and gradual shifts in climate parameters due to a changing climate pose a serious threat to the nation's roadway infrastructure. A systematic approach is needed to define risks and assess consequences of climate change, consider the uncertainties, rank priorities, and initiate an adaptation strategy in a cost-effective manner. The objective of this study is to develop a framework that could be used to assess the impact of climate change on pavements in a rational way using either the net present value (NPV) or the real option (RO) approach to compare several options and to make the most prudent decision regarding selecting an option and the time of adopting that option. The NPV approach will generally go against an investment in cases with high uncertainty, even if they are very promising, and does not take into account the flexibility or decisions that could be implemented on the basis of changing conditions. In contrast, the RO method offers a flexible deferment option when the uncertainties regarding outcomes are resolved to a certain extent. A framework with a step-by-step method for evaluating the feasibility of building roads that are resilient to a changing climate is presented, along with an example. The worked-out example shows that there could be considerable value in using RO analysis, and this value can be leveraged to develop better economic policies for building roads that are resilient to a changing climate.	32	2019	10.1061/(ASCE)IS.1943-555X.0000494	
Environmental impacts of climate change adaptation of road pavements and mitigation options	Enriquez-de-Salamanca, A	INTERNATIONAL JOURNAL OF PAVEMENT ENGINEERING	English	Article	Road pavements; climate change adaptation; road traffic noise; environmental impacts; mitigation	TRAFFIC NOISE; MIXTURES	Roads contribute to climate change, mainly due to traffic emissions, but they are also affected by changes in the climate. Climate variations modify pavements' exposure in a positive or negative way, reducing or increasing degradation. When climate impacts are negative, it is necessary to apply adaptation measures, such as changes in design or maintenance frequency, or traffic management. These adaptation measures may have new environmental impacts, especially an increased use of energy and emissions or acoustic impacts, which require mitigation measures. The environmental impacts of climate change adaptation are currently mostly ignored or undervalued. The aim of this paper is to draw attention to this topic, in order to achieve a proper consideration in adaptation decision-making.	32	2019	10.1080/10298436.2017.1326236	
Assessing the vulnerability of coastal infrastructure to sea level rise using multi-criteria analysis in Scarborough, Maine (USA)	Johnston, A; Slovinsky, P; Yates, KL	OCEAN & COASTAL MANAGEMENT	English	Article		CLIMATE-CHANGE; ADAPTATION; IMPACT	Sea level rise and climate change will have widespread impacts on coastal towns and cities, many of which have seen dramatic increases in development over recent decades. In addition to potential private property damage, the critical public infrastructure that supports these regions will become increasingly vulnerable to coastal flooding. This paper describes a straightforward, structured methodology for identifying and prioritizing critical infrastructure vulnerabilities in the coastal community of Scarborough, Maine, USA. The study uses GIS mapping and analysis techniques to identify infrastructure vulnerabilities in a coastal town under three different potential future flooding scenarios. A simple multi-criteria analysis matrix is used to explore the often hard to quantify, multifaceted consequences of infrastructure loss. Numerical scores are attributed to represent the economic, social, health and safety and environmental impacts of coastal flooding, allowing vulnerable locations to be ranked in order of overall importance. The results are summarized in a series of tables, maps and data sheets that convey data in readily accessible formats. High traffic roads, including evacuation routes, and major utility corridors are identified as the most critical vulnerable infrastructure assets in the town. Targeted improvements are recommended in these critical areas to improve system and community resilience to climate change and sea level rise. Our approach makes use of standard techniques, requires limited data and is therefore readily transferable for use in infrastructure planning in other similar communities. The methodology encourages public engagement and education, and the results can be used by the local authorities to pursue external funding opportunities to support investment in proactive infrastructure adaptation. The identification of key system weaknesses will allow future infrastructure investment to be targeted to the most critical areas, and assist in improving emergency response plans. (C) 2014 Elsevier Ltd. All rights reserved.	31	2014	10.1016/j.ocecoaman.2014.04.016	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Climate change impacts on asphalt road pavement construction and maintenance: An economic life cycle assessment of adaptation measures in the State of Virginia, United States	Qiao, YN; Santos, J; Stoner, AMK; Flinstch, G	JOURNAL OF INDUSTRIAL ECOLOGY	English	Article	adaptation; climate change; climate model downscaling; flexible pavement; life-cycle cost analysis; maintenance effects	COSTS; INFRASTRUCTURE	Pavement design and management practices must be adapted in response to future climate change. While many studies have attempted to identify different methods to adapt pavements to future climate conditions, the potential economic impacts of the adaptations still remain largely unquantified. This study presents the results of a comprehensive life-cycle cost analysis (LCCA) aimed at quantifying the potential economic impacts of a climate adaptation method, in which an upgraded asphalt binder (Performance Grade PG 76-22) is used in the construction and maintenance of flexible pavement sections in lieu of the original binder (PG 70-22) for improved resistance against high temperatures. For each of three major Virginia Department of Transportation (VDOT) districts with different climates, three case studies consisting of typical interstate, primary, and secondary pavement sections were considered. The LCCA accounted for the costs incurred during the mixture's production, maintenance, and use phases of the pavement life cycle by explicitly considering future climate projections, pavement life-cycle performance, maintenance effects, and work zone user delays. The study concludes that pavements using the upgraded binder not only perform better over time but are also economically advantageous compared to those with the original binder under the conditions of the anticipated future climate conditions (2020-2039).	31	2020	10.1111/jiec.12936	
Infrastructure and climate change: a study of impacts and adaptations in Malawi, Mozambique, and Zambia	Chinowsky, PS; Schweikert, AE; Strzepek, NL; Strzepek, K	CLIMATIC CHANGE	English	Article			The African Development Bank has called for $40 Billion USD per year over the coming decades to be provided to African countries to address development issues directly related to climate change. The current study addresses a key component of these issues, the effect of climate change on the road infrastructure of Malawi, Mozambique, and Zambia. The study incorporates a stressor–response approach to estimate the effects of projected precipitation, temperature, and flooding changes on the paved and unpaved road infrastructure of these countries. The paper highlights the result of running 425 climate scenarios for each road type and policy option from 2010 to 2050. Based on this broad analysis, it is estimated that the three southern African countries are facing a potential $596 million price tag based on median climate scenarios to maintain and repair roads as a result of damages directly related to temperature and precipitation changes from potential climate change through 2050. The challenge for policy makers is to determine the potential risk that a country is facing based on the uncertainties associated with the multiple aspects of climate change modeling.	31	2015	10.1007/s10584-014-1219-8	
Infrastructure Network Design with a Multi-Model Approach: Comparing Geometric Graph Theory with an Agent-Based Implementation of an Ant Colony Optimization	Heijnen, P; Chappin, E; Nikolic, I	JASSS-THE JOURNAL OF ARTIFICIAL SOCIETIES AND SOCIAL SIMULATION	English	Article	Ant Colony Optimization; Steiner Minimal Tree; Infrastructure; Routing; Model Comparison	STEINER MINIMAL TREE; ALGORITHM	Network infrastructures, such as roads, pipelines or the power grid face a multitude of challenges, from organizational and use changes, to climate change and resource scarcity. These challenges require the adaptation of existing infrastructures or their complete new development. Traditionally, infrastructure planning and routing issues are solved through top-down optimization strategies such as mixed integer non linear programming or graph approaches, or through bottom up approaches such as particle swarm optimizations or ant colony optimizations. While some integrated approaches have been proposed int he literature, no direct comparison of the two approaches as applied to the same problem have been reported. Therefore, we implement two routing algorithms to connect a single source node to multiple consuming nodes in a topology with hard boundaries and no-go areas. We compare a geometric graph algorithm finding an (sub) optimum edge-weighted Steiner minimal tree with a Ant Colony Optimization algorithm implemented as an Agent Based Model. Experimenting with 100 randomly generated routing problems, we find that both algorithms perform surprisingly similar in terms of topology, cost and computational performance. We also discovered that by approaching the problem from both top-down and bottom-up perspective, we were able to enrich both algorithms in a co-evolutionary fashion. Our main findings are that the two algorithms, as currently implemented in our test environment hardly differ in the quality of solution and computational performance. There are however significant differences in ease of problem encoding and future extensibility.	31	2014		
Lesson learned from adaptation response to Devils Lake flooding in North Dakota, USA	Zheng, HC; Barta, D; Zhang, XD	REGIONAL ENVIRONMENTAL CHANGE	English	Article	Devils lake; Flooding; Adaptation; Risk management; Perception; Climate change	CLIMATE-CHANGE	The water level of Devils Lake, a terminal lake in the northeast of North Dakota, U.S., has risen nearly 10 m since 1993, inundating farm land and causing significant damages to the infrastructure and surrounding communities. The currently adopted flood adaptation policy is continuing infrastructural protection (CIP), under which the infrastructure, such as levees or roads, is raised gradually in response to the rising water. Since the Devils Lake city and the adjacent communities are built within the historical confines of the lake, we introduce and estimate potential costs of two diametrical, but long-term targeted adaptation strategies involving either buyout or relocation (B/R) to contrast against the CIP. The comparison shows that B/R, while more expensive initially, would be cheaper than CIP accumulated over longer term. We further explore the reason that policymakers prefer CIP: the near-term uncertainty regarding the future lake levels has led to significant discount of long-term potential risk. With future risk significantly discounted, not only B/R, but any other alternatives that feature long-term perspective, could become less attractive than CIP. Were we able to predict the flooding more accurately or willing to discount future less, we might have chosen a different plan of action. The ultimate choice of CIP among the possible adaptation options reveals that policymakers have privileged the present and favored near-term remedies instead of long-term solutions. Although certainly not on the same scale, the lesson we have learned in dealing with Devils Lake has far-reaching implications on climate change adaptation strategies. The passive decision to wait and ignore the full potential for disaster ultimately leaves us with no other option, but to continue to wait and see and then spend more.	31	2014	10.1007/s10113-013-0474-y	
On the time varying mitigation performance of reflective geoengineering technologies in cities	Lontorfos, V; Efthymiou, C; Santamouris, M	RENEWABLE ENERGY	English	Article	Urban heat island; Reflective cool materials; Ageing; Urban mitigation technologies	URBAN HEAT ISLANDS; AIR-QUALITY; STRATEGIES; ROOFS	Cities face important overheating problems caused by the local and global climate change. Detailed mitigation and adaptation plans and strategies, are designed and applied to counterbalance the impact of the overheating challenges. Albedo management seems to be among the more considered mitigation strategies. A barrier to the wider use of reflecting technologies is the lack of quantitative experimental data and concrete knowledge about their mitigation contribution. Up to now, the performance of the reflective mitigation technologies is assessed based on simulation results considering the initial optical properties of the materials and neglecting ageing and weatherization phenomena. The article present information on the global performance of reflecting mitigation technologies, as measured in a large scale urban mitigation project employing several types of reflecting technologies. It is shown, that because of the weatherization effects, the mitigation potential of the materials is reduced, during the first year after their installation, by at least, 25%. Despite the ageing effects, reflective pavements have found to contribute in reducing the peak summer ambient temperature up to 1,7 K, while their surface temperature was up to 12,3 K lower than that of conventional pavement reducing considerably the sensible heat released to the atmosphere. (C) 2017 Elsevier Ltd. All rights reserved.	31	2018	10.1016/j.renene.2017.09.033	
Road Infrastructure and Climate Change: Impacts and Adaptations for South Africa	Schweikert, A; Chinowsky, P; Kwiatkowski, K; Johnson, A; Shilling, E; Strzepek, K; Strzepek, N	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Climate change; Infrastructure; Adaptation; Global		This paper presents the results of a study on the impact of climate change on road infrastructure in South Africa. The approach used built on previous work associated with the UNU-WIDER Development under Climate Change (DUCC) effort, emphasizing understanding of the impact of climate change on roads. This paper illustrates how climate change effects on road infrastructure can be evaluated at a national and provincial level to produce quantitative estimates of climate change from multiple future scenarios. The results of the study indicate that the national-level climate change cost impact in South Africa will vary between US$116.8million and US$228.7million annually in the 2050 decade for the median and maximum climate scenarios if a no-adaptation policy action is taken. Conversely, if a proactive adaptation action is taken, these costs can be reduced to US$55.7million. The savings in costs arising from climate change impacts based on this policy approach is equivalent to building more than 10,000km of new, secondary paved road by 2050. The analysis focused on the advantage of a proactive policy approach: the upgrade of road infrastructure where climate impacts will exceed current design and maintenance standards. A stressor-response methodology created by the writers is briefly explained, including the application of 54 potential climate futures using general circulation models (GCMs) approved by the Intergovernmental Panel on Climate Change (IPCC). This paper focuses on provincial-level impacts of both a proactive and a reactive approach. Decadal and average annual costs are detailed through 2100.	31	2015	10.1061/(ASCE)IS.1943-555X.0000235	
Prioritization of Climate Change Adaptation Interventions in a Road Network combining Spatial Socio-Economic Data, Network Criticality Analysis, and Flood Risk Assessments	Espinet, X; Rozenberg, J	TRANSPORTATION RESEARCH RECORD	English	Article		TRANSPORT; SYSTEM; IMPACT	Climate change puts at risk all current and future transport projects. Investing proactively in climate adaptation of transport infrastructure is paramount to providing resilience and sustainable transport systems that may promote social and economic growth. Despite the importance of such investments, the financial resources of many road administrations are constrained, creating an urgent need to allocate these resources efficiently to capture the highest social, environmental, and economic benefits. This paper aims to tackle this issue by presenting a methodology to prioritize climate change adaptation interventions based on a set of economic, social, and risk reduction criteria. This method uses a network-wide approach to the road system in order to capture co-benefits, redundancies, and costs of disruption of road segments due to flood events. All underlying data in each of the criteria is part of a geospatial database that includes the location of agriculture, fishery production areas, high poverty, and flood maps. The methodology was developed at the request of the World Bank Africa Team to support the Government of Mozambique to prioritize climate change adaptation intervention in two central provinces, Zambezia and Nampula. After combining criteria for agriculture, fishery, poverty, network criticality, and hazard risk, the results suggest that most roads in the coastal districts of these provinces could be identified as top priority for climate change adaptation interventions.	30	2018	10.1177/0361198118794043	
Climate Change and Lithuanian Roads: Impacts, Vulnerability and Adaptation	Nemaniute-Guziene, J; Kazys, J	10TH INTERNATIONAL CONFERENCE ENVIRONMENTAL ENGINEERING (10TH ICEE)	English	Proceedings Paper	climate change; adaptation; resilience; roads		In Lithuania, like in other countries, climate change causes and will cause changes in natural and anthropogenic environment. The entire transport sector will be impacted, influencing the way it plans, designs, constructs and maintains infrastructure in the future. Roads are already sensitive to current climate variability. If today's extreme weather events become both more frequent and extreme, so too will the level of disruption that they cause. Thus, roads must be adapted to changing climate conditions. The aim is to ensure resilience, to ensure that roads remain open under extreme weather conditions. The easiest and the most effective economically way is to implement adaptation measures for the new or reconstructed roads. But the existing older roads should be adapted also. The steps required to improve and maintain resilience of roads are definition of climate projections, identification of key roads and their vulnerability, identification and research on technologies for adaptation, preparation of methodologies, establishment of field operational trials. The aim of the research is to review Lithuanian roads in the context of climate change and its consequences. Methodology: climate and associated data collection and review, initial prognoses of the change (in short, medium and long term perspective) of meteorological elements, vulnerability assessment of the study area and the roads. Results: initial recommendations for adaptation action planning.	28	2017	10.3846/enviro.2017.138	
Using climate risk and vulnerability assessments to prioritise Caribbean road investments	Amat, NB; Bonilla, LR; Parkinson, J	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-ENGINEERING SUSTAINABILITY	English	Article; Early Access		ADAPTATION TIPPING POINTS; TRANSPORTATION; RESILIENCE	Climate risk and vulnerability assessments were undertaken in the Caribbean for national ministries, with funding from the Caribbean Development Bank. The studies evaluated the impacts of climate-related natural hazards on road transport infrastructure and identified measures to strengthen resilience. Geographic information systems were used to map infrastructure assets and structural condition, and climate-related variables were then integrated to model current and future hazard scenarios. The datasets were analysed to identify hotspot areas of the road network where adaptation interventions were proposed, and to prioritise climate-resilient investments. The assessment findings helped decision makers to understand system resilience, adaptive capacity and how critical risk hotspot areas could be mitigated. Improved road infrastructure design and a more proactive approach to road and structure maintenance will help increase the resilience of the road networks by reducing vulnerability to hazards and minimising the impact of climate change.	28	2022	10.1680/jensu.21.00008	
Assessing the vulnerability of transport network to flood hazard using GIS analysis. Case study along Orient-East Med TEN-T Corridor, on Timis-Cerna Valley, Romania	Stoica-Fuchs, B	PRESENT ENVIRONMENT AND SUSTAINABLE DEVELOPMENT	English	Article	flash flood; road; railway; TEN-T European Network; Geographic Information Systems (GIS)	RISK-MANAGEMENT; ADAPTATION; HIGHWAY; BANAT	In the context of current climate change, it is estimated that flood risk will increase significantly, with important consequences for the human habitat and transport networks. Research literature features a continuous concern both for the improvement of flood hazard modeling and for the quantification of economic costs specific to material and human damage caused by floods. In the present study, we intend to perform an analysis on the vulnerability of the transport network along the Orient-East Med (OEM) Corridor, part of the TEN-T Core network at European level. By integrating flood bands with high (10 years) and medium (100 years) probability of recurrence, as well as various typologies of the transport network in a GIS environment, we successfully identified and characterized road and railway sectors susceptible to flooding events. Vector overlay analysis and statistical methods were validated by means of local research literature, field observations and aerial imagery. Our results feature the geographic distribution and statistical characterization of transport infrastructure vulnerable to flood risk along Timis-Cerna Valley, in south-western Romania. We also discuss the state of current flood risk mitigation measures for transport network in the study area, along with the importance of our research for regional and local spatial planning documentations and investment prioritization activities. Similar spatially-enabled analysis could enable better protection for the current and proposed transport infrastructure and minimize the damaging effects of flash floods.	27	2021	10.15551/pesd2021152012	
Tackling air pollution and extreme climate changes in China: Implementing the Paris climate change agreement	Tambo, E; Wang, DQ; Zhou, XN	ENVIRONMENT INTERNATIONAL	English	Article	Air pollution; Climate changes; China; Implementation; Paris climate change agreement	HEALTH; IMPACTS; QUALITY; HAZE	China still depends on coal for more than 60% of its power despite big investments in the process of shifting to nuclear, solar and wind power renewable energy resources alignment with Paris climate change agreement (Paris CCA). Chinese government through the Communist Party Central Committee (CPCC) ascribes great importance and commitment to Paris CCA legacy and history landmark implementation at all levels. As the world's biggest carbon dioxide emitter, China has embarked on SMART pollution and climate changes programs and measures to reduce coal-fired power plants to less than 50% in the next five years include: new China model of energy policies commitment on CO2 and greenhouse gas emissions reductions to less than 20% non-fossil energy use by 2030 without undermining their economic growth, newly introduced electric vehicles transportation benefits, interactive and sustained air quality index (AQI) monitoring systems, decreasing reliance on fossil fuel economic activities, revision of energy price reforms and renewable energy to less energy efficient technologies development. Furthermore, pending CPCC improved environmental initiatives, implemented strict regulations and penalties on local companies and firms' pollution production management, massive infrastructures such as highways to reduce CO2 expansion of seven regional emissions trading markets and programs for CO2 emissions and other pollutants are being documented. Maximizing on the centralized nature of the China's government, implemented Chinese pollution, climate changes mitigation and adaptation initiatives, SMART strategies and credible measures are promising. A good and practical example is the interactive and dynamic website and database covering 367 Chinese cities and providing real time information on environmental and pollution emissions AO. Also, water quality index (WQI), radiation and nuclear safety monitoring and management systems over time and space. These are ongoing Chinese valuable and exemplary leadership in Paris CCA implementation to the global community. Especially to pragmatic and responsible efforts to support pollution and climate changes capacity development, technology transfer and empowerment in emissions surveillance and monitoring systems and SMART integrated climate changes mitigation packages in global Sustainable Development Goals (SDGs) context, citizenry health and wellbeing. (C) 2016 Elsevier Ltd. All rights reserved.	27	2016	10.1016/j.envint.2016.04.010	
Traffic Noise Pollution in a Historical City Center - Case Study Project within Environmental Engineering Field of Study	Petrescu, V; Ciudin, R; Isarie, C; Cioca, LI; Nederita, V	3RD INTERNATIONAL ENGINEERING AND TECHNOLOGY EDUCATION CONFERENCE & 7TH BALKAN REGION CONFERENCE ON ENGINEERING AND BUSINESS EDUCATION	English	Proceedings Paper	Environment; noise; road; traffic; urban areas		Noise reduction for urban areas, especially noise generated by traffic is one of the major problems in today's European cities. This paper is focused on more aspects that are addressing to traffic noise, like pavement, driver's behavior, frequency of stops, pick hours, traffic agglomerations, etc. Research leading to this paper was conducted within the project Adaptation to the Climate Change developed in partnership with Environmental protection Agency Sibiu, focusing for this case study on traffic related pollution in a historical city center of Sibiu. Were considered three types of pavements (cobblestones, streets covered with dense asphalt, and graded asphalt road surfaces), three types of vehicles (small passenger car, family car and SUV), and testing's were done using 3M Quest SoundPro Sonometer. Higher noise levels were registered for cobblestone and dense asphalt surfaces. Acoustic measurements and maps emphasizing studied are presented, and the identified parameters considered to be related to the traffic noise are given.	27	2015	10.1515/cplbu-2015-0033	
Budget-Constrained Demand-Weighted Network Design for Resilient Infrastructure	Gupta, A; Dilkina, B	2019 IEEE 31ST INTERNATIONAL CONFERENCE ON TOOLS WITH ARTIFICIAL INTELLIGENCE (ICTAI 2019)	English	Proceedings Paper			Our work is motivated by an important network design problem in climate adaptation. As floods become more frequent and severe due to climate change, it is increasingly crucial that road infrastructure be strategically upgraded to support post-disaster recovery efforts and normal functionality. We focus on the problem of allocating a fixed budget towards restoring edges to maximize the satisfied travel demand between locations in a network, which we formalize as the budget-constrained prize-collecting Steiner forest problem. We prove that the satisfiable travel demand objective exhibits restricted supermodularity over forests, and utilize this property to design an iterative algorithm based on maximizing successive modular lower bounds for the objective that finds better solutions than a baseline greedy approach. We also propose an extremely fast heuristic for maximizing modular functions subject to knapsack and graph matroid constraints that can be used as a subroutine in the iterative algorithm, or as a standalone method that matches the greedy baseline in terms of quality but is orders of magnitude faster. We evaluate the algorithms on synthetic data, and apply them to a real-world instance of retrofitting the Senegal national road network against flooding.	26	2019	10.1109/ICTAI.2019.00070	
Impact of Sea-Level Rise on Roadway Flooding in the Hampton Roads Region, Virginia	Sadler, JM; Haselden, N; Mellon, K; Hackel, A; Son, V; Mayfield, J; Blase, A; Goodall, JL	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article		CLIMATE-CHANGE ADAPTATION; TRANSPORTATION	This study determines the most critically vulnerable major roadways in Norfolk and Virginia Beach, Virginia. Sea-level rise predictions are combined with the mean higher high water and 99% tidal datums and storm surge predictions to project flood water surface elevations through the year 2100. LiDAR data are used to compare major roadway elevations with the projected flood water elevations to determine which roadway segments would be flooded under different scenarios. Traffic data are used to determine critical road segments in the region (heavily traveled and low elevation). Results suggest that by the year 2100, and assuming intermediate sea-level predictions, approximately 10% of major roadways will regularly flood at high tide and 15% will flood at the 99% tide; this increases to more than 65% given a 100-year storm surge event. Five critical road segments are identified that would recurrently flood at high tide by 2100. These road segments should be the focus of infrastructure investments to improve the resiliency of the transportation network within the cities. (c) 2017 American Society of Civil Engineers.	26	2017	10.1061/(ASCE)IS.1943-555X.0000397	
Urban climate and adaptation strategies	Larsen, L	FRONTIERS IN ECOLOGY AND THE ENVIRONMENT	English	Review		HEAT-WAVE; DEATHS	Extreme heat poses a threat to the livability and sustainability of cities, and disproportionally harms marginalized groups. The frequency of extreme heat events is expected to increase in the future as climate change exacerbates urban heat island (UHI) effects. Common UHI mitigation strategies - such as cool pavements (light-colored surfacing or permeable pavements), cool roofs (often categorized as white, blue, or green roof strategies to differentiate the approaches), and increased planting of vegetation - vary in effectiveness depending on a city's baseline climate, as well as on city size and layout. Microclimate mitigation efforts must move beyond exterior site-level strategies to consider land-use planning at the neighborhood level and the role of passive cooling strategies for buildings. Green infrastructure offers benefits in the form of improved stormwater management, air quality, carbon sequestration, and microclimate regulation. The creation of a new utility - one akin to a public company that provides services such as electricity or water and that recognizes the multiple and overlapping environmental and social benefits of green infrastructure - may expedite implementation of such strategies.	26	2015	10.1890/150103	
Vulnerability of infrastructure to Sea Level Rise: A combined outranking and system-dynamics approach	Tonmoy, FN; El-Zein, A	SAFETY, RELIABILITY AND RISK ANALYSIS: BEYOND THE HORIZON	English	Proceedings Paper		CLIMATE-CHANGE	In order to develop an adaptation plan for Sea Level Rise (SLR), coastal councils often conduct hazard line studies to investigate present and expected future risks on coastal stretches (e. g., beaches) that harbour various types of infrastructures (e. g., roads, sewerage system, water supply system, electricity, telecom etc). Interdependencies of infrastructure components and systems are frequent with disruption of services in one, likely to cascade through the infrastructure network and produce a compound effect on users. To help decision-makers at a local council in prioritising management actions, we developed an analytical vulnerability assessment tool called EVA-INFRA (Environmental Vulnerability Assessment for infrastructures) which starts from the IPCC framework of vulnerability and considers the biophysical impacts of the hazard as well as a measure of its social and institutional dimensions. In this paper, we describe the incorporation of a system dynamics model inside EVA-INFRA that can quantify the cascading effects of disruption of any infrastructure component, leading to a more precise assessment of vulnerability.	26	2014		
A real options analysis of Australian wheat production under climate change	Sanderson, T; Hertzler, G; Capon, T; Hayman, P	AUSTRALIAN JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	English	Article	adaptation; climate change; real options; wheat production	ADAPTATION; SYSTEMS	A significant portion of the world's agricultural systems currently operate at the extreme end of the climate conditions that are considered to be suitable for crop and livestock production. Under these conditions, even moderate climate changes are anticipated to drive substantial transformational changes to agricultural systems. Transformations require new investments and infrastructure and can leave some assets stranded. These transformations can be partially or wholly irreversible, and hysteresis effects can make switching difficult and mistakes costly to reverse. This study demonstrates how a real options decision framework, Real Options for Adaptive Decisions' (ROADs), can be used to investigate how uncertainties about the climate affect the adaptation and transformation of agricultural systems. By building upon recent developments in the mathematics of stochastic optimisation, we extend traditional economic analysis of agricultural investment decisions based on net present values to better represent incomplete knowledge and uncertainty. We report results from a case study in South Australia that describes the transition pathways farmers might follow as their industries are transformed in response to climate change.	25	2016	10.1111/1467-8489.12104	
A survey on impacts of climate change on road transport infrastructure and adaptation strategies in Asia	Regmi M.B., Hanaoka S.	Environmental Economics and Policy Studies	English	Article	Adaptation strategies; Asia; Climate change; Environmental guidelines; Impacts on road		This study assesses the impacts of climate change on road transport in Asia. It presents the findings of a survey of stakeholders from Asian countries on the existing state of awareness of climate change and its impacts on road transport. Issues related to emergency preparedness, infrastructure design standards and practices, policies, institutions, and coordination essential for implementation of adaptation strategies in the transport sector are also discussed. The study identifies the need to (1) raise awareness of stakeholders of climate change impacts; (2) review existing road design standards and construction practices considering likely impacts; (3) introduce climate change impact-assessment guidelines; (4) establish organizational units to implement adaptation strategies; and (5) enhance coordination among various stakeholders to develop resilient road infrastructure. The limited literature in the Asian context indicates further research is needed on climate change adaptation in Asia. © 2011 Springer.	25	2011	10.1007/s10018-010-0002-y	
An overview of resilience and climate change	Hill, AC; Kakenmaster, W	BULLETIN OF THE ATOMIC SCIENTISTS	English	Article	Climate change; future-proof; infrastructure; adaptation; climate denial; city planning; sea level rise; land-use; resilience	SEA-LEVEL RISE	What do we mean when we speak in terms of resilience? Why has resilience become the hot buzzword, and why is it useful for political leaders who want to avoid saying the words climate change? Will the choice of words make a difference when it comes to the need to design infrastructure - roads, bridges, tunnels, houses, factories, power plants, airports, railroads - with rising sea levels, increased storms, and hotter temperatures in mind?	25	2018	10.1080/00963402.2018.1436803	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Climate Proofing Infrastructure in Bangladesh: The Incremental Cost of Limiting Future Flood Damage	Dasgupta, S; Huq, M; Khan, ZH; Masud, MS; Ahmed, MM2; Mukherjee, N; Pandey, K	JOURNAL OF ENVIRONMENT & DEVELOPMENT	English	Article	Bangladesh; climate change; infrastructure; adaptation cost		Bangladesh is one of the most flood prone countries in the world. Two thirds of the country is less than 5 m above sea level. Past monsoon flood records indicate that about 21% of the country is subject to annual flooding and an additional 42% is at risk of floods with varied intensity. Although annual regular flooding has traditionally been beneficial, providing nutrient-laden sediments and recharging groundwater aquifers, the country often experiences severe flooding during a monsoon that causes significant damage to crops and properties with adverse impacts on rural livelihoods and production. The 1998 flood inundated two thirds of the land area, resulting in damages and losses of over US$2 billion, or 4.8% of GDP. Climate models suggest increased precipitation, higher transboundary water flows, and sea-level rise will all increase the destructive power of monsoon floods. Using climate change scenarios out to 2050, hydrological and hydrodynamic models, this article estimates an incremental cost to climate-proof roads and railways, river embankments protecting productive agricultural lands, and drainage systems and erosion control measures for major towns of US$2,671 million initially and US$54 million in annual recurrent costs.	25	2011	10.1177/107049651140840 1	
Cost and Environmental Evaluation of Flexible Strategies for a Highway Construction Project under Traffic Growth Uncertainty	Fawcett, W; Urquijo, IR; Krieg, H; Hughes, M; Mikalsen, L; Gutierrez ORR	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article	Highway design; Highway construction; Real options; Flexibility; Adaptation; Life-cycle costing; Life-cycle assessment; Monte Carlo simulation	REAL OPTIONS; FLEXIBILITY	Uncertainty about the scale of future demand presents a challenge for infrastructure design. The attraction of flexible strategies, incorporating upgrade options that can be exercised when and if required, has been recognized for a long time. The techniques of real options allowed the benefits of flexible strategies to be quantified for the first time. A new and simplified methodology for real options analysis has been developed and implemented in software. It performs evaluation in both cost and environmental impact terms. A case study of a real highway in Spain was evaluated using the new methodology and software. Seven alternative strategies for the roadway (subgrade, base course, and surface course) were evaluated, six with upgrade options that are exercised if the traffic demand crosses specified thresholds. The rate of traffic growth, and also the discount rate for financial evaluation, were treated as uncertain variables. The highway was designed when the Spanish economy was growing strongly and a high roadway specification performed best. Before the highway was built the economy crashed and construction was canceled. Recalculation for the posteconomic shock conditions with lower traffic growth and a higher interest rate favored a lower highway specification with upgrade options. Sensitivity analysis shows how the specification choice varies with the values taken by the uncertain variables. A novel specification was proposed to maximize flexibility when there is high uncertainty about traffic growth, and evaluation showed that it performed better in many conditions. The methodology of evaluating flexible strategies could be used in many applications, including infrastructure for climate change adaptation.	25	2015	10.1061/(ASCE)IS.1943-555X.0000230	
Rational Method to Determine Investment Amount for Making Roadways Resilient to a Changing Climate	Mallick, RB; Nazarian, S	JOURNAL OF INFRASTRUCTURE SYSTEMS	English	Article		CHANGE ADAPTATION; REAL OPTIONS; UNCERTAINTY; WATER	The increase in maximum air temperature and annual rainfall caused by climate change can shorten the lives of pavements and hence increase the mileage of roads that would require rehabilitation at any point in the future. Most agencies are aware of the potential of the use of better materials such as high-modulus asphalt in reducing the negative impacts, thereby making roads resilient to climate change. However, using better materials does involve higher investments; currently, the major hindrance is the inability to decide on a justifiable level of investment. This is a challenge because climate change predictions have major uncertainties associated with them, and there could be competing needs for the limited budget that is available. This paper presents a rational framework that is based on the use of system dynamics and Monte Carlo simulations to identify an appropriate level of investment for making roads resilient to climate change. The process consists of predicting the mileage of roads that will need rehabilitation because of climate change with and without the use of better materials, considering the reduction in this mileage caused by using better materials as a future return on a present investment on better materials, and then comparing that return with one that could be expected from a regular investment with a reasonable interest rate. The comparisons are made probabilistically, so that depending on the level of selected confidence level, one can identify the investment that would result in the same return in a certain number of years as the return from resilient pavements in the same number of years. This investment would then be used as an appropriate and justifiable number for investing in better materials for making roads resilient to climate change. A worked-out example is presented, which shows an appropriate investment (that is far greater than one would spend for a conventional pavement) of approximately $2,400 per 1.6 km (1 mi) of a roadway network to obtain the same benefit from the reduction of cost of rehabilitation as an amount that could be obtained from an interest-paying investment in 15 years. The framework allows users to utilize their preferred method of pavement analysis, costs, mileage of roads, and results of laboratory and/or field study on pavement life-enhancing ability of better materials. (C) 2017 American Society of Civil Engineers.	25	2018	10.1061/(ASCE)IS.1943-555X.0000411	
The vulnerability of transport logistics to extreme weather events	Doll, C; Papanikolaou, A; Maurer, H	INTERNATIONAL JOURNAL OF SHIPPING AND TRANSPORT LOGISTICS	English	Article	weather extremes; climate change; damage costs; supply chain risks; infrastructure assets; operations; delay costs; transport safety; adaptation; transport logistics	CLIMATE	Records of international organisations and reinsurance companies highlight the rising damages caused by extreme weather events. The burden of these hazards for transport and possible adaptation strategies have been explored by the European research project WEATHER. In this paper, we summarise the main findings and link them to supply chain security. In this context, we develop a method for assessing the criticality of certain elements in large networks. This is crucial as shipping constitutes a major element of supply chains and as world economic conditions simultaneously demand for cost savings and more reliability in supply mechanisms. Our findings suggest that extreme weather has significant impacts on transport systems. Highest losses are estimated for road, and here in for user delays and accident consequences. We conclude that weather forecasts should be continuously monitored and the development of business continuity plans on company level should be fostered.	25	2014	10.1504/IJSTL.2014.06078 7	
A Regional Hydrologic Vulnerability Assessment Protocol for Road-Stream Crossings	Clark, GE; Ahn, KH; Palmer, RN	WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2016: HYDRAULICS AND WATERWAYS AND HYDRO-CLIMATE/CLIMATE CHANGE	English	Proceedings Paper			Recent flood events caused by tropical storms resulted in large economic impacts in the Northeastern US and catalyzed efforts to understand the complex interactions between human and natural systems. Specifically, the resilience of our transportation infrastructure to climate and the impact of our transportation systems on the aquatic environment are important to both state and federal decision makers. In is important that new, innovative approaches be developed that consider both the robustness of our infrastructure today and its ability to cope with forecasted extremes due to climate change. This paper presents ongoing research associated with the broad regional application of a hydrologic vulnerability framework for road-stream crossings. A calibrated, process-based hydrological model is used to develop estimates of flood flows at various return frequencies. Road-stream crossings are identified and the maximum critical flows for those crossings are calculated. Daily runoff from the hydrological model is coupled with a statistical peak-method to determine the average recurrence interval for flood flows at ungaged locations. Finally, a vulnerability analysis is performed that maps the annual exceedance probability (AEP) of the critical flow through crossing infrastructure to the estimated AEP of flood flows at the crossing locations. This study supports the development of a decision-support tool for prioritizingculvert repair and replacement in the region. It also creates a more robust infrastructure design that suggests adaptation strategies in conjunction with climate information.	24	2016		
Adaptation Planning to Mitigate Coastal-Road Pavement Damage from Groundwater Rise Caused by Sea-Level Rise	Knott, JF; Daniel, JS; Jacobs, JM; Kirshen, P	TRANSPORTATION RESEARCH RECORD	English	Article			Sea level in coastal New England is projected to rise 3.9-6.6 ft (1.2-2.0 m) by the year 2100. Many climate-change vulnerability and adaptation studies have investigated surface-water flooding from sea-level rise (SLR) on coastal-road infrastructure, but few have focused on rising groundwater. Groundwater modeling in New Hampshire's Seacoast Region has shown that SLRinduced groundwater rise will occur three to four times farther inland than surface-water flooding, potentially impacting 23% of the region's roads. Pavement service-life has been shown to decrease when the unbound layers become saturated. In areas where groundwater is projected to rise with SLR, pavements with groundwater 5.0 ft (1.5 m) deep or less are at risk of premature failure as groundwater moves into the pavement's underlying unbound layers. In this study, groundwater hydrology and multi-layer elastic pavement analysis were used to identify two case-study sites in coastal New Hampshire that are predicted to experience pavement service-life reduction caused by SLR-induced groundwater rise. Various pavement structures were evaluated to determine adaptation feasibility and costs to maintain the designed service-life in the face of rising groundwater. This investigation shows that relatively simple pavement structural modifications to the base and asphalt concrete (AC) layers of a regional corridor can eliminate the 80% to 90% service-life reduction projected with 1.0 ft SLR (year 2030) and will delay pavement inundation by 20 years. Pavements with adequate base-layer materials and thickness require only AC thickness modification to avoid premature pavement failure from SLR-induced groundwater rise.	24	2018	10.1177/036119811875744 1	
Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage	Neumann, JE; Price, J; Chinowsky, P; Wright, L; Ludwig, L; Streeter, R; Jones, R; Smith, JB; Perkins, W; Jantarasami, L; Martinich, J	CLIMATIC CHANGE	English	Article		SEA-LEVEL RISE; COSTS	Changes in temperature, precipitation, sea level, and coastal storms will likely increase the vulnerability of infrastructure across the United States. Using four models that analyze vulnerability, impacts, and adaptation, this paper estimates impacts to roads, bridges, coastal properties, and urban drainage infrastructure and investigates sensitivity to varying greenhouse gas emission scenarios, climate sensitivities, and global climate models. The results suggest that the impacts of climate change in this sector could be large, especially in the second half of the 21st century as sea-level rises, temperature increases, and precipitation patterns become more extreme and affect the sustainability of long-lived infrastructure. Further, when considering sea-level rise, scenarios which incorporate dynamic ice sheet melting yield impact model results in coastal areas that are roughly 70 to 80 % higher than results that do not incorporate dynamic ice sheet melting. The potential for substantial economic impacts across all infrastructure sectors modeled, however, can be reduced by cost-effective adaptation measures. Mitigation policies also show potential to reduce impacts in the infrastructure sector - a more aggressive mitigation policy reduces impacts by 25 to 35 %, and a somewhat less aggressive policy reduces impacts by 19 to 30 %. The existing suite of models suitable for estimating these damages nonetheless covers only a small portion of expected infrastructure sector effects from climate change, so much work remains to better understand impacts on electric and telecommunications networks, rail, and air transportation systems. In addition, the effects of climate-induced extreme events are likely to be important, but are incompletely understood and remain an emerging area for research.	24	2015	10.1007/s10584-013-1037 4	
Development of a participatory approach for mapping climate risks and adaptive interventions (CS-MAP) in Vietnam's Mekong River Delta	Yen, BT; Son, NH; Tun, L; Amjath-Babu, TS; Sebastian, L	CLIMATE RISK MANAGEMENT	English	Article	Participatory mapping; Climate risk and adaptation; CS-MAP; Rice production; Vietnam	INFORMATION	The El Nino-Southern Oscillation (ENSO) in 2016 adversely affected Vietnam particularly in the Mekong River Delta (MRD), where more than 90% of the country's rice export is produced annually. During that time, salinity intrusion and drought significantly affected agricultural production in the area. Furthermore, flooding is another recurring event in the area that is increasing in frequency. An assessment conducted by CGIAR Centers showed that even as warnings were provided by the government for the 2016 ENSO, these were not translated into appropriate preparations and responsive actions for agriculture. To address this critical issue, the Department of Crop Production (DCP) of the Ministry of Agriculture and Rural Development (MARD) of Vietnam, and CGIAR Research Program on Climate Change, Agriculture and Food Security in Southeast Asia (CCAFS-SEA) collaborated to develop and test an participatory approach for mapping climate risks and adaptive interventions (CS-MAP) to recognize climate-related risks, identify potentially affected areas and develop regional and provincial adaptation plans for rice production. The CS-MAP is a participatory approach involving experts from various local and national offices for: (1) identifying climate-related risks; (2) delineating affected areas and risk levels; (3) proposing corresponding adaptive plans; (4) fine tuning and verifying proposed measures; and (5) developing integrated provincial and regional adaptation plans. Risks and adaptive interventions maps were developed for normal and ENSO years by using technical data (i.e. topography and hydrology), infrastructures (i.e. dikes, road and canals), and local observations. CS-MAP is now is under various stages of development and implementation in 13 MRD provinces highlighting the organizational uptake and integration of the approach.	24	2019	10.1016/j.crm.2019.04.00 4	
Investigating the impact of maintenance regimes on the design life of road pavements in a changing climate and the implications for transport policy	Taylor, MAP; Philp, ML	TRANSPORT POLICY	English	Article	Climate change; Adaptation; Maintenance; Road pavement degradation; Mathematical modelling		Environmental conditions are one of the key components that determine the design life and maintenance required for road pavements. This study investigates how climate change can impact road pavement design life and the required maintenance regimes required to maximise the life of the surface. Using a pavement degradation model previously adapted by the authors for use with the Thornthwaite Moisture Index climate indicator, the authors investigate the impact of climate change on the design life and maintenance requirements along a real life case study corridor in South Australia. A literature review conducted by this study determines how climate change is being considered in infrastructure related policies and literature, with a focus on road pavements. The paper then further discussed the impacts of climate change on road pavement degradation and the implications for management and maintenance of this infrastructure, and the associated impacts for transport policy makers. (C) 2015 Elsevier Ltd. All rights reserved.	24	2015	10.1016/j.tranpol.2015.01.005	
The influence of weather characteristics variability on individual's travel mode choice in different seasons and regions in Sweden	Liu, CX; Susilo, YO; Karlstrom, A	TRANSPORT POLICY	English	Article	Weather changes; Regional and seasonal variability; Travel mode choice; Marginal effects	CLIMATE-CHANGE; IMPACT; FORECASTS; BICYCLE	This paper investigates the influence of weather on the Swedish people's mode choice decision in different seasons and regions using a long term series of the Swedish National Transport Survey datasets (NTS) and weather data from the Swedish Meteorological and Hydrological Institute (SMHI). The weather data includes mean of daily temperature, amount of rain precipitation and road surface condition. The daily mean temperature is normalised based on each region and season and classified into five categories as 'very cold', 'cold', 'normal', 'warm', and 'very warm'. This normalisation approach enables us to investigate the impact of individual's heterogeneity in perceiving regional and seasonal variability of temperature. The impacts of these weather indicators' variability on individual's mode choice is investigated with multinomial logit models. The results show that the impacts of weather differ in different seasons and different regions. Pedestrians' perception of variation of temperature differs between those in the northern Sweden and those in the central and southern Sweden. Such perception also differs in summer and in spring and autumn. Similarly, northern Sweden cyclists are more aware of temperature variation than cyclists in the central and southern Sweden in spring and autumn when temperature changes significantly. The influence of temperature variation on motorised modes also varies among seasons and regions. However, the trend is less straightforward than that on non-motorised modes. The findings highlight the importance to incorporate individual and regional unique anticipation and adaptations behaviours within our policy design and infrastructure management. (C) 2015 Elsevier Ltd. All rights reserved.	24	2015	10.1016/j.tranpol.2015.01.001	
An analysis of pavement heat flux to optimize the water efficiency of a pavement-watering method	Hendel, M; Colombert, M; Diab, Y; Royon, L	APPLIED THERMAL ENGINEERING	English	Article	Evaporative cooling; Pavement heat flux; Pavement-watering; Urban heat island; Climate change adaptation; Heat wave	NUMERICAL-SIMULATION; SURFACES	Pavement-watering as a technique of cooling dense urban areas and reducing the urban heat island effect has been studied since the 1990's. The method is currently considered as a potential tool for and climate change adaptation against increasing heat wave intensity and frequency. However, although water consumption necessary to implement this technique is an important aspect for decision makers, optimization of possible watering methods has only rarely been conducted. An analysis of pavement heat flux at a depth of 5 cm and solar irradiance measurements is proposed to attempt to optimize the watering period, cycle frequency and water consumption rate of a pavement-watering method applied in Paris over the summer of 2013. While fine-tuning of the frequency can be conducted on the basis of pavement heat flux observations, the watering rate requires a heat transfer analysis based on a relation established between pavement heat flux and solar irradiance during pavement insolation. From this, it was found that watering conducted during pavement insolation could be optimized to 30-min cycles and water consumption could be reduced by more than 80% while reducing the cooling effect by less than 13%. (C) 2014 Elsevier Ltd. All rights reserved.	23	2015	10.1016/j.applthermaleng.2014.11.060	
Improving a pavement-watering method on the basis of pavement surface temperature measurements	Hendel M., Colombert M., Diab Y., Royon L.	Urban Climate	English	Article	Climate change adaptation; Evaporative cooling; Pavement temperature; Pavement-watering; Urban heat island		Pavement-watering has been studied since the 1990's and is currently considered a promising tool for urban heat island reduction and climate change adaptation. However, possible future water resource availability problems require that water consumption be optimised. Although pavement heat flux can be studied to improve pavement-watering methods (frequency and water consumption), these measurements are costly and require invasive construction work to install appropriate sensors in a dense urban environment. Therefore, we analyzed infrared camera measurements of pavement surface temperatures in search of alternative information relevant to this goal. Firstly, surface temperature reductions of up to 4. °C during shading and 13. °C during insolation were found. Secondly, the infrared camera successfully detected temperature spikes indicative of surface drying and can therefore be used to optimize the watering frequency. Measurements made every 5. min or less are recommended to minimize relevant data loss. Finally, if the water retaining capacity of the studied pavement is known, optimisation of total water consumption is possible on the sole basis of surface temperature measurements. © 2014 Elsevier B.V.	23	2014	10.1016/j.uclim.2014.11.002	
Investigation of climate change impacts on early-age cracking of jointed plain concrete pavements in Canada	Shafiee, M; Maadani, O	CANADIAN JOURNAL OF CIVIL ENGINEERING	English	Article; Early Access	climate change; early-age cracking; jointed plain concrete pavement (JPCP); HIPERPAV (R)		Canada's climate is warming at a rate about double the global average, leading to potential negative impacts on public infrastructures such as jointed plain concrete pavement (JPCP). In light of this reality of changing climate, the work contained in this paper is aimed at evaluating JPCP's early-age behaviour in response to environmental conditions. HIPERPAV (R) software and the associated models developed by the U.S. Federal Highway Administration (FHWA) were used to identify cracking potential. A sensitivity analysis was performed to assess the effect of different levels of air temperature, mix temperature, base layer temperature, wind speed, and relative humidity. Additionally, projected extreme temperatures predicted by the Canadian Regional Climate Model (CanRCM) were used to determine the relative impact of climate change on cracking risk. The results demonstrated the increased cracking risk under changing climate in several Canadian cities by mid-century and highlighted the importance of developing a pathway forward for climate adaptation.	23	2022	10.1139/cjce-2021-0180	
Climate Change Implications for Asphalt Binder Selection in Pavement Construction across Ontario	Basit, A; Shafiee, M; Bashir, R; Perras, MA	INTERNATIONAL CONFERENCE ON TRANSPORTATION AND DEVELOPMENT 2021: TRANSPORTATION PLANNING AND DEVELOPMENT	English	Proceedings Paper			The climate in Canada has warmed and will continue to warm faster in the future, which will result in more intense and frequent temperature variations. Asphalt binder selection based on the Superpave performance grade (PG) system relies on historic climatic conditions in relation to the expected in-service temperature range of the flexible pavement. In view of climate change, it is crucial to investigate the extent to which pavement surface temperatures will be affected by ambient conditions of the future in order to assess the relative impact on the appropriate PG for more durable and resilient pavement construction. In this study, the latest long-term pavement performance (LTPP) model was used to determine the asphalt pavement surface temperatures. For different representative concentration pathways (RCP), the relative impact of climate change on pavement temperature extremes and thereby appropriate PG to meet projected pavement temperatures was assessed using the LTPP models. The results of this study indicate that in the future, climate variations will cause changes to asphalt binder grades across the examined locations in Ontario, which depend on the severity of the projected warming. This research offers useful suggestions that can be incorporated by the road agencies and designers towards adaptation of pavement construction materials suitable to the changing climate.	22	2021		
Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation	Espada R.J., Apan A., McDougall K.	International Journal of Disaster Resilience in the Built Environment	English	Article	Built environment; Disaster mitigation; Flooding; Infrastructure; Resilience; Vulnerability	adaptive management; building; climate change; disaster management; flood control; GIS; infrastructure; integrated approach; model test; natural disaster; resilience; risk assessment; spatiotemporal analysis; vulnerability; Australia; Queensland; Columba	Purpose – The purpose of this paper is to present a novel approach that examines the vulnerability and interdependency of critical infrastructures using the network theory in geographic information system (GIS) setting in combination with literature and government reports. Specifically, the objectives of this study were to generate the network models of critical infrastructure systems (CISs), particularly electricity, roads and sewerage networks; to characterize the CISs' interdependencies; and to outline the climate adaptation (CA) and flood mitigation measures of CIS. Design/methodology/approach – An integrated approach was undertaken in assessing the vulnerability and interdependency of critical infrastructures. A single system model and system-of-systems model were operationalized to examine the vulnerability and interdependency of the identified critical infrastructures in GIS environment. Existing CA and flood mitigation measures from government reports were integrated in the above-mentioned findings to better understand and gain focus in the implementation of natural disaster risk reduction (DRR) policies, particularly during the 2010/2011 floods in Queensland, Australia. Findings – Using the results from the above-mentioned approach, the spatially explicit framework was developed with four key operational dimensions: conceiving the climate risk environment; understanding the critical infrastructures' common cause and cascade failures; modeling individual infrastructure system and system-of-systems level within GIS setting; and integrating the above-mentioned results with the government reports to increase CA and resilience measures of flood-affected critical infrastructures. Research limitations/implications – While natural DRR measures include preparation, response and recovery, this study focused on flood mitigation. Temporal analysis and application to other natural disasters were also not considered in the analysis. Practical implications – By providing this information, government-owned corporations, CISs managers and other concerned stakeholders will allow to identify infrastructure assets that are highly critical, identify vulnerable infrastructures within areas of very high flood risk, examine the interdependency of critical infrastructures and the effects of cascaded failures, identify ways of reducing flood risk and extreme climate events and prioritize DRR measures and CA strategies. Originality/value – The individualist or "pigeon-hole" approach has been the common method of analyzing infrastructures' exposure to flood hazards and tends to separately examine the risk for different types of infrastructure (e.g. electricity, water, sewerage, roads and rails and stormwater). This study introduced an integrated approach of analyzing infrastructure risk to damage and cascade failure due to flooding. Aside from introducing the integrated approach, this study operationalized GIS-based vulnerability assessment and interdependency of critical infrastructures which had been unsubstantially considered in the past analytical frameworks. The authors considered this study of high significance, considering that floodplain planning schemes often lack the consideration of critical infrastructure interdependency. © 2015, Emerald Group Publishing Limited.	22	2015	10.1108/IJDRBE-02-2014-0019	
Climate Change Impact Assessment on the Temporary Transport Infrastructure	Prokopyev, E; Roslyalkova, N; Ryazantsev, P	INNOVATION MANAGEMENT AND EDUCATION EXCELLENCE THROUGH VISION 2020, VOLS I -XI	English	Proceedings Paper	climate change; logging; wood removal; winter roads; forest roads; modeling	NORTHERN CANADA	Global warming is already impacting the activities of many sectors of the economy. We studied this influence on forestry, particularly, temporary road infrastructure used for logging in winter. The goal of the paper is to investigate the relationship between the wood removal volumes and timing of operations temporary infrastructure in the different climate zones. We tested hypotheses for the dependence of wood removal on: a) annual allowable cut; b) road density; c) road density except wetlands. This paper used the data covers 1999-2009 and the territory of the Republic of Karelia. We examined two types of winter temporary road (ice roads and snow-ice roads) and two versions of their lifetime (earlier and later construction). The investigation made use of panel model with the fixed effects. Also we used one-way analysis of variance (ANOVA) to explain the territorial effects. Our main findings are that the volume depends on the type and lifetime versions of winter roads. One day winter road operation increases monthly volume of wood removal by 1485-1746 m3. We have determined the territory that is the most vulnerable to climate warming. This approach is suitable for identifying areas where should be increase road density to avoid deforestation. It can be applied to justify the state co-financing of forest road construction and to develop adaptation measures for forestry and forest industry of to climate warming.	21	2018		
Climate change projections for variables affecting road networks in Europe	Makkonen, L; Yhlaisi, J; Tornqvist, J; Dawson, A; Raisanen, J	TRANSPORTATION PLANNING AND TECHNOLOGY	English	Article	road structure; infrastructure; climate change; Europe; road network; adaptation	MODEL; SIMULATIONS	Global climate change will affect road networks during this century. The effects will be different in various parts of the world due to differences in local climate change and in the structure and properties of roads. In this paper, climate change projections are presented for climate variables that are most likely to affect the long-term performance of road networks in Europe. We apply four regional climate simulations up to the year 2100 using two plausible future emission scenarios. The results show that the changing climate will require significant adaptation measures in the near future in order to maintain the operability of the European road network.	21	2014	10.1080/03081060.2014.9 59352	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
A systematic assessment of the effects of extreme flash floods on transportation infrastructure and circulation: The example of the 2017 Mandra flood	Diakakis M., Boufidis N., Salanova Grau J.M., Andreadakis E., Stamos I.	International Journal of Disaster Risk Reduction	English	Article	Climate change; Disasters; Extreme; Flash flood; Transportation		Flash floods are one of the most catastrophic natural hazards in many areas of the world, inducing significant losses on a yearly basis. Transportation and its infrastructure remain particularly vulnerable to such events despite their crucial role in many socioeconomic activities and commuter safety. Despite the adverse climate change projections, there is limited research providing a holistic and quantified overview of the impact of rare, extreme flash floods on the transportation of affected areas both in terms of infrastructure and circulation. The research team surveyed the effects of an extreme flash flood at Mandra, Greece, aiming to provide a systematic overview of the extent and typology of its impacts on transportation. The study quantifies the effects on different elements of transportation infrastructure, as well as vehicle circulation disturbances using floating car data. Results show an extensive impact with approximately 40% of the road network inundated or inaccessible and over 80% of river crossings (bridges, fords, and culverts) suffering damages, debris deposition and/or flooding, while critical cross-sections of the drainage network were diminished. Circulation was affected heavily with significant vehicle speed drops, travel times and distances increasing in and around the affected area. The findings indicate a considerably higher degree of impacts in comparison with less rare flash floods, implying that transportation systems may require extensive adaptation to address the increase of extreme events' frequency induced by climate change. © 2020	20	2020	10.1016/j.ijdrr.2020.101542	
ADAPTATION TO FLOODING AND MITIGATING IMPACTS OF ROAD CONSTRUCTION - A FRAMEWORK TO IDENTIFY PRACTICAL STEPS TO COUNTER CLIMATE CHANGE	Mallick, RB; Zaumanis, M; Frank, R	BALTIC JOURNAL OF ROAD AND BRIDGE ENGINEERING	English	Article	climate change; flooding; road construction; energy; emission; system dynamics	SOIL	Adaptation and mitigation are the two critical actions that are needed to counter the looming threats of climate change on transportation. For roadways, flooding constitutes one of the most important impacts of climate change, and adaptation to build more resilient roadways must be made. For a proper adaptation, the first step is a way to properly assess the vulnerability of roadways to flooding. Road construction impacts the environment negatively through emissions and energy consumption, and a proper way to determine the practical methods to reduce the impact is also necessary. This paper presents a framework to assess the vulnerability of roadways to flooding and evaluate the impact of different changes in construction on energy consumption and emission. Two system dynamics based models were developed and results of the simulations have been presented. Simulation tools for these two models have also been developed and made available on the public domain. The results of the simulation point out the beneficial effects of providing low permeability and dense and thick surface layers to reduce vulnerability to flooding and that of using drier aggregates, reducing heat losses, reduced mix temperatures and extension of pavement lives on the emission and energy consumption during roadway construction.	20	2015	10.3846/bjrbe.2015.44	
Climate change adaptation advantage for African road infrastructure	Chinowsky, P; Schweikert, A; Strzepek, N; Manahan, K; Strzepek, K; Schlosser, CA	CLIMATIC CHANGE	English	Article			The African continent is facing the potential of a $183.6 billion USD liability to repair and maintain roads damaged from temperature and precipitation changes directly related to predicted climate change through 2100. This cost is strictly to retain the current road inventory. This cost does not include costs associated with impacts to critically needed new roads. In many African countries, limited or non-existent funds for adaptation and mitigation are challenging these countries to identify the threats that are posed by climate change, develop adaptation approaches to the predicted changes, incorporate changes into mid-range and long-term development plans, and secure funding for the proposed and necessary adaptations. Existing studies have attempted to quantify the impact of climate change on infrastructure assets that will be affected by climate change in the coming decades. The current study extends these efforts by specifically addressing the effect of climate change on the African road infrastructure. The study identifies both total costs and opportunity costs of repairing and maintaining infrastructure due to increased stressors from climate change. Proactive and reactive costs are examined for six climate scenarios, with costs ranging, respectively, from an average of $22 million USD to $54 million USD annually per country. A regional analysis shows contrast between impacts in five areas of the continent, with impacts ranging from 22 % opportunity cost to 168 % These costs have the potential to delay critical infrastructure development on the continent and present a challenge to policy makers balancing short-term needs with long-term planning.	20	2013	10.1007/s10584-012-0536-z	
Infrastructure Resilience for Climate Adaptation	Gupta, A; Robinson, C; Dilkina, B	PROCEEDINGS OF THE 1ST ACM SIGCAS CONFERENCE ON COMPUTING AND SUSTAINABLE SOCIETIES (COMPASS 2018)	English	Proceedings Paper	climate resilience; computational sustainability; mobility		Developing and maintaining resilient transportation infrastructure is a key strategy for meeting several UN sustainable development goals in the face of climate change-driven extreme flooding events. We present a framework for performing data-driven vulnerability analysis for flooding on existing transportation networks, and use this analysis to inform decision-making about investments for climate adaptation. We apply this approach to study the potential impacts of severe flooding on regional mobility in Senegal, using a combination of flood hazard maps and a travel demand model based on call detail record data. We use the estimated number of infeasible trips as a direct measure of flooding-induced mobility impacts, as well as an objective for minimizing these impacts. We then compare three alternative road network upgrade strategies to assess the extent to which each strategy would preserve network functionality under a given flooding scenario. We illustrate that strategies driven solely by travel demand can lead to underinvestment in roads that are at risk of flooding, while solely focusing on repairing flooded road segments neglects the criticality of those repairs to mobility. For example, in a 100 year flooding scenario with a fixed budget, our strategy that considers both flooding and mobility data can achieve a 53% reduction in the number of infeasible trips, while a strategy that just considers flooding data achieves only a 38% reduction for the same cost. Our framework can be applied more broadly to integrate information from a variety of sources about climate hazards and potential human impacts to make better informed decisions about investments in critical infrastructure systems.	20	2018	10.1145/3209811.3209859	
Road Infrastructure and Climate Change in Vietnam	Chinowsky, PS; Schweikert, AE; Strzepek, N; Strzepek, K	SUSTAINABILITY	English	Article	climate change; road infrastructure; stressor response functions; Vietnam; O18; R42	IMPACT; COSTS	Climate change is a potential threat to Vietnam's development as current and future infrastructure will be vulnerable to climate change impacts. This paper focuses on the physical asset of road infrastructure in Vietnam by evaluating the potential impact of changes from stressors, including: sea level rise, precipitation, temperature and flooding. Across S6 climate scenarios, the mean additional cost of maintaining the same road network through 2050 amount to US$10.5 billion. The potential scale of these impacts establishes climate change adaptation as an important component of planning and policy in the current and near future.	20	2015	10.3390/su7055452	
Performing A Regional Transportation Asset Extreme Weather Vulnerability Assessment	Abkowitz, M; Jones, A; Dundon, L; Camp, J	WORLD CONFERENCE ON TRANSPORT RESEARCH - WCTR 2016	English	Proceedings Paper	resilience; vulnerability; risk; asset management; extreme weather		Extreme weather is creating a growing challenge for disaster managers and transportation planners. The Tennessee Department of Transportation (TDOT) recently completed a study sponsored in part by the U.S. Federal Highway Administration (FHWA) to conduct an assessment of critical transportation assets in the state that are most vulnerable to plausible extreme weather events out to 2040. This vulnerability assessment required building an asset inventory, determining which of those assets should be considered critical, identifying various types of extreme weather events to which the critical assets may be exposed, and quantifying the potential asset damage and system disruption for the selected extreme weather event types and critical asset combinations. Combining this information then produced an overall vulnerability rating for the critical transportation assets in the state. The Tennessee study is unique in that it represents an inland region whose climate and topography expose the state to a variety of extreme weather events, and which are not dominated by concerns associated with sea level rise and storm surge. Moreover, all significant passenger and freight transport modes and support facilities were considered across a large region. As a result, the vulnerability assessment serves as an important screening tool to help stakeholders better understand where to focus their resources as they consider potential adaptation measures, and as a catalyst for facilitating a more proactive approach to building transportation resilience to extreme weather events. The methodology and tools developed in the study are also transferable to other regions attempting to better understand the vulnerabilities of their transportation infrastructure to climate change and extreme weather. This paper describes the study approach and findings, including a discussion of steps being taken to incorporate the study results into agency operations and planning. (C) 2017 The Authors. Published by Elsevier B.V.	19	2017	10.1016/j.trpro.2017.05.344	
Sentinel-2 imagery for mapping and monitoring imperviousness in urban areas	Kuc G., Chormański J.	International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives	English	Conference Paper	Climate change; Imperviousness; Planet scope; Sentinel-2; Urban areas	Catchments; Flood control; Remote sensing; Runoff; Satellite imagery; Urban growth; Water management; Hydrologic process; Hydrological modeling; Innovative approaches; Innovative solutions; Normalized difference vegetation index; Normalized differences; Quantitative comparison; Urban Heat Island Effects; Climate change	Nowadays there is need to take the action to find out the innovative solutions to reduce the negative effects of climate change in urban areas. Cities face multiple challenges in water management and flood protection at local scale, especially given an uncertain future climate and a rapidly growing population. The density of impervious surfaces (roofs and pavement) is a key element in evaluating hydrologic processes and occurring the surface runoff – the major component of water cycle in urban catchment. Satellite imagery are powerful and up-to-date data for estimation human impact on urban space. It is also highlighted the possibility of using those results in urban development studies according to adaptation cities to climate change. The Copernicus SENTINEL constellation brings out the potential to provide high quality and free of charge satellites images that enable to estimate parameters related to urban structure and imperviousness. Multitemporal Sentinel-2 data are widely used to calculate the indices for urban sprawl. The normalized difference built-up index (NDBI) and normalized difference vegetation index (NDVI), indicators providing information on urban heat island effect, are useful for change detection of imperviousness percentage in urban areas. The main objective of this research is fusion of multi-temporal and multi-resolution SENTINEL-2 MSI data for developing a new, innovative approach for improving water management in urban catchments at local scale provide valuable input data for hydrological model. The results obtained were compared by quantitative comparison with imperviousness HRL of Copernicus Program, visual comparison with OpenStreetMap data as well as qualitative comparison with the high resolution Planet's. © Authors 2019.	19	2019	10.5194/isprs-archives-XLII-1-W2-43-2019	
The impacts of the 28 June 2012 storms on UK road and rail transport	Jaroszweski, D; Hooper, E; Baker, C; Chapman, L; Quinn, A	METEOROLOGICAL APPLICATIONS	English	Article	transport; extreme events; delay propagation; climate change adaptation; data visualization; weather	CLIMATE-CHANGE	Extreme weather events can cause severe disruption to transport systems, greatly reducing the ability to maintain important social and economic functions such as the delivery of goods and materials within the supply chain. There is a need for greater qualitative and quantitative understanding of how transport systems respond under adverse conditions, to inform event management and to aid adaptation actions. The present study uses the intense storms of 28 June 2012 as a case study to present a novel exploration of the impacts of an extreme event using high spatial and temporal resolution transport data for the UK road and rail networks, as well as weather data from the UK Meteorological Office's MIDAS surface station network and NIMROD weather radar. This event caused widespread disruption, severing the main rail links between England and Scotland and causing 10000 delay minutes to train services throughout the country, as well as causing reduced speeds on local roads and motorways. The present study describes the meteorological situation in the build-up to and during the event, and uses Network Rail train delay data to visualize the way in which the failure of several sections of critical transport infrastructure caused disruption that propagated quickly through the rail network of Great Britain. Highway Agency motorway speed data are used to quantify the impact of this event on the M6 motorway in the West Midlands. Ways in which the insights gained from these data can be used to aid the transport sector in the prioritization of adaptation actions are discussed.	19	2015	10.1002/met.1477	
Flexible pavements and climate change: A comprehensive review and implicatio	Qiao Y., Dawson A.R., Parry T., Flintsch G., Wang W.	Sustainability (Switzerland)	English	Article	Adaptation; Climate change; Life cycle cost; Maintenance; Mitigation; Pavement; Performance	adaptation; climate change; environmental impact; infrastructure; life cycle; maintenance; microclimate; mitigation; pavement; performance assessment; qualitative analysis; quantitative analysis; transportation	Flexible pavements and climate are interactive. Pavements are climate sensitive infrastructure, where climate can impact their deterioration rate, subsequent maintenance, and life-cycle costs. Meanwhile, climate mitigation measures are urgently needed to reduce the environmental impacts of pavements and related transportation on the macroclimate and microclimate. Current pavement design and life cycle management practices may need to be modified to adapt to changing climates and to reduce environmental impacts. This paper reports an extensive literature search on qualitative and quantitative pavement research related to climate change in recent years. The topics cover climate stressors, sensitivity of pavement performance to climatic factors, impacts of climate change on pavement systems, and, most importantly, discussions of climate change adaptation, mitigation, and their interactions. This paper is useful for those who aim to understand or research the climate resilience of flexible pavements. © 2020 by the authors.	18	2020	10.3390/su12031057	
Pavement Risk Assessment for Future Extreme Precipitation Events under Climate Change	Lu, DH; Tighe, SL; Xie, WC	TRANSPORTATION RESEARCH RECORD	English	Article			Pavement infrastructure is experiencing unanticipated climate conditions caused by global warming. Extreme weather events, such as extreme precipitations, are increasing in intensity and frequency, creating rising concern in pavement vulnerability and resilience analysis. Previous design approaches based on historical climate data may no longer be adequate for addressing future conditions. To promote pavement resilience under climate change, assessing pavement risk for extreme events is essential for prioritizing vulnerable infrastructure and developing adaptation strategies. The objective of this study is to develop a quantitative evaluation methodology for assessing pavement risk from extreme precipitations under climate change. Hazard analysis, fragility modeling, and cost estimation are the three major components for risk evaluation. An ensemble of 24 global climate models is used for predicting future extreme precipitations under various climate-forcing scenarios. The Mechanistic-Empirical Pavement Design Guide is employed to simulate performance change for performing fragility modeling. Risk assessment models considering a full range of hazards were used to quantify risk of asset value loss over specified analysis periods. Results indicate that future extreme precipitation events are expected to cause an increased medium risk of asset value loss. However, high uncertainties are involved in the estimation owing to variations in predicted climates. Major pavement damages do not necessarily equate with highest risk because the probability of occurrence of major damage is relatively lower. The proposed approach provides a practical tool for analysing the interaction among extreme precipitation levels, pavement designs, damage states, occurrence probability, and asset value at risk.	18	2018	10.1177/0361198118781657	
Climate Change Impact and Vulnerability Analysis in the City of Bratislava: Application and Lessons Learned	Luckerath, D; Streberova, E; Bogen, M; Rome, E; Ullrich, O; Pauditsova, E	CRITICAL INFORMATION INFRASTRUCTURES SECURITY (CRITIS 2019)	English	Proceedings Paper	Risk analysis; Vulnerability assessment; Climate change; Critical infrastructure protection; Climate change adaptation		Consequences of climate change, like more frequent extreme weather events, are major challenges for urban areas. With diverse approaches for adaptation strategy development available to cities, comparability with respect to risks, vulnerabilities, and adaptation options is limited. The lack of standardized methods and approaches to prioritize and select appropriate adaptation options restricts the exchange of best practices between cities. This paper presents the application of a vulnerability analysis for the city of Bratislava, Slovakia. It describes how the approach was employed to analyze the effects extreme precipitation has on the road network and reports on how different stakeholders were involved in the process, how relevant data was employed for the assessment, and which results were produced. Based on this process description, typical problems, resultingmethod adaptations, and lessons learned are described.	17	2020	10.1007/978-3-030-37670-3_7	
Evaluating Climate Change Impact an Low-Volume Roads in Southern Canada	Tighe, SL; Smith, J; Mills, B; Andrey, J	TRANSPORTATION RESEARCH RECORD	English	Article		COUPLED MODEL	Information extracted from global climate models suggests that average temperatures and annual precipitation will increase over the next several decades, with potential implications for pavement performance and design. With Canadian data from the Long-Term Pavement Performance program, the Mechanistic-Empirical Pavement Design Guide was used to quantify the impacts of projected climatic changes on pavement performance of low-volume roads at six sites. A series of analyses was conducted to assess the impact of pavement structure, material characteristics, traffic loads, and changes in climate on incremental and terminal pavement deterioration and performance. Results suggest that rutting (asphalt, base, and subbase layers) and both longitudinal and alligator cracking will be exacerbated by climate change, with transverse cracking becoming less of a problem. In general, maintenance, rehabilitation, and reconstruction will be required earlier in the design life; however, the effects of climate change were found to be modest relative to effects of regional baseline climate differences and increased future traffic. For road authorities, key adaptations will relate to when and how to modify current design and maintenance practices. Pavement engineers should be encouraged to develop a protocol for considering potential climate change in the development and evaluation of future designs and maintenance programs. Incorporating other climate-related road infrastructure issues for instance those associated with concrete pavements; surface-treated roads; and airfields bridges, and culverts-would be beneficial. At a minimum, long time series of historic climatic and road weather observations (e.g., > 30 years) should be incorporated into analyses of pavement deterioration and assignment of performance graded materials.	17	2008	10.3141/2053-02	
Evaluating climate change vulnerability assessments: a case study of research focusing on the built environment in northern Canada	Ford J.D., Champalle C., Tudge P., Riedlsperger R., Bell T., Sparling E.	Mitigation and Adaptation Strategies for Global Change	English	Article	Arctic; Built environment; Climate change; Evaluation framework; Literature review; Northern Canada; Vulnerability	adaptive management; building; climate change; decision making; environmental research; infrastructure; literature review; risk assessment; stakeholder; valuation; vulnerability; Arctic; Canada	Vulnerability assessments (VAs) have been widely used to understand the risks posed by climate change and identify opportunities for adaptation. Few studies, however, have evaluated VAs from the perspective of intended knowledge users or with reference to established best practices. In this paper, we identify and evaluate VAs focusing on the built environment in northern Canada. We document 16 completed VAs, which range from engineering-based studies of the vulnerability of specific infrastructural assets (e.g. building foundations, roads) to community-based assessments characterizing the vulnerability of the built environment in general in specific communities. We then evaluate projects based on the extent to which they incorporate best practices for vulnerability assessment, informed by a review of the scholarship and interviews with practitioners and knowledge users in the north (n = 21). While completed VAs have increased our understanding of the risks posed by climate change, none perform well across all evaluation criteria, and interviewees identified the need for improvement to VAs to inform decision making. Specifically, there is a need for greater emphasis on stakeholder engagement and effective communication of research findings, and interdisciplinary collaboration to capture the multiple drivers of vulnerability, cost impacts, and examine the performance of infrastructural assets under different climate scenarios. © 2014, Springer Science+Business Media Dordrecht.	17	2015	10.1007/s11027-014-9543-x	
Landslide Hazards and Climate Change Adaptation of Transport Infrastructures in Germany	Klose, M; Auerbach, M; Herrmann, C; Kumerics, C; Gratzki, A	ADVANCING CULTURE OF LIVING WITH LANDSLIDES, VOL 1: ISDR-ICL SENDAI PARTNERSHIPS 2015-2025	English	Proceedings Paper	Landslide hazards; Transport infrastructure; Climate change adaptation; Germany	STATE; RISK	This paper provides insights into a new landslide hazards project which is part of a national research program on safe and sustainable transport in Germany funded by the Federal Ministry of Transport and Digital Infrastructure (BMVI). Here we report on a work in progress and present selected results of a pilot study conducted prior to the launch of the research program in 2016. The main goal of the landslide hazards project is to assess the future landslide hazard potential for the federal transport system under the influence of climate change. A federal road-related pilot study with focus on developing an approach to this type of hazard assessment was a first step in this direction. The developed approach is based upon a Geographic Information System (GIS) as mapping tool to combine a landslide susceptibility map with spatial datasets of regional climate change projections. Here we present the basic framework of this approach only, and provide information on landslide activity and climate change. This information refers to findings from three example landslide sites in Germany. The purpose of this paper is to introduce these landslide projects of German transport research against the backdrop of the existing national strategy of climate change adaptation.	17	2017	10.1007/978-3-319-59469-9_48	
Natural hazards and First Nations community setting: challenges for adaptation	Kulshreshtha, S; Wheaton, E; Wittrock, V	MANAGEMENT OF NATURAL RESOURCES, SUSTAINABLE DEVELOPMENT AND ECOLOGICAL HAZARDS III	English	Proceedings Paper	First Nations community; Kainai blood tribe reserve; drought; flood; adaptation; government policy	CLIMATE-CHANGE; VULNERABILITY	Natural hazards are a common occurrence on the semi-arid prairies, both in terms of extreme dryness (droughts), and extreme moisture (floods). Although when such events occur, they generate devastating impacts on the economic and social system of any community, when that community happens to be a First Nations community, these challenges are further compounded by the regulations that govern these communities. The community selected for this investigation was the Kainai Blood Indian Reserve, Alberta, Canada. The impacts of past extreme weather events (droughts and floods) were serious for the people of the Reserve, although floods likely had the most immediate impacts on the residents. The response capabilities of emergency services were stressed, infrastructure, such as roads, was damaged and the potable water sources were compromised. The droughts appeared to have less direct impact on the residents of the Reserve because their water supply is from communal groundwater sources. Adaptations to the extreme events were seriously handicapped by regulations that create economic limitations faced by the Kainai Nation residents. These include: limited money transfers by the Federal government to the Nation, absence of property rights, lack of local economic opportunities, high unemployment rates, and relatively lower human capital (level of education and skills). Moreover, future adaptation measures will continue to be challenging unless government policies are changed to meet the requirements of KBIR and similar First Nations communities.	17	2012	10.2495/RAV110261	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Evacuation planning for plausible worst case inundation scenarios in Honolulu, Hawaii	Kim K., Pant P., Yamashita E.	Journal of Emergency Management	English	Article	Evacuation; Honolulu; Hurricane storm surge; Risk reduction; River flooding; Sea level rise; Travel demand modeling	computer simulation; disaster planning; flooding; human; Pacific Ocean; policy; risk management; traffic and transport; travel; United States; weather; Computer Simulation; Disaster Planning; Floods; Hawaii; Humans; Pacific Ocean; Public Policy; Risk Management; Transportation; Travel; Weather	Honolulu is susceptible to coastal flooding hazards. Like other coastal cities, Honolulu's long-term economic viability and sustainability depends on how well it can adapt to changes in the natural and built environment. While there is a disagreement over the magnitude and extent of localized impacts associated with climate change, it is widely accepted that by 2100 there will be at least a meter in sea level rise (SLR) and an increase in extreme weather events. Increased exposure and vulnerabilities associated with urbanization and location of human activities in coastal areas warrants serious consideration by planners and policy makers. This article has three objectives. First, flooding due to the combined effects of SLR and episodic hydro-meteorological and geophysical events in Honolulu are investigated and the risks to the community are quantified. Second, the risks and vulnerabilities of critical infrastructure and the surface transportation system are described. Third, using the travel demand software, travel distances and travel times for evacuation from inundated areas are modeled. Data from three inundation models were used. The first model simulated storm surge from a category 4 hurricane similar to Hurricane Iniki which devastated the island of Kauai in 1992. The second model estimates inundation based on five tsunamis that struck Hawaii. A 1-m increase in sea level was included in both the hurricane storm surge and tsunami flooding models. The third model used in this article generated a 500-year flood event due to riverine flooding. Using a uniform grid cell structure, the three inundation maps were used to assess the worst case flooding scenario. Based on the flood depths, the ruling hazard (hurricane, tsunami, or riverine flooding) for each grid cell was determined. The hazard layer was analyzed with socieconomic data layers to determine the impact on vulnerable populations economic activity, and critical infrastructure. The analysis focused both on evacuation needs and the critical elements of the infrastructure system that are needed to ensure effective response and recovery in the advent of flooding. This study shows that the coastal flooding will seriously affect the economy and employment. Extreme flooding events could affect 38 percent of the freeways, 44 percent of the highways, 69 percent of the arterial roads, and 40 percent of the local streets in the area examined. Approximately 80 percent of the economy and 76 percent of the total employment in the urban core of Honolulu is exposed to flooding. Evacuation modeling shelter accessibility, and travel time to shelter analyses revealed that there is a significant short-age in sheltering options, as well as increases in travel times and distances as inundation depth increases. The findings are useful for evacuation and shelter planning for extreme coastal events, as well as for climate change adaptation planning in Honolulu. Recommendations for emergency responders as well as those interested in the integration of long-term SLR and low probability; high consequence coastal hazards are included. The study shows how to integrate travel demand modeling across multiple hazards and threats related to evacuating sheltering and disaster risk reduction.	16	2015	10.5055/jem.2015.0223	
Integrating potential climate change into the mechanistic-empirical based pavement design	Li, Qi; Mills, L; McNeil, S; Attoh-Okine, NO	CANADIAN JOURNAL OF CIVIL ENGINEERING	English	Article	climate change; mechanistic-empirical based pavement design; uncertainty; pavement performance		Given anticipated climate change and its inherent uncertainty, a pavement could be subjected to different climatic conditions over its life and might be inadequate to withstand future environmental stresses beyond those currently considered during pavement design. This paper incorporates climate change effects into the mechanistic-empirical (M-E) based pavement design to explore potential climate change and its uncertainty on pavement design and performance. Three important questions are addressed: (1) How does pavement performance deteriorate differently with climate change and its uncertainty? (2) What is the risk if climate change and its uncertainty are not considered in design? and (3) How do pavement designers respond and incorporate this change into M-E design ? Three test sites in the United States are examined and results demonstrate a robust and effective approach to integrate climate change into pavement design as an adaptation strategy.	16	2013	10.1139/cjce-2012-0465	
DESIGNING FOR ENVIRONMENTAL AND INFRASTRUCTURE SUSTAINABILITY: ONTARIO CASE STUDIES FOR RETROFITS AND NEW DEVELOPMENTS	Denich, C; Zaghal, A	JOURNAL OF GREEN BUILDING	English	Article	Low Impact Development (LID); Green Infrastructure (GI); stormwater management; bioswale; bioretention; permeable pavement; sustainability; climate change adaptation and resiliency; green streets; policy guidelines; Species at Risk (SAR) Act		The Low Impact Development (LID) approach has been implemented worldwide for managing stormwater quantity and quality within the context of land development, re-development, and retrofits within an existing development site. Since the inception of the concept in the 1990s, the application of LID has covered different land uses, spatial scales, and environmental objectives, leading to an expanded vision for applying and testing the LID approach. Recently, holistic methodologies and frameworks have linked land planning to key ecological landscapes larger than the previous site scale practice. This new emerging paradigm considers the watershed, subwatershed, and neighbourhood, in addition to the site scale, and consequently, recommends a landscape-based LID and broader Green Infrastructure (GI) solutions (Benedict and McMahon, 2002; Tzoulas et al, 2007; NRDC, 2011). As part of the holistic understanding of land planning and environmental features and functions within the intended spatial scale, LID and GI measures have been designed and constructed as retrofit measures (i.e., measures implemented within existing development) and as measures implemented within new development areas. Under this new paradigm, the land planning context is linked to environmental objectives to provide end points for environmental conservation and restoration within an ecological landscape such as watersheds, subwatersheds, and stream corridors. This paper presents three case studies for the design and construction of LID and GI measures within different land use contexts and for providing multiple environmental objectives.	15	2014	10.3992/1943-4618-9.1.40	
A need for new methods in the paradigm shift from mobility to sustainable accessibility	Johansson, H; Sandvik, KO; Zsidakovits, J; Lutczyk, G	TRANSPORT RESEARCH ARENA TRA2016	English	Proceedings Paper	Sustainable; low carbon; backcasting; scenario planning		Planning of the transport system is usually based on forecasting of future traffic volumes. The forecast is based on current trends in the society, predictions of future economic growth and costs of transport. In all parts of Europe these trends and models point towards further growth of transport and traffic volumes. The highest growth is predicted in the Eastern part where car ownership is getting closer to the levels in the Western part. Safety factors and seamless mobility can justify improved road network but the forecasts also indicate a need for larger roads with more capacity. These new roads not only induce more traffic and thereby more emissions of GHG but also larger energy use and emissions of GHG during construction, operation and maintenance. In the last report IPCC warns that infrastructure developments that lock societies into GHG-intensive emissions pathways may be difficult or very costly to change. This reinforces the importance of early action for ambitious mitigation. To reach the climate objectives there is a need for technical solutions in energy efficient vehicles partly or fully dependent on electricity and a replacement of fossil fuels with bio fuels. These solutions however are not enough. There is also a need to change direction in planning and development of society and infrastructure in accordance with behavioral changes. It is a clear paradigm shift from planning for more traffic with cars and trucks towards a more sustainable mobility with accessibility through walking, cycling and public transport with less cars and improved logistics and modal shift instead of more trucks. Under such conditions of paradigm shift forecast is a very unreliable method. So there is a need for other methods. This paper is a result of the work within the CEDR I4 group on mitigation and adaptation to climate change. Based on examples from Sweden, Norway, Hungary and Poland within the group the paper explores an alternative method for planning. The first step is to describe the current situation, what the trends are and what the drivers are, to get a general picture of the problem. A clear objective is also needed. Since most countries do not have precise GHG objectives for road transport example is given how national objectives can be translated to a road transport objective. Then the gap between the trend and the GHG objectives can be described for road transport. An inventory should be made of possible measures to reduce the GHG emissions. This has been done in many countries and by EU commission which can work as a basis, but update may be necessary and there should be space for new ideas. The measures can be clustered into packages. From them scenarios can be built and tested towards the GHG objectives and other targets. Backcasting from the scenarios that fulfill the objectives can be used to develop an implementation strategy with policy instruments and measures to move in the direction towards the objectives. Due to uncertainty check points are recommended some years in between to adjust the strategy. (C) 2016 The Authors. Published by Elsevier B.V.	14	2016	10.1016/j.trpro.2016.05.093	
Forest management options for adaptation to climate change: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region	Keenan R.J., Nitschke C.	Australian Forestry	English	Article	adaptation; change; climate; Forests; impact; management	Climate change; Conservation; Environmental regulations; Genes; Highway planning; Management; Rain; Seed; adaptation; change; climate; Forests; impact; Forestry	Australia has a highly diverse and variable climate and its forests are well-adapted to climatic variation. However, human-induced changes in climate could exceed historical ranges of variability and have effects on forests well beyond the experience of forest managers. These conditions will require implementation of management practices appropriate to a changing climate but there has been little analysis of potential management options for Australian native forests. The paper analyses potential management options for the tall, wet eucalypt forests in Victoria's Central Highlands. This region has already experienced a strong drying and warming trend and a high incidence of severe bushfires over the last 15 years. Future changes are likely to include rising CO2, increasing temperatures and an overall decrease and changing seasonal patterns in rainfall. This is likely to result in higher fire danger weather conditions, changes in phenology of flowering, seeding and germination and shifts in forest composition and productivity. A range of different management options were considered and analysed in terms of current practice, costs and implementation feasibility. Many management actions identified to support adaptation to climate change were assessed as currently being implemented as part of sustainable forest management arrangements. Options that are not generally currently implemented include developing gene-management programs and off-site gene banks, ex-situ conservation and increasing cooperation in species management, increasing stand and regional species diversity, identification and deployment of more drought- or disturbance-tolerant species or genotypes, planning to reduce disease losses through monitoring and sanitation harvests, managing stand structure to reduce impacts on water availability and implementing silvicultural techniques to promote stand vigour, as practised elsewhere in Australia. The likelihood of more intense rainfall events will require changes to infrastructure, such as forest road design and construction specifications. Implementing adaptation will require new approaches to forest management, potentially involving significant human intervention, new ecological, environmental and social research, new modes of communication with the public, new policies and revised regulations and management prescriptions. © 2016 Institute of Foresters of Australia (IFA).	14	2016	10.1080/00049158.2015.1130095	
Functional Loss Risks of highways in Permafrost Areas Due to Climate Change	Trofimenko, YV; Evgenev, GI; Shashina, EV	PROCEEDINGS OF THE INTERNATIONAL SCIENTIFIC CONFERENCE TRANSPORTATION GEOTECHNICS AND GEOECOLOGY (TGG-2017)	English	Proceedings Paper	permafrost; climate change; highway; risk assessment; technology of self-adjusting soils stabilization		The article gives the analysis of functioning of highways, which are exposed to the destruction risks caused by climate change in the territories of the Arctic zone and the location of permafrost, original methods for preserving transport infrastructure facilities survival are proposed. Methods for quantitative risk assessment of natural hazards for transport infrastructure, adaptation measures in road construction to possible climate change are discussed. The technology of self-adjusting soils stabilization using vapor-liquid seasonal cooling devices immersed inside screw piles is proposed for improving the reliability of pile-elevated road structures. (C) 2017 The Authors. Published by Elsevier Ltd.	14	2017	10.1016/j.proeng.2017.05.041	
Impact of climate change on London's transport network	Arkell, BP; Darch, GJC	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-MUNICIPAL ENGINEER	English	Article	infrastructure planning; transport management; weather		There is much discussion about the contribution of transport to global warming, but what about the impact of our changing climate on transport modes, infrastructure and passengers? This paper examines the potential impacts of climate change on London's transport systems, based on the findings of a research study undertaken for the London Climate Change Partnership between 2004 and 2005. Recent extreme weather events have had significant impact on London's transport systems; for example, the effect of high temperatures on London Underground and major flooding of roads and railway stations. Scenarios of climate change show that London will experience hotter summers, wetter winters, more intense rainfall and a rise in sea level over the coming century. This poses a number of risks to the operation and use of transport systems in a city where 26 million trips are made every day. The study focuses on four case studies. Each case study assesses: the issue now, drawing on current weather-related effects; how climate change will affect the future; the action already underway in London to address climate impacts; and options and timescales for adaptation. It is apparent that most risks already exist climate change will simply make them worse. With forward planning, successful and cost-effective adaptation can be achieved.	14	2006	10.1680/muen.2006.159.4.231	
Assessment of the Physical and Mechanical Properties of Permafrost in Nunavik, Quebec, Canada	Bilodeau, JP; Verreault, J; Doré, G	COLD REGIONS ENGINEERING 2019	English	Proceedings Paper	Nunavik; runway; permafrost; creep; thaw settlement		Nunavik is a territory in Northern Quebec where 14 communities depend essentially on aerial transportation for their subsistence, economic development, and quality of life. Some airport runways built on permafrost in the late 80s showed worrying degradation signs only a few years after construction. The effect of runway embankments on the thermal regime at the embankment toes and where drainage is deficient, among other things, is well documented throughout the literature. These phenomena, as well as the general permafrost degradation, are amplified by climate changes, especially in northern regions. Because the permafrost degradation is worrying for transportation infrastructure, a project was undertaken to characterize the physical and mechanical properties of some permafrost soils in Northern Quebec, with the objective to assess their creep and thaw sensitivity. Frozen core samples were recovered at seven airstrips and two access roads, and undisturbed specimens were brought back to Laval University geotechnical laboratory. The samples from the most critical and representative study sites were subjected to basic geotechnical characterization along with triaxial creep. The creep tests allowed obtaining estimates of the creep rate for the soils at different deviatoric stress and temperatures. As for the thaw consolidation tests, they allowed estimating the settlements associated with a potential thawing of permafrost for various ice contents. The present paper focuses on the creep behavior. With the available ground thermal regimes and climate change scenarios, the results allow anticipating the thaw and creep settlements for some soils in Nunavik and can be used as part of a global adaptation strategy for infrastructure built on permafrost.	13	2019		
Quantifying Hazard and Climate Change Fragility for the Airport Access Road in Salluit, Nunavik, Quebec	Brooks, H; Doré, G; Locat, A; Allard, M	COLD REGIONS ENGINEERING 2019	English	Proceedings Paper	Permafrost; Infrastructure; Hazard Assessment		With changing climatic conditions and increasing infrastructure demands, infrastructure owners, operators, and planners must possess tools to objectively aid their decisions on climate change adaptation and infrastructure maintenance. Risk analysis tools, either qualitative or quantitative, would be very beneficial to select engineering designs and allocate funds for the expected maintenance of linear infrastructure on permafrost. To this end, the paper provides an example application of a newly developed Excel spreadsheet, called Arquluk-RISK, which quantitatively calculates hazard and risk based on site soil, permafrost, and climate condition variabilities. This example focuses on the hazard analysis of total and differential thaw settlement, active layer detachment slides, and culvert collapse and gradient failure for current climate conditions for the airport access road in Salluit, Nunavik (northern Quebec), Canada. The software and analysis includes the variation in increasing mean annual air temperature in the comine decades.	13	2019		
Wildfire, Hydrologic Risk, and Climate Change	Lennon, PEJ; Li, YL; Miller, R; Dorney, C; Hyman, R; Beucler, B; Keller, J; Rodehorst, B; Dix, B	WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2017: GROUNDWATER, SUSTAINABILITY, AND HYDRO-CLIMATE/CLIMATE CHANGE	English	Proceedings Paper	Climate change; Climate uncertainty; Wildfire; Infrastructure vulnerability; Adaptation	SEDIMENT TRANSPORT; FLOWS	The transportation engineering approaches to climate resiliency (TEACR) study is a federal highway administration initiative to broaden the understanding of climate change impacts on infrastructure design. One TEACR case study was an investigation into the impacts of wildfire and changing climate on the design of hydraulic infrastructure. Wildfire and the related hydrologic impacts represent an increasing risk to infrastructure due to land management practices and changing climate. Trends in wildfire have had a significant upward trend since the 1960s with increases in wildfire occurrence and fire severity. Post-fire monitoring studies have shown conditions where a 5-year precipitation event produces a 50-year flow event. Our study includes investigation of watershed post-wildfire hydrologic response and post-fire adaptation practices by the U.S. Forest Service. In the TEACR study, an 11-step decision-making framework for evaluating climate change uncertainty and risk in the engineering design process was developed. The process is demonstrated in the context of a sample wildfire analysis for a culvert in Big Thompson Creek Canyon, Colorado. Hydrologic modeling of the wildfire-impacted watershed was performed using theoretical watershed modeling with wildfire and watershed impact research data published by the USGS, the Colorado Wildfire Risk Assessment Program, and the NRCS. Climate change inputs were developed for the study from the Intergovernmental Panel on Climate Change's CMIP5 dataset. The study concluded with a Monte-Carlo based benefit/cost analysis to determine the recommended approach for the project.	13	2017		
Concrete and Sustainability - Some Thoughts from a Swedish Horizon	Silfwerbrand, J	NORDIC CONCRETE RESEARCH	English	Article	Climate change; CCS; optimization; prolongation of service life; adaptation		Concrete production, especially the cement production, stands for 5-8 percent of the global CO2 emissions. Since concrete is the most frequently used man-made construction materials, this fact is not surprising. Concrete is also the only realistic alternative in order to improve the living circumstances in many countries around the world. Due to its size, the concrete sector has a great responsibility for limiting the consequences of the on-going climate change. The Swedish cement producer Cementa has an ambitious zero vision stating zero CO2 emissions in year 2030. The measures include energy efficiency, bio mass instead of fossil fuels, blended cements, CO2 uptake through carbonation and Carbon Capture Storage (CCS). This paper discusses these measures but also others such as optimization of the concrete mix, optimization of the structural geometry and prolongation of the service life. The paper is ended by a section on adaptation since concrete will also have an important role concerning protection of the built environment for climate change. Protection structures against flood, reconstruction of dams, new waste-water systems and bright permeable concrete pavements reflecting sunlight and improving drainage after heavy rain constitute some examples.	12	2020	10.2478/ncr-2020-0019	
IMPROVED SYSTEM OF ADAPTATION OF MOTOR TRANSPORT FOR OPERATION IN EXTREMELY LOW-TEMPERATURE AREAS	Egorova, TP; Delakhova, AM	PROCEEDINGS OF THE INTERNATIONAL CONFERENCE: AVIAMECHANICAL ENGINEERING AND TRANSPORT (AVENT 2018)	English	Proceedings Paper	Arctic; accessibility by transport; cross-country vehicles; snowmobile; ice roads; seasonality; climate		The goal of research is to develop a conceptual solution of the problem of transport vehicle adaptation to operation in the north and arctic regions of the Republic Sakha of (Yakutia) and to establish a business system to make the area more accessible for vehicles. Methodology and research technique are based on theories proposed by both national and foreign scientists and researchers, who addressed the issues of transport system development in the north regions, technological forecasting, innovation management and economic analysis. Efforts to adapt standard models of vehicles for operation under Arctic conditions and to introduce cross-country transport machines have unraveled a number of challenging issues in the complex cycle of developing a vehicle and delivering it to consumer. One of the problems derives from Technical Regulations introduced in 2015, which prescribe strict rules regarding changes to vehicles' design, making it almost impossible to legitimately modify and improve standard models to adapt them for Arctic conditions. Lack of systematic support from certification and development tests of vehicles utilized under Arctic conditions is the reason behind such flaws in the regulations. The present paper contains a conceptual solution to this problem and describes an established business system for shaping an infrastructure for certification and development tests of transport vehicles for operation in Arctic conditions. Characteristic properties of the transport system adopted in the arctic zone of the Republic Sakha of (Yakutia) that condition adaptation measures for vehicles are analyzed. Vehicles adjusted for Arctic and brought to the national market are reviewed. The novelty of the present study consists in developing a mechanism of shaping an infrastructure for certification and development tests of vehicles for operation in the arctic zone of the Republic Sakha of (Yakutia), as well as establishing a foundation for taking necessary measures directly in the Republic Sakha of (Yakutia). The authors defined a task of mathematical and economic modeling of a vehicle choice to substantiate sponsorship claim of interregional transportation in arctic regions from all budget levels.	12	2018	10.2991/avent-18.2018.24	
Assessment of Sea-Level Rise Adaptations in Coastal Infrastructure Systems: Robust Decision Making under Uncertainty	Batouli, M; Mostafavi, A	CONSTRUCTION RESEARCH CONGRESS 2016: OLD AND NEW CONSTRUCTION TECHNOLOGIES CONVERGE IN HISTORIC SAN JUAN	English	Proceedings Paper			Sea-level rise is one of the most concerning and costly effects of climate change. Resulting sea-level rise impacts may include failure or destruction of infrastructure, immobilization due to transportation system breakdown, and catastrophic saltwater contamination of water supplies. The problem of sea-level rise adaptation is characterized by deep uncertainty that makes it complex to evaluate the economic value of adaptation investments. The key element to evaluate the effectiveness of adaptation strategies is to quantify the long-term cost of physical networks under uncertain sea-level rise scenarios. In this paper, a simulation framework is created and tested to investigate the long-term impacts of sea-level rise on infrastructure systems in order to evaluate the effectiveness of various adaptation strategies. To this end, the transf ormation of infrastructure systems under various scenarios of sea-level rise and adaptation strategies is modeled using the proposed simulation framework. Then, the impacts of sea-level rise are determined in terms of the life cycle costs of infrastructure networks. These estimated costs are used for evaluating the feasibility of various adaptation strategies under future uncertain sea-level rise scenarios. The application of the proposed simulation framework is shown in a case study of a road network using the sea-level rise scenarios in Southeast Florida. The results of the analysis are threefold: (1) prioritization of infrastructure assets for adaptation investment; (2) identification of the right timing of adaptation investments for different links in an infrastructure network; and (3) evaluation of the present value of adaptation investments for the entire network. The results enable more informed decision-making in order to implement robust adaptation under uncertain sea-level rise scenarios.	11	2016		
Impacts of Climate Change in the Andean Foothills of Chile: Economic and Cultural Vulnerability of Indigenous Mapuche Livelihoods	Parraguez-Vergara E., Barton J.R., Raposo-Quintana G.	Journal of Developing Societies	English	Article	Andes; Climate change; indigenous livelihoods; Mapuche; vulnerability	accessibility; adaptive management; agricultural management; climate change; communication; cultural change; economic conditions; indigenous knowledge; indigenous population; livelihood; questionnaire survey; resource scarcity; road transport; severe weather; vulnerability; Andes; Araucania; Chile	The Mapuche communities have the highest levels of vulnerability in Chile in terms of income, basic needs, and access to services. Nevertheless, those living in the Andean foothills have historically been exposed to extreme weather. Examining three Andean municipalities of the Araucania Region from 1990 to 2015, including climate data, interviews with mayors, and adaptation responses of the Chilean state, the article provides evidence of a changing climate and increased vulnerability. The results show trends in scarcity of water, reduction of agricultural production, colonization of plants and population shifts to higher altitudes, increase pressure on Andean ecosystems, and displacement of traditional Mapuche knowledge and practices. Based on these findings, the authors argue it is necessary to change the context in which Mapuche communities develop their livelihoods. This involves strengthening the knowledge of local actors in order to increase their resilience, with adaptation initiatives that emerge from the local context. It also requires enhanced capacity for municipal emergencies and suitable adaptations in road infrastructure, housing, communications, and agricultural planning. At the national level, this also requires recognition of the specific vulnerabilities of indigenous people. © 2016, © 2016 SAGE Publications.	11	2016	10.1177/0169796X166678674	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
A dynamic model for water management at the farm level integrating strategic, tactical and operational decisions	Robert M., Thomas A., Sekhar M., Raynal H., Casellas É., Casel P., Chabrier P., Joannon A., Bergez J.-É.	Environmental Modelling and Software	English	Article	Adaptation; Climate change; Farmer's decision-making process; Modeling; Water management policy	Agriculture; Climate change; Climate models; Computer resource management; Concrete pavements; Economics; Groundwater; Models; Water management; Water resources; Adaptation; Adaptive decision making; Competitive environment; Decision making process; Management flexibility; Management strategies; Temporal and spatial scale; Water management policy; Decision making; adaptive management; agricultural management; climate change; complexity; computer; computer simulation; decision making; farm; farming system; integrated approach; irrigation; model; policy approach; rainfall; semiarid region; village; water management; India	Farming systems are complex and have several dimensions that interact in a dynamic and continuous manner depending on farmers' management strategies. This complexity peaks in Indian semi-arid regions, where small farms encounter a highly competitive environment for markets and resources, especially unreliable access to water from rainfall and irrigation. NAMASTE, a dynamic computer model for water management at the farm level, was developed to reproduce interactions between decisions (investment and technical) and processes (resource management and biophysical) under scenarios of climate-change, socio-economic and water-management policies. The most relevant and novel aspects are i) system-based representation of farming systems, ii) description of dynamic processes via management flexibility and adaptation, iii) representation of farmers' decision-making processes at multiple temporal and spatial scales, iv) management of shared resources. NAMASTE's ability to simulate farmers' adaptive decision-making processes is illustrated by simulating a virtual Indian village composed of two virtual farms with access to groundwater. © 2017 Elsevier Ltd	10	2018	10.1016/j.envsoft.2017.11.013	
Life cycle engineering for roads (LCE4ROADS), the new sustainability certification system for roads from the LCE4ROADS FP7 project	Bustamante, EG; Flores, RF	LIFE-CYCLE OF ENGINEERING SYSTEMS: EMPHASIS ON SUSTAINABLE CIVIL INFRASTRUCTURE	English	Proceedings Paper	Certification system; sustainability; roads; LCA; LCE		This paper aims to show the results achieved on the development of a new sustainability certification system for roads named LCE4ROADS, as part of the FP7 project Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures (GA No 605748). The certification system developed is based on current EN and ISO standards for sustainability in construction (EN15804) and LCA and LCC (ISO 14040-44 and ISO15686) and considers previous developments from other research projects like MIRAVEC, EVITA or COST 354. Key aspects at European level like the adaptation and resilience to Climate Change and the implementation of freight corridors (the so called TEN-T) are considered.	10	2017		
Mainstreaming adaptation strategy for flood risk due to climate change impact on Jakabaring, Palembang, Indonesia	Hamdani, Y; Ilmiaty, RS; Noviarti, D; Hidayat, A	4TH INTERNATIONAL CONFERENCE ON CLIMATE CHANGE 2019 (4TH ICCC 2019)	English	Proceedings Paper			Jakabaring and its surrounding which is part of Palembang are also experienced a high level exposure to hazard of inundation, where the area is heavily affected by tides which are mostly swamps, consisting of reclamation and protection swamps that are vulnerable to the effects of climate change. This study aims to determine the level of risk due to inundation hazards that occur in current conditions and projected conditions through risk assessment with spatial approaches and adaptation strategies needed, The vulnerability parameters that used are exposure (topography, land use, infrastructure), adaptation capacity (drainage), sensitivity (population density, education level, age, gender and poverty). In the baseline condition, Jakabaring and its surrounding areas is on moderate level of risk. Meanwhile in the projection condition (2030), Jakabaring and its surrounding areas is on high level of risk. The adaptation strategies due to climate change impact that can be carried out are river normalization, drainage normalization, infiltration measure, pumping, green open space, canalization, bio-pore, water retention ponds, multiplying gardens in residential area, roads enhancement, pavement enhancement, polders along rivers, and supervision of swamp regulations.	10	2020	10.1088/1755-1315/423/1/012015	
The effect of pavement-watering on subsurface pavement temperatures	Hendel M., Royon L.	Urban Climate	English	Article	Climate change adaptation; Pavement temperature; Pavement-watering; Urban heat island		Pavement-watering is currently viewed as a potential climate change adaptation and urban heat island mitigation technique. The effects of pavement-watering on pavement temperature measured 5. cm deep are presented and discussed. Subsurface temperature measurements could not be used to improve or optimize pavement-watering methods as was seen in previous work on surface temperatures or subsurface pavement heat flux measurements. © 2015 Elsevier B.V.	10	2015	10.1016/j.uclim.2015.10.006	
Effects of Climate Change on Snowpack, Glaciers, and Water Resources in the Northern Rockies	Luce C.H.	Advances in Global Change Research	English	Book Chapter	Adaptation; Climate change; Glaciers; Snowpack; Streamflow		Many of the effects of climate change on ecosystems will be mediated through changes in hydrology. Decreasing snowpack and declining summer flows with warming will alter timing and availability of water supply, affecting agricultural, municipal, and public uses in and downstream from national forests. Declining summer low flows will affect water availability during late summer, the period of peak demand for irrigation and power supply. Increased magnitude of peak streamflows will damage roads near perennial streams, ranging from minor erosion to extensive damage, thus affecting public safety, access for resource management, water quality, and aquatic habitat. Primary adaptation strategies to address changing hydrology in the Northern Rockies include restoring the function of watersheds, connecting floodplains, reducing drainage efficiency, maximizing valley storage, and reducing hazardous fuels. Tactics include adding wood to streams, restoring American beaver populations, modifying livestock management, and reducing surface fuels and forest stand densities. Primary strategies for infrastructure include increasing the resilience of stream crossings, culverts, and bridges to higher peak flows and facilitating response to higher peak flows by reducing the road system and disconnecting roads from streams. Tactics include installing higher capacity culverts, and decommissioning roads or converting them to alternative uses. Erosion potential to protect water quality can be addressed by reducing hazardous fuels in dry forests, reducing non-fire disturbances, and using road management practices that prevent erosion. © 2018, Springer International Publishing AG.	9	2018	10.1007/978-3-319-56928-4_3	
Building an adaptation tool for visualizing the coastal impacts of climate change on prince Edward island, Canada	Fenech A., Chen A., Clark A., Hedley N.	Climate Change Management	English	Book Chapter	Canada; Climate change adaptation; Coastal erosion; Prince Edward Island; Visualization		A quantitative risk assessment of Prince Edward Island's coastal residences (homes, cottages), safety and security infrastructure (roads, bridges, water treatment plants, hospitals, fire departments, etc.) and heritage (churches, graveyards, lighthouses, archaeological sites, parks, etc.) was conducted for every one meter of coastline by estimating the possible future coastlines for Prince Edward Island. Over 1000 residences (houses and cottages) and 17 lighthouses were shown to be vulnerable to coastal erosion. Such scientific results were significant but were threatened to sit on a shelf in a scientific report unless communicated sufficiently to the organizations and communities of Prince Edward Island. A geovisual interface, known as the Coastal Impacts Visualization Environment (CLIVE), was developed enabling citizens to interactively navigate and view a 3-dimensional (3D) virtual environment of the province of Prince Edward Island constructed from accurate historical spatial data and recent LiDAR surveys of topography. A public engagement tour was held across Prince Edward Island during the month of July 2014 at eight communities. This paper introduces the results of the coastal erosion study, the development of the CLIVE tool, and the results of a public consultation. © 2017, Springer International Publishing AG.	8	2017	10.1007/978-3-319-53742-9_14	
Development of a framework for the valuation of EcoSystem Services of Green Infrastructure	Jayasooriya V.M., Ng A.W.M.	Proceedings - 20th International Congress on Modelling and Simulation, MODSIM 2013	English	Conference Paper	Benefit valuation; Eco-system Services (ESS); Green Infrastructure (GI)	Air quality; Climate change; Ecosystems; Engineering geology; Investments; Operations research; Rain; Resource valuation; Roofs; Runoff; Storm sewers; Storms; Urban growth; Water pollution control; Best management practices; Economic and social benefits; Green infrastructure; Social and environmental; Storm-water managements; Sustainable urban drainage systems; Valuation of ecosystem services; Water sensitive urban design (WSUD); Economic and social effects	With the rapid urban growth and development, the quality of green space available is consequently been degrading. Furthermore, many land characteristics have been altered such that the whole water cycle has been significantly changed. Some of the considerable adverse effects occur by these changes include the increase of runoff which can lead to flooding and the poor quality of receiving waters. Therefore, to improve the quality of the prevailing surface conditions whilst managing the stormwater, Green Infrastructure (GI) have been introduced which is becoming one of the promising practices of restoring the natural environment across many countries around the world. The term GI in the literature is commonly referred as Low Impact Development (LID), Best Management Practices (BMP), Sustainable Urban Drainage Systems (SUSD), Water Sensitive Urban Design (WSUD) and Low Impact Urban Design and Development (LIUDD) in different contexts (Eliot and Trowsdale, 2006). GI in broader terms can be defined as an "interconnected network of green space that conserves natural systems and provides assorted benefits to human populations" (McMahon and Benedict, 2006). GI can be grouped into two main categories structural and non-structural. The former include green roofs, rainwater tanks, wetlands, bio swales, pervious pavement, stormwater detention systems, planter boxes, cisterns, rain barrels and downspout disconnection amongst others. Nonstructural GI is designing the buildings or roads to minimize the imperviousness, improvement of the infiltration ability of soils by amending the properties and improving the vegetation of specific site or region. (Eliot and Trowsdale, 2006) Though GI is best known as an alternative to conventional stormwater management strategies, it has been proven that apart from managing stormwater GI can provide a wide range of benefits known as Eco-system Services (ESS) (CNT, 2009). Such benefits include reducing Urban Heat Island (UHI), improving air quality, saving the energy, climate change and adaptation, improving habitats and community livability amongst others. Currently, different countries across the world are committing investments on promoting the benefits of having GI within their communities and therefore it is very important to have a comprehensive study on the value of the ESS they can provide. Such holistic assessment will demonstrate to stakeholders as well as the general public that the application of GIs not only a stormwater management strategy but have many social and environmental benefits. Furthermore, when these benefits can be transferred into monetary value then wider community will appreciate the importance of GI implementation in their society.ESS of GI in six main initial categories. They are water, energy, air, UHI, climate change and community liveability. The ESS of GI can be studied in terms of environmental, economic and social benefits. Since the representation of benefit of each of the ESS in monetary terms can concentrate the results in to a final common resource unit, the economic benefits of these practices can produce are used for the cumulative valuation in the framework development. The valuation is done by using formulas adopted by different researchers in previous studies and applied for the conditions in Melbourne Australia. Melbourne is the second largest city in Australia with a highest rate of urban growth. Due to this scenario the green space available within the area is alarmingly degraded by creating the importance among professionals and government bodies in developing new ways to improve the region's natural environment. Therefore, the aim of this project is to develop a framework for valuing ESS of GI for Melbourne, Australia. The framework is then applied to a hypothetical case study with a green roof area of 300 square meters considering rainfall, temperature, and pricing for utilities in Melbourne area. The results of the ESS assessment indicates that a green roof located in Melbourne can approximately reduce 93 kiloliters of rainfall runoff per year and provide an economic benefit of 1245 AUD per annum by considering its energy, air quality and climate change benefits. © International Congress on Modelling and Simulation, MODSIM 2013.All right reserved.	8	2013		
Measures to reduce transportation greenhouse gas emissions in Romania [Badania w celu zmniejszenia emisji gazów cieplarnianych transportu w Rumunii]	Vasile E., Balan M., Balan G.-S., Grabara I.	Polish Journal of Management Studies	English	Article	Greenhouse gas emissions; Reducing emissions from transport; Transport		The greenhouse gas emissions from transport have registered a severe increase over the years about 23% of carbon dioxide (CO2) emissions resulted from burning fossil fuels worldwide. In this context, it is observed the increasing need to shift to sustainable transport patterns for taking into consideration a wide-scale use of alternative energy sources (e.g. bio-fuels, biogas) and also, the investments in environmental technologies research and development etc. Romania has a national transport system situated on average level in terms of conventional standards of Europe's transport system. But, it was noted that the infrastructure of roads, railways, maritime and air transport is vulnerable in terms of extreme weather conditions. Considering the indirect effects of climate change, they are manifested by deteriorating road and rail infrastructure. The paper presents some of the measures adapted by Romania to reduce the greenhouse emissions produced by the transport sector. The adaptation of the Romanian transport sector to climate change impacts should take into account the use of technologies by focusing on increased safety standards, and ensuring continuity of services. In order to implement these measures it is increased the need to invest into designing vehicles that can withstand the adverse effects of climate change. The new transport infrastructure and means of transport should be designed, beginning with the design phase, in order to be resilient to the effects of the climate change. © 2012, Czestochowa University of Technology. All rights reserved.	8	2012		
Vulnerability and adaptation in two Communities in the Inuvialuit settlement region	Andrachuk M., Pearce T.	Community Adaptation and Vulnerability in Arctic Regions	English	Book Chapter	Infrastructure; Inuvialuit; Subsistence harvesting; Tuktoyaktuk; Ulukhaktok		This chapter compares the Inuvialuit communities of Ulukhaktok and Tuktoyaktuk in the western Canadian Arctic according to the CAVIAR analytical framework. The comparison highlights examples of similarities and differences in exposure-sensitivities and adaptations related to subsistence harvesting and community infrastructure. Subsistence hunting, fishing and trapping on the land and sea ice continue to be valued activities for Inuit in Ulukhaktok and Tuktoyaktuk. In both communities, however, changes in seasonal patterns, sea ice, and weather variability have affected the health and availability of some important wildlife species and have exacerbated risks associated with hunting and travel. Infrastructure in Tuktoyaktuk is highly susceptible to damage due to degradation of permafrost and coastal erosion. The shorelines of the community are prone to erosion, particularly during strong storm events that have damaged buildings and roads in the past. A prominent difference in the capacity of these communities to deal with climate-related exposure-sensitivities is the diversity of their economies and extent to which they rely on subsistence harvesting. This comparison provides insight into the localized nature of vulnerabilities, and policies to support adaptation. © 2010 Springer ScienceBusiness Media B.V.	8	2010	10.1007/978-90-481-9174-1_3	
Vulnerability assessment survey of oil and gas facilities to climate-driven sea level rises and storm surges on the west coast of Trinidad	Singh, B; El Fouladi, A; Ramnath, K	RISK ANALYSIS VI: SIMULATION AND HAZARD MITIGATION	English	Proceedings Paper	climate change; sea level rise; storm surges; impacts and adaptation; coastal zone; Trinidad and Tobago		Greenhouse gas (GHG) climate change/global warming is one of the most pressing environmental concerns today. Small Island States, such as Trinidad and Tobago, are highly vulnerable to climate change because of their small size and low elevation, as in the case of this study, which increases their sensitivity to climate change and limits their ability to adapt. In fact, the adaptive capacity of human systems is generally low in Small Island States, and vulnerability generally high. The Petroleum Company of Trinidad and Tobago (PETROTRIN) recently conducted a detailed vulnerability assessment survey and storm surge simulation through modelling for the west coast of Trinidad stretching from Vessigny River in the North to Cap-de-Ville in the South along the Gulf of Paria. This survey was undertaken so as to identify the impacts of climate driven, sea level rises and extreme storm surge events on Petrotrin's and Trinmar's infrastructure and operations. The methodology used to conduct this vulnerability assessment survey involved coupling A-OGCM (Atmosphere-Ocean General Circulation) model simulations of future sea level rises and TAOS (Total Arbiter of Storms) estimates of storm surges to a GIS-based inundation and erosion scheme so as to estimate land loss and infrastructure facilities at risk from inundation and erosion. The results of the study show that field installations in Petrotrin at Guapo, such as access roads, pipelines, storage tanks and even pump jacks and the offshore operations of Trinmar including offshore platforms, jetties and harbours and administrative buildings would be at severe risk of inundation and erosion deriving from sea level rises and storm surge events.	8	2008	10.2495/RISK080381	
Analysis of the risk of Transport infrastructure disruption from extreme rainfall	Pregnolato M., Ford A., Dawson R.	12th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP 2015	English	Conference Paper		Crashworthiness; Flood control; Floods; Hazards; Rain; Surface waters; Traffic control; Transportation; Travel time; Accessibility model; Empirical analysis; Integrated assessment; Modern infrastructure; Probabilistic risk; Surface water runoff; Transport infrastructure; Weather generator; Risk assessment	Transport infrastructure networks are increasingly vulnerable to disruption from extreme rainfall events due to increasing surface water runoff from urbanization and changes in climate. The impacts of such disruptions typically extend far beyond the original disaster footprint, because of the increased interconnection and spatial extent of modern infrastructure systems. This paper presents an integrated assessment methodology to quantify the flooding risks from extreme rainfall, measured in terms of expected travel time across the road network. The method is driven by a probabilistic rainfall weather generator that can simulate time series of current and future rainfall. This is integrated with a high resolution urban flood model, CityCAT, to provide information on depth and velocity of floodwater. This hazard layer is combined with empirical analysis of vehicle speeds during a flood, to perturb a transport accessibility model to determine the impact of a given event on journey times. The study assessed the potential impact of flooding on the network performance in relation to macroscopic urban travel times using Newcastle-upon-Tyne (UK) as a case study. Results showed relevant delays for two different hazard scenarios, for a maximum of 24 minutes and 42 minutes respectively. The impacts are significant and implementation of a probabilistic risk-based approach will provide a rational means to prioritise adaptation measures to reduce delays in these circumstances.	7	2015		
CLIMATE CHANGE IMPACTS ON ROADS IN BOSNIA AND HERZEGOVINA	Dzebo, S; Ljevo, Z; Saric, A	ROAD AND RAIL INFRASTRUCTURE V	English	Proceedings Paper	climate change; resilient roads; road infrastructure		Safe and efficient transport system are essential in the functioning of business and society at large. The consequence of extreme weather events due to climate change are usually interruption of road network and inaccessibility to urban and economic areas. In Bosnia and Herzegovina climate change manifested itself by gradual changes in climate parameters in the last ten years. So, changes go unnoticed but still have effect on durability and functioning of road infrastructure, like continuous temperature rise, changing of ground water levels, extreme rainfall events, higher maximum temperature and higher number of consecutive hot days, drought (consecutive dry days), extreme wind speed, foggy days, heavy rain for longer periods. As with many hazards, the best way to avoid damage caused by climate change are prevention and preparedness. This paper presents impacts of climate change on roads in Bosnia and Herzegovina, and measures for mitigation and adaptation of road network.	7	2018	10.5592/CO/CETRA.2018.962	
Measurement of the cooling efficiency of pavement-watering as an urban heat island mitigation technique	Hendel M.A., Colombert M., Diab Y., Royon L.	Journal of Sustainable Development of Energy, Water and Environment Systems	English	Article	Climate change adaptation; Pavement heat storage; Pavement surface temperature; Pavement watering; Urban heat island (UHI)		The Paris region (Ile-de-France) was amongst the hardest hit by the August 2003 heat wave, due in part to subsequent amplification of its urban heat island. This has created high heat-wave awareness in climate change adaptation studies for the city of Paris. Over the summer of 2013, pavement watering was studied experimentally in two locations as a climate change adaptation method. Pavement watering was found to lower pavement surface temperatures by several degrees for several hours after watering, while also strongly reducing its cooling rate a few hours before and after sunset. Heat flux and storage at a depth of 5 cm in the pavement were also found to have been significantly reduced, especially during direct sunlight exposure, but also when the pavement was in the shade. Uninterrupted watering appears necessary during direct sunlight exposure of the pavement to maximize efficiency. © 2015, International Centre for Sustainable Development of Energy, Water and Environment Systems SDEWES. All rights reserved.	6	2015	10.13044/j.sdewes.2015.03.0001	

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The role of Greater Copenhagen utility in implementing the city's Cloudburst Management Plan	Ziersen J., Clauson-Kaas J., Rasmussen J.	Water Practice and Technology	English	Article	Climate adaptation; Cloudburst; Hydraulic modelling; Joint effort; Sustainable urban drainage system; Synergies	Budget control; Catchments; Hydraulic models; Climate adaptation; Climate change adaptation; Cloudburst; Management strategies; Optimal solutions; Stakeholder involvement; Sustainable urban drainage systems; Synergies; Climate change	This paper describes Greater Copenhagen Utility's role in planning, coordinating and implementing Copenhagen's Climate Change Adaptation Plan and Cloudburst management strategy. Detailed hydraulic modelling of the seven catchments in the city resulted in the preparation of a cloudburst management plan with more than 350 interventions, at a budget of EUR 1.3 billion. Among the planned projects are designated cloudburst boulevards, retention spaces, green roads and cloudburst tunnels. The joint efforts in coordinating climate change adaptation with city planning and infrastructure implementation, are shown to be key to succeeding with the projects. Stakeholder involvement in preparing the cloudburst management strategy is important in identifying the optimal solutions. © HOFOR A/S 2017.	6	2017	10.2166/wpt.2017.039	
Adaptation investments for transport resilience: Trends and recommendations	Pregnolato M., Dawson D.A.	International Journal of Safety and Security Engineering	English	Article	Adaptation; Flood; Investment; Network; Rail; Resilience; Risk; Road; Transport	Climate change; Economics; Geographical regions; Investments; Network security; Networks (circuits); Rails; Risk analysis; Risk assessment; Risks; Roads and streets; Spatial distribution; Adaptation; Assessment approaches; Methodological frameworks; Resilience; Road; Strategic requirements; Transport; Transport infrastructure; Floods; adaptive management; climate change; comparative study; economic growth; environmental assessment; extreme event; flood; flooding; GIS; investment; methodology; natural hazard; railway transport; risk assessment; road transport; transportation infrastructure; trend analysis; vulnerability; United Kingdom; Wales	Climate change, extreme weather and flooding threaten to increase damage and disruption to our transport networks and the services that they provide. There is increased need for adaptation to maintain current asset conditions and services, and a strategic requirement to prioritise such investments in adaptation to reduce future risks. Physical network risks will not be evenly distributed across nations (e.g. due to geographical and climate change patterns), and some regions will require more investment and adaptive interventions than others to maintain services due their vulnerability to natural hazards. Comparatively, the distribution of investment for transport infrastructure does not have a uniform spatial distribution, and can favour schemes that reduce congestion on networks with high demand without considering the actual risk of being impacted. These two issues, if unchallenged, will present an unfavourable future for areas with high network risks and low transport demand that will widen spatial inequality or resilience, mobility and potential for economic growth. This study advances a methodological framework to analyse the spatial distribution of flood risk on UK road and rail networks in the light of potential bias of regional investment. Using GIS mapping, network data and risk analysis, regional futures are categorised and discussed. There is a clear North/South divide in transport networks at risk from potential coastal and fluvial flooding, with southern regions having 10-30% of their network situated in known flood risk areas. Investment in transport infrastructure is also disproportionately favoured towards regions with high transport demand, and peripheral regional such as Wales and the South West are at risk from increase disparity from high flood risk networks and a low potential for investment. The study provides preliminary evidence for the need to consider assessment approaches for long-term investment in resilience, drawing recommendations for future research. © 2018 wit Press.	5	2018	10.2495/SAFE-V8-N4-515-527	
Anticipating and responding to pavement performance as climate changes	Dawson A.	Green Energy and Technology	English	Article		Pavements; Rain; Maintenance demand; Materials selection; Pavement drainage; Pavement performance; Pavement structures; Support conditions; Techniques and tools; Temperature rise; Climate change	As climate changes, the performance of pavements can be expected to change too. More rainfall can be expected to lead to softer subgrades and less support to the pavement structure with consequences for more rapid cracking and rutting. Even if the amount of rainfall doesn't change, many places can expect the rain to fall in less frequent but more intense storms leading to challenges for current pavement drainage systems. If temperature rises, then asphaltic pavements may be expected to suffer from greater rutting in hot weather; but if the temperature rise causes greater evaporation then improved support conditions could arise; and if the temperature rise is in an area that historically experiences fully frozen conditions in the winter, then weak, thawing pavements could result. Predicting these and other effects of climate change involves an understanding of the sensitivity to climatic effects of both material properties and of overall pavement performance. In turn the predictions of such changes might indicate the need for adaptation in design, construction or materials selection—the extent of the need being dependent on the severity and risk associated with the predicted changes. In this way appropriate responses can be made to the challenges that future climate change will bring. In some places no change to practice may be required. However, for most authorities the immediate response should be to restate design codes and specifications with climate change in view. Mostly, the practices, techniques and tools for an adequate response are already available but users may need to employ adjusted practice if they don't want future maintenance demands to become excessive. © Springer-Verlag Berlin Heidelberg 2014.	5	2014	10.1007/978-3-662-44719-2_4	
Climate change risk assessments and adaptation for roads - results of the ROADAPT project	Bles, T; Bessembinder, J; Chevreuil, M; Danielsson, P; Falemo, S; Venmans, A; Ennesser, Y; Lofroth, H	TRANSPORT RESEARCH ARENA TRA2016	English	Proceedings Paper	Climate change; risk management; adaptation; road; vulnerability		Infrastructure is the backbone of our society. Citizens, companies and governments have come to rely on and expect uninterrupted availability of the road network. Extreme weather is an important factor for the reliability of the road network. At the same time it is generally understood that the climate is changing and that this will have significant effects on the road infrastructure. Since road infrastructure is vital to society, climate change calls for timely adaptation. Immediately, questions arise how to deal with the large uncertainties involved in the projections of future climate, how to assess their effects on the road infrastructure and related socio economic developments, and how to integrate adaptation into decision making. The ROADAPT project was commissioned under the CEDR Call 2012 'Road owners adapting to climate change'. It adopts a risk based approach using the RIMAROCC framework (Risk Management for Roads in a Changing Climate, developed under a previous ERA NET ROAD project). The approach addresses cause, effect and consequence of weather-related events to identify the top risks that require action with mitigating measures for climate change adaptation. Output of the ROADAPT project is a single ROADAPT-RIMAROCC integrating guideline. (C) 2016 Published by Elsevier B.V.	5	2016	10.1016/j.trpro.2016.05.041	
Cool pavements	Hendel M.	Eco-efficient Pavement Construction Materials	English	Book Chapter	Climate change adaptation; Conductive pavement; Cool pavements; Evaporative pavement; Green pavement; Heat-harvesting pavement; Phase-changing pavement; Reflective pavement; Solar pavement; Urban climate		Cool pavements designate alternative pavements designed to reduce their contribution to urban heating. Urban heating generally refers to the sensible heat exchanged with the atmosphere by urban materials but can also include the radiative load they impose on pedestrians. In either case, pavement surface temperature is a very important parameter, which cool pavements seek to decrease compared with standard pavement designs.The energy balance of a pavement surface or very thin pavement slab helps identify the outbound flows that cool pavements attempt to promote and fundamental physical principles that govern them. On this basis, cool pavements can be classified as reflective pavements, green and evaporative pavements, high-inertia or phase-changing pavements, and conductive or heat-harvesting pavements.This chapter presents the urban heat island and the urban heating phenomena and provides an overview of cool pavement technologies, detailing areas that require further scientific investigation. © 2020 Elsevier Ltd All rights reserved.	5	2020	10.1016/B978-0-12-818981-8.00006-0	
Early Pictures of Global Climate Change Impact to the Coastal Area (North West of Demak Central Java Indonesia)	Andreas, H; Pradipta, D; Abidin, HZ; Sarsito, DA	PROCEEDING OF THE 6TH INTERNATIONAL SYMPOSIUM ON EARTH HAZARD AND DISASTER MITIGATION (ISEDM) 2016	English	Proceedings Paper	Global Climate Change; sea level rise; tidal inundation; adaptation	LAND SUBSIDENCE; JAKARTA	In the last several decades we have been realized for the Global Climate Change situation. Some indicators are worldwide increasing temperature, decreasing volume of ice in Antarctica, and the sea level rise. Relating to the decreased of ice volume and the sea level rise, this situation has been predicted to endanger the living at the coastal area in the future. Prediction models have shown some coastal cities area would suffer flood by tidal inundation and even permanent flooding. Coincidently, today in the North West of Demak District Central Java Indonesia we literally can see the early picture of Global Climate Change impact to the coastal areas as mention. The occurrence of tidal inundation in this area was recognized at least in the early 2000 and even earlier, and in the recent years the tidal inundation comes not only at a high tide but even at the regular tide, and in fact some of this area are obviously sinking to the sea through times. This early picture is truly showing a disaster. Adaptation has been made in facing the disaster such as increasing the house and infrastructures, and built dyke. We have been done some investigations to this area by field observations (mapping the flooded area, interviewing people and seeing the adaptations, conduct GPS measurement to see deformation, etc.), gather information from digital media and also using remotely time series of high resolution satellite image data to mapping the tidal inundation in this area. We noted people increased their house and the local goverment elevated the road and the bridge, etc. regulary over less decade periode. Our conclusions said that the adaptation only made temporaly since the sea level keep rising worsening by the land subsidence significantly.	5	2017	10.1063/1.4987101	
Impact of climate change on pavements	Hemed, A; Ouadif, L; Bahi, L; Lahmili, A	SEVENTH INTERNATIONAL CONGRESS WATER, WASTE AND ENVIRONMENT (EDE7-2019)	English	Proceedings Paper	climate change; weather conditions; pavements		Climate change is reflected in changes in average weather conditions and the more frequent occurrence of extreme conditions. It also affects the field of road transport and shows impacts both on traffic and road users as well as on the road infrastructure itself. The main objective of this work is therefore to evaluate the impact of climate change on the performance of road infrastructure (pavements) and to educe recommendations through proposals for adaptation measures. The impacts of climate change on road infrastructure result in changes in some road design parameters (average temperatures, radiation index, etc.). The different cases of cracking (fatigue or other) are assessed separately using degradation indices for each layer composing a pavement (surface layer, base layer, stabilized layer, etc.)	5	2020	10.1051/e3sconf/202015001008	
Using intelligent transportation systems to adapt to potential climate change impacts on seasonal truck weight limits	Montufar, J; McGregor, R	2006 IEEE EIC CLIMATE CHANGE CONFERENCE, VOLS 1 AND 2	English	Proceedings Paper	climate change; seasonal weight limits; winter weight premiums; spring weight restrictions; adaptation technologies		Freight transportation by truck is at the foundation of the economy of the prairie region of Canada. The trucking mode is controlled by a myriad of regulations limiting vehicle weights and dimensions. One important aspect of truck weight regulation in the prairie region concerns their seasonal nature. This seasonal feature is designed to reduce truck loads during thawing periods (using spring weight restrictions) and increase them during freeze-up periods (using winter weight premiums). By limiting loads, spring restrictions help protect pavements when they are in their weakest state. By relaxing load limits on the other hand, winter premiums improve trucking efficiency during those periods when pavements are particularly strong due to their frozen state. Both the spring and winter components of these regulations are matters that can be impacted by climate change, with potentially important subsequent effects on transportation efficiency in the prairie region. In recent years advanced technologies have provided opportunities to effect rationalization and harmonization of seasonal weight limits in the prairie region-with much greater sensitivity to climatic conditions, and changes in those conditions. This paper outlines how and what technologies are being adopted to allow for adaptation and more aggressive real-time knowledge-based harmonization and rationalization of seasonal weight limits in a world of changing climatic conditions.	5	2006		
Airfields and access roads performance assessment in Nunavik, Québec, Canada	Beaulac I., Doré G.	Proceedings of the International Conference on Cold Regions Engineering	English	Conference Paper		Airport runways; Canada; Climate change; Drilling; Permafrost; Photography; Permafrost degradation; Problematic airports; Transportation infrastructures; Unstable access roads; Unstable runways; Road construction	In Nunavik, permafrost degradation is now inevitable and it will eventually threaten the integrity of transportation infrastructures owned by Ministère des Transports du Québec (MTQ). This study was initiated by the MTQ in order to adapt its transportation infrastructures to the new climatic reality. The purpose of this study is to carry out a performance assessment of the Nunavik runways and access roads since their construction in order to determine the appropriate adaptation techniques to reduce permafrost degradation. Thereafter, initial and current base material thickness longitudinal profiles of various runways were compared to determine if settlement occurred. Comparisons between the initial and current runways condition were carried out using air photographs. The assessment made it possible to identify six unstable runways and two unstable access roads. This paper presents the three most unstable runways in Nunavik: Kangiqsuk, Salluit and Taoujaq. Recommendations for the problematic airports, such as permafrost characterization through deep drilling and implementation of mitigation methods, were given at the end of the study. Three mitigation methods are proposed to counter permafrost degradation at Nunavik airports: heat drain, air convective embankment and reflective surface. Copyright ASCE 2006.	4	2007	10.1061/40836(210)61	
High-accuracy coastal flood mapping for Norway using lidar data	Breili K., James Ross Simpson M., Klokkervold E., Roaldsdotter Ravndal O.	Natural Hazards and Earth System Sciences	English	Article		accuracy assessment; coastal zone; coastal zone management; flood; lidar; mapping method; satellite data; sea level change; stakeholder; storm surge; Norway	Using new high-accuracy light detection and ranging (lidar) elevation data we generate coastal flooding maps for Norway. Thus far, we have mapped 80% of the coast, for which we currently have data of sufficient accuracy to perform our analysis. Although Norway is generally at low risk from sea level rise largely owing to its steep topography and land uplift due to glacial isostatic adjustment, the maps presented here show that, on local scales, many parts of the coast are potentially vulnerable to flooding. There is a considerable amount of infrastructure at risk along the relatively long and complicated coastline. Nationwide we identify a total area of 400 km2, 105 000 buildings, and 510 km of roads that are at risk of flooding from a 200-year storm surge event at present. These numbers will increase to 610 km2, 137 000, and 1340 km with projected sea level rise to 2090 (95th percentile of RCP8.5 as recommended in planning). We find that some of our results are likely biased high owing to erroneous mapping (at least for lower water levels close to the tidal datum which delineates the coastline). A comparison of control points from different terrain types indicates that the elevation model has a root-mean-square error of 0.26 m and is the largest source of uncertainty in our mapping method. The coastal flooding maps and associated statistics are freely available, and alongside the development of coastal climate services, will help communicate the risks of sea level rise and storm surge to stakeholders. This will in turn aid coastal management and climate adaptation work in Norway. © 2020 BMJ Publishing Group. All rights reserved.	4	2020	10.5194/nhess-20-673-2020	
How climate change will affect water utilities	Bloetscher F., Hammer N.H., Berry L.	Journal - American Water Works Association	English	Article		Rural areas; Storms; Coastal area; Critical component; Level of Service; Operational control; Steady creeps; Stormwater retention; Water system; Water utility; Climate change	With climate change, our best option is adaptation as, for most places, the slow, steady creep of climate change allows us the time to come up with the money to address issues. Adaptation will take different forms depending on location. A toolbox for SLR has been constructed. For example, we can install more coastal salinity structures, raise roadbeds, abandon some local roads, increase stormwater pumping, or add stormwater retention, to address many of the problems in coastal areas. The technology is available today. Each place will differ, and the costs, timing, and level of service will differ as well. Ultimately utilities need to develop a more managed integrated water system, with more operational controls, more infrastructure, and requiring more operational dollars. The needs will be large-in the trillions nationally. But there are two things in our favor: time and money. The expenditures will occur over many, many years. Most important in the near term is the early planning and identification of critical components of infrastructure, and policy needs and timing for them. Rural areas and the West are more challenging; there is time to raise money, but planning for the long term needs to start now. The key is to develop the appropriate plans to adapt to the changes wrought. In some places this will be minimal-others, significant. Protection of assets for the next 100-150 years is achievable as long as we have the science, the understanding, and the will to do it. Plan now, and over the rest of this century-starting now-we can raise the trillions of dollars needed.	4	2014	10.5942/jawwa.2014.106.0112	
How does the UK transport system respond to the risks posed by climate change? An analysis from the perspective of adaptation planning	Wang T., Qu Z., Yang Z., Ng A.K.Y.	Maritime Transport and Regional Sustainability	English	Book Chapter	Adaptation planning: Case study; Climate change; Rail; Risks; Road; UK		This chapter studies the adaptation experience of UK road and rail systems in managing the risks posed by climate change (e.g., flooding, rising temperature, and storm surge). In particular, it explores the current and potential issues in climate adaptation planning through in-depth investigation of four cases, namely Highways England, Network Rail, Transport for London and Environment Agency (London), and Devon County Council. Although considerable adaptation measures and actions have been implemented at both the national and regional levels in the last decade, the road and rail systems in the United Kingdom still confront diverse challenges. These include, but are not limited to, insufficient scientific data, aging infrastructure, unclear planning horizon, and unspecialized climate risk management. A combined analysis of the relevant literature, local reports, news, and interviews with domain transport experts offers a broad view of adaptation planning in UK roads and railways and valuable insights for creating an integrated inland transport adaptation system. An analysis of road and rail adaptation measures to climate change not only benefits both sectors by cross-reference but also generates new adaptation solutions in terms of using one system to enhance the resilience of the other when climate risks occur. © 2020 Elsevier Inc. All rights reserved.	4	2019	10.1016/B978-0-12-819134-7.00006-X	
Justification of measures to reduce greenhouse gases emissions by transport and adaptation of transport infrastructure facilities to climate change in permafrost zones	Trofimenko Yu.V., Yakubovich A.N.	Ecology and Industry of Russia	Russian	Article	Adaptation; Climate change; Environmental safety; Greenhouse gases; Permafrost zone; Transport complex; Transport infrastructure facilities		The models, methods, as well as the results of the justification of measures to reduce greenhouse gases (GHG) emissions by the transport complex for the period up to 2030 to improve its environmental safety, as well as assessing the effectiveness of measures (the use of seasonal cooling devices (SOA) - heat stabilizers) are considered transport infrastructure facilities (TIFs) of road, rail, air and water transport when implementing different climate change scenarios in the areas of permafrost. For sections of roads and railways (in the embankment), runways of airfields in the territories examined in the next 30 years, high climatic risks that require the use of heat stabilizers are not forecasted. For these objects can be applied less costly protective measures. The pile foundation of bridges and other transportation facilities can be sufficiently effectively protected by heat stabilizers from the effects of climate change. In relation to the strip and raft foundations of port facilities, other production facilities in the territories examined, the use of the SOA is a very effective measure to reduce climate risks. An increase in the expected effectiveness of measures to adapt them in the case of transition from continuous permafrost to its island and rare island species has been established for all types of TIFs. The reduced efficiency of the use of heat stabilizers in soils of low humidity, especially in sandy soils for all types of TIFs, was recorded. © 2019 Izdatel'stvo Kalvis. All Rights Reserved.	4	2019	10.18412/1816-0395-2019-02-55-61	
Primary forests: Definition, status and future prospects for global conservation	Kormos C.F., Mackey B., Della Sala D.A., Kumpe N., Jaeger T., Mittermeier R.A., Filardi C.	Encyclopedia of the Anthropocene	English	Book Chapter	Biodiversity; Climate change; Community conservation; Conservation; Indigenous; Primary forest; Protected areas		Primary forests are forests that are: (1) largely undisturbed by industrial-scale land uses and infrastructure such as logging, mining, and dams and roads; (2) the result of ecological and evolutionary processes including the full range of successional stages over time and with natural disturbance processes operating within historic bounds; (3) more likely to possess the full complement of their evolved, characteristic plant and animal species with few if any exotics; (4) dominated by a largely continuous tree canopy cover, and (5) have unpolluted soil and water. These forests are major strongholds for biodiversity and include the planet's most biodiverse terrestrial ecosystems. They provide essential climate change mitigation and adaptation, freshwater, and other ecosystem service benefits. They are also critically important for livelihoods and for cultural and spiritual reasons and are home for many Indigenous Peoples and local communities. Primary forests are unfortunately in rapid decline globally. Over centuries, Earth has lost about 35% of its preagricultural forest cover. Today, only about 32% (~1.3 billion hectares) of the world's forests are primary forest. We know that protected areas, indigenous, and community conservation are effective mechanisms for maintaining primary forests. National and international forest policies should prioritize the conservation of our planet's remaining primary forests. © 2018 Elsevier Inc. All rights reserved.	4	2017	10.1016/B978-0-12-809665-9.09711-1	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Simulated climate adaptation in stormwater systems: evaluating the efficiency of adaptation strategies	McCurdy A.D., Travis W.R.	Environment Systems and Decisions	English	Article	Climate change; Infrastructure adaptation; Scenario simulation; Stormwater management	adaptation; adaptive management; climate change; culvert; decision making; infrastructure planning; prediction; scenario analysis; strategic approach; water management; Colorado; United States	Adaptations in infrastructure may be necessitated by changes in temperature and precipitation patterns to avoid losses and maintain expected levels of service. A roster of adaptation strategies has emerged in the climate change literature, especially with regard to timing: anticipatory, concurrent, or reactive. Significant progress has been made in studying climate change adaptation decision making that incorporates uncertainty, but less work has examined how strategies interact with existing infrastructure characteristics to influence adaptability. We use a virtual testbed of highway drainage crossings configured with a selection of actual culvert emplacements in Colorado, USA, to examine the effect of adaptation strategy and culvert characteristics on cost efficiency and service level under varying rates of climate change. A meta-model approach with multinomial regression is used to compare the value of better climate change predictions with better knowledge of existing crossing characteristics. We find that, for a distributed system of infrastructural units like culverts, knowing more about existing characteristics can improve the efficacy of adaptation strategies more than better projections of climate change. Transportation departments choosing climate adaptation strategies often lack detailed data on culverts, and gathering that data could improve the efficiency of adaptation despite climate uncertainty. © 2017, Springer Science+Business Media New York.	4	2017	10.1007/s10669-017-9631-2	
Vulnerability and Adaptation to Climate Change in the Canadian Arctic	Pearce T., Smit B.	Climate Vulnerability: Understanding and Addressing Threats to Essential Resources	English	Book Chapter	Adaptation; Canadian Arctic; Climate change; Food security; Inuit; Livelihoods; Permafrost; Subsistence; Traditional knowledge; Vulnerability	Ecosystems; Erosion; Food supply; Health risks; Permafrost; Adaptation; Canadian Arctic; Food security; Inuit; Livelihoods; Subsistence; Traditional knowledge; Vulnerability; Climate change	Arctic ecosystems are already experiencing and responding to climate change. Inuit communities are highly dependent on the natural environment for their livelihoods, and hence are particularly sensitive to the effects of climate change. Community-based studies across the Canadian Arctic have identified several widespread vulnerabilities. Subsistence hunting is susceptible to changes in wildlife populations and access to hunting areas; permafrost degradation has implications for community infrastructure and for coastal erosion; changes in the availability of harvested food contribute an additional risk to people s health; the erosion of environmental knowledge and land skills enhances the vulnerability of Inuit hunters to climate risks; and economic opportunities may come with more shipping, but may be constrained by closed ice roads and limits on the sport hunting industry. © 2013 Elsevier Inc. All rights reserved.	4	2013	10.1016/B978-0-12-384703-4.00439-1	
Assessing the vulnerability of ministère des Transports du Québec infrastructures in Nunavik in a context of thawing permafrost and development of an adaptation stategy	Boucher M., Guimond A.	Proceedings of the International Conference on Cold Regions Engineering	English	Conference Paper	adaptation strategy; degradation; mitigation technique; Permafrost; thawing	Access roads; Active Layer; Adaptation strategies; Adaptation techniques; Airport infrastructure; Deep drilling; Differential settlements; Embankment stabilization; Engineering works; Environmental constraints; Field campaign; Frozen sample; Infrastructure assets; Mitigation techniques; Monitoring programs; Permafrost degradation; Runway embankment; Snow accumulation; Stabilization works; Warming climate; Airports; Climate change; Degradation; Embankments; Permafrost; Roads and streets; Stabilization; Sustainable development; Thawing; Cost engineering	The warming climate in Nunavik is affecting 9 of 13 MTQ airport infrastructure facilities in Nunavik with significant differential settlement and considerable longitudinal settling. A monitoring program along with installation of settlement plates at the most problematic locations was set up by the MTQ. Field campaigns of geophysical investigation and deep drilling were done to characterise the permafrost and to determine the depth of the active layer. The behaviour of the thawing permafrost was studied in laboratory on intact frozen samples. Over the last few years, the MTQ has been supervising research projects to predict and quantify the scale of the damage that can be expected in the wake of climate change and on adaptation techniques intended to mitigate the effects of thawing permafrost witnessed on the access road to the Salluit airport and the Tasiujaq runway. Preventive stabilization work has also been carried out on the Puvirnituq runway embankment. The work done since 2004 has allowed the MTQ to develop a specific strategy for adapting each of its infrastructure assets impacted by permafrost degradation. Adaptation solutions are chosen using a cost-benefit/effectiveness analysis and take into consideration both the safety of the engineering works and the technical and environmental constraints. These solutions entail either reducing snow accumulation and removing water from the toe of the embankment, or cooling the embankment during the winter. The vulnerability of the embankment of the Salluit airport access road prompted implementation of this strategy, and the design of embankment stabilization is currently under way. © 2012 American Society of Civil Engineering.	3	2012		
Framework to address the climate change impacts on road infrastructure assets and operations	Evans C., Tsolakis D., Naudé C.	32nd Australasian Transport Research Forum, ATRF 2009	English	Conference Paper		Adaptation response; Appropriate investment; Australia; Climate change impact; Decision makers; Extreme events; Main roads; Planning process; Queensland; Road authorities; Road infrastructures; Road network; Road transport sectors; Road transports; Temperature changes; Transport operations; Transport sectors; Transport systems; Weather patterns; Gas emissions; Greenhouse gases; Motor transportation; Sea level; Climate change	The road transport sector is a key area that contributes to climate change (CC) by way of greenhouse gas emissions. However, the transport sector is in turn itself affected by CC. Whilst, transport systems and infrastructure are designed to withstand typical weather patterns, CC impacts arising in the near and longer-term can have an impact on the efficiency of transport operations and ability of infrastructure to withstand extreme events outside the 'typical' threshold. The purpose of this paper is to summarise the findings of a study undertaken for Queensland Department of Main Roads (QDMR) in 2008. This paper highlights the possible impacts of CC on road transport with specific reference to the Queensland, Australia context. It provides an overview of the impacts of CC on the Queensland road network. In particular, the effects of CC on operations and infrastructure due to temperature changes, changes in precipitation, rising sea levels, and increased storm activity. Additionally, the short- and long-term impacts of CC as they may affect Queensland and the implications of these for road infrastructure assets, are then considered. The paper also provides a framework that will assist road agencies in the formulation of an appropriate response to these changes in the immediate future that is urgently required, especially in terms of how they manage their road networks. A Climate Change Framework (CCF) is presented, which is designed to assist road authorities in determining appropriate investment priorities, and to enable efficient development of CC mitigation and adaptation responses for transport decision makers. It is argued in the paper that CC impacts should be incorporated as a key component in road authorities' planning processes.	3	2009		
Planning for preservation of original natural vegetation in cities	Florgård C.	Urban Planning in the 21st Century	English	Book Chapter			As cities grow, they usually spread to their rural surroundings. Over the last decades the interest in preservation of the original vegetation of these rural surroundings as parts of the future green infrastructure in the cities has increased in many countries. Vegetation types that may be preserved can be natural and semi-natural forests and woodlands, meadows, pastureland, heaths, mires and wetlands. Preservation of parts of the original natural vegetation provides many aesthetic, social, biological, functional and economic advantages, even in the case of small remnants very close to houses, roads and other developed areas. When a rural area is transformed into an urban area, habitat conditions will be changed, which may negatively impact preserved vegetation. A crucial problem is that natural vegetation cannot be replaced by planting replacement species. Therefore, damage is irreversible if it is greater than the resilience capacity of the original vegetation. The impacts can involve changes in climate, hydrological conditions, soil conditions, pollution situation, fragmentation of biotopes, as well as mechanical impacts such as littering, trampling, cutting and driving vehicles. Vulnerability and resistance are dependent on the type of impact, type of habitat and vegetation type. In planning and design the most resilient vegetation types can be chosen for preservation. Built up areas, roads and other types of infrastructure can be located in a pattern developed to minimize future impacts. Preservation of natural vegetation can be made successful by the use of political decisions, planning measures such as town and city comprehensive plans and detailed development plans, regulations, contracts and so on, but it can also fail through the use of the very same tools. The most important factors are the presence of a committed planningteam, the presence of a person with the commitment and determination that this aggproach should be implemented, and the use of a well functioning information system involving all participants in the planning, design, construction and management of the area. The responsible person must have a strong formal position within the process so that he/she has the possibility to adequately manage the situation. Possibilities of preserving vegetation are only to a minor extent dependent on the density and structure of the development. A thorough and detailed adaptation of the development pattern to the existing vegetation has been found to be of greater significance than the development pattern. Preservation should be secured by the use of legislation, planning, design, contracts and economic measures. However, the most important factor for a successful preservation is found to be a committed and determined planning and design team, and a person in a central position of the planning and design process who shares the same commitment and determination. A nature survey should be carried out before the planning and design process begins. This survey should include vegetation, soil, hydrology, local climate and other factors of importance to the planning and design process. Concerning its extent and wealth of details it must always be adapted to the situation. Early in the process a simple survey integrated in the process is found to be more effective than a highly developed survey distinct from the planning and design process. Later in the process, this first survey has to be completed with extended surveys. © 2009 by Nova Science Publishers, Inc. All rights reserved.	3	2013		
The impact of different watering strategies on the cooling effects of pavement-watering during heat-waves	Parison S., Hendel M., Jurski K., Royon L.	Proceedings of 33rd PLEA International Conference: Design to Thrive, PLEA 2017	English	Conference Paper	Climate change adaptation; Pavement-watering; Thermal comfort; Urban cooling; Urban heat island	Climate change; Potable water; Thermal comfort; Water management; Climatic effects; Cooling technique; Equivalent temperature; Field experiment; Future improvements; Mean radiant temperature; Short-term climate changes; Water consumption; Pavements	Pavement-watering is currently being viewed as a promising cooling technique for dense cities seeking short-term climate change adaptation methods. In this regard, the city of Paris has implemented a field experiment since 2013 in order to improve pedestrian's thermal comfort during heat waves, using the city's non potable water network. The campaigns conducted in 2013 and 2014 have demonstrated that pavement-watering has a positive impact on pedestrians' thermal comfort. In 2015 and 2016, different watering strategies were experienced, aiming to reduce the method's water consumption. In 2015, fewer statistically significant events were found in the morning with regard to the previous years, though the air temperature at 1.5m was reduced up to 1.2°C and by 0.6°C on average. Relative humidity and mean radiant temperature were also affected, resulting in a reduction of UTCI-equivalent temperature up to 2.8°C and by 1.2°C on average. Over the summer of 2016, the impact of the new watering strategy remains uncertain, due to several reasons. The impact of that change on the micro-climatic effects of pavement-watering is though discussed and future improvements are proposed. Copyright © NCEUB 2017.	3	2017		
Urban and peri-urban agriculture as a means to advance disaster risk reduction and adaptation to climate change	Dubbeling M.	Regional Development Dialogue	English	Article		adaptive management; climate change; disaster management; greenhouse gas; urban agriculture; urban economy	Climate change and climate-related disasters add to the challenges already faced by cities and are recognized as one of the most serious environmental, societal and economic challenges facing the world today. Cities consume as much as 80 per cent of energy production worldwide and urban areas currently account for over 71 per cent of energy-related global greenhouse gases (GHG). Climate change adds to the existing challenges faced by cities. Climate change, together with a decrease in absorption capacity of GHGs owing to the reduction in the amount of green cover, parks, trees and agricultural surfaces in urban areas, poses serious threats to urban infrastructure, access to basic services and quality of life in cities and negatively affects the urban economy. Climate change is also aggravating the urban heat is day temperatures in built up areas owing to human and air of heat by buildings and pavements.	3	2013		
A registration system for preventing/mitigating urban flood disasters as one way to smartly adapt to climate change in Japanese cities	Yamashita S., Matsuda S., Watanabe R., Shimatani Y., Moriyama T., Hayashi H., Iyooka H., Hamada T., Yamashita T., Kakudo K., Minagawa T.	International Review for Spatial Planning and Sustainable Development	English	Article	Rainwater retention; Smart adaptation; Urban flooding; Watershed management		Intensive rainfall and frequent inundation have become a serious problem in urban areas all over the world. Climate change and heat island effect may be the cause of the phenomena. Widespread impervious pavement/surface of the ground makes things worse. In order to promote an effective river basin management in urban areas and reduce runoff, a registration system called "Safety Plan for 100mm/h-Rainfall" ("100mm/h Anshin Plan" in Japanese), a scheme for preventing and mitigating inundation caused by extremely heavy, short-term rainfall (such as 100mm/h-rainfall) was established in April 2013 by the central government in Japan. This study carried out a questionnaire survey to examine how municipalities effectively utilize the registration scheme for their watershed management. As a result, it is found that there are municipalities who have started/revised subsidizing installation of private rainwater retention/infiltration facilities in association with the registration system; however, municipalities in general are not so active in promoting runoff reduction by subsidizing private facilities. In addition, in the plans emphasizing public works for runoff reduction, public involvement is not so active, whereas in the plans devised with relatively new committees of watershed management, public involvement as well as private retention activities tend to be active. Based on the results, prospects of how a safety plan should be utilized in an urban watershed are discussed and examined from practicality's point of view. © SPSD Press from 2010, SPSD Press, Kanazawa.	2	2016	10.14246/irspsd.4.2_18	
Adaptation Strategies to Address Rising Water Tables in Coastal Environments Under Future Climate and Sea-Level Rise Scenarios	Manda A.K., Klein W.A.	Coastal Zone Management: Global Perspectives, Regional Processes, Local Issues	English	Book Chapter	Climate change; Coastal; Groundwater inundation; Sea-level rise; Water table		Climate change and sea-level rise will impact coastal aquifers by facilitating saltwater intrusion and/or changing the quantity of water recharging the groundwater system. Another less obvious, but equally important result of climate change and sea-level rise is rising water tables and/or groundwater inundation. Shallow water tables and groundwater inundation are likely to impact various types of infrastructure (e.g., septic systems, building foundations, roads, etc.) in coastal regions. Here, we report on the need to critically account for shallow water tables and groundwater inundation in research studies that address climate change and sea level. We highlight the need for consideration of adaptive and innovative groundwater management strategies that will address future changes to the groundwater systems, particularly those in coastal regions. © 2019 Elsevier Inc. All rights reserved.	2	2018	10.1016/B978-0-12-814350-6.00017-3	
Affordable coastal protection in the Pacific: Impacts of local resource availability and transport costs	Shand T., Carley J., Whalley O., Estigarribia L., Blacka M.	Australasian Coasts and Ports 2017 Conference	English	Conference Paper	Climate change; Coastal adaptation; Coastal erosion; Coastal protection; Cost-benefit; Multi-criteria; Pacific Island Countries	Climate change; Cost benefit analysis; Cost effectiveness; Erosion; Hazards; Landforms; Location; Revetments; Coastal adaptation; Coastal erosion; Coastal protection; Cost benefits; Multi-criteria; Pacific islands; Shore protection	The reshaping and loss of land due to coastal erosion is an ever-present concern for Pacific Island Countries (PICs) and may be caused by both natural and anthropogenic factors. Where erosion conflicts with road, maritime, community or aviation infrastructure, these high value assets are put at risk. This infrastructure has high economic value and often provides critical lifelines for these geographically-dispersed nations. While a range of measures may be used to adapt to the erosion hazard, including avoidance of hazardous locations or relocation of assets, these are often not feasible, especially when land availability is limited or infrastructure is expensive to relocate. In these cases, the land and assets must be protected. Conventional responses to coastal erosion include formalised rock or concrete revetments and seawalls. These structures are engineered to withstand scour, wave impact and overtopping, and formal design guidance is available. Major obstacles for the construction of coastal protection in PICs include the lack of suitable local materials (especially rock of sufficient size and quality) and the high cost of importing materials. A range of non-conventional or 'non-engineered' methods for coastal (land) protection have been trialled throughout the region with varying levels of success. This study has catalogued existing approaches to coastal protection and critically evaluated them against engineering, environmental, social and economic criteria. Conventional approaches such as rock revetments typically have long design lives and moderate construction cost where materials and construction plant are available locally. Costs significantly increase where materials must be transported, particularly long distances to remote island locations. In these locations, alternative protection measures such as structures requiring lower material volumes or those that use local materials and labour but have shorter design lives may become more cost effective. A set of guidance tables have been derived to assist coastal managers in selecting the most cost effective and environmentally and socially appropriate protection method given local resource constraints and transport costs. © Australasian Coasts and Ports 2017 Conference. All rights reserved.	2	2017		
Ecological necessity and practical demands upon defragmentation in Germany [Die ökologische Notwendigkeit zur Wiedervernetzung und Anforderungen an deren Umsetzung]	Reck H.	Natur und Landschaft	German	Article			Ecosystem connectivity contributes decisively to the preservation of biodiversity because life is dependent on the mobility of species. However, by now most of the habitats in Germany are so reduced and isolated from each other and the traffic network has become so dense that lasting conservation of biodiversity is no longer possible without great defragmenta-tion effort. Traffic density now figures 8,000,000,000 car-kilometres per year on a network of 231,420 km supra-local roads. The population of people and of cars is dense too, at 231 per km2 and 118 par km2, respectively. To protect indigenous species, it is necessary: 1. To strengthen threatened popula-tions and to stabilize them by re-establishing the exchange of indivi-duals between isolated populations (population networks, maintaining genetic diversity); 2. for migrating species and mobile key species (bioengineers) to be able to move between habitats (among other things, a sufficient number of migration corridors must be re-stored) and 3. to re-enable processes of spatial adaptation to natural and anthropogenic landscape dynamics - this is also important in order to mitigate or avoid adverse effects of climate change (maintaining sufficient dispersal movement). A coherent network of 'Green Infrastructure' must be established at national and state (Lander) level across and along traffic and settlement networks to fulfil obligations of the Convention on Biological Diversity as well as European and national laws. Integrated spatial planning is vital in order that defragmenta-tion measures can enable people to experience and observe fauna and flora and to seek recreation in a sound, diversified cultural landscape.	2	2013		

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Impacts of climate change on the Hungarian road infrastructure	Timár A.	Pollack Periodica	English	Article	Climate change; Dimensioning of road pavement and engineering structures; Road materials and construction technology; Road operation and management; Road planning and design		The paper presents some preliminary results of an on-going research aiming to assess expected impacts of climate change on road infrastructure planning, design and operation, as well as determining what measures could be considered and recommended to manage these potential impacts. Following an overview of the main parameters (temperatures and precipitation) characterizing expected climate change in the period of 2071-2100, the impacts on roads of high temperatures, freeze-thaw cycles, prolonged growing season, high intensity precipitation, wet conditions and flooding are studied. According to the author, the anticipated effects of climate change should be manageable with current, or slightly modified engineering practice and the materials available, possibly with adaptation. Recommendations are formulated concerning the adaptation process. © 2010 Akadémiai Kiadó.	2	2010	10.1556/Pollack.5.2010.1.2	
Measures to reduce transportation greenhouse gas emissions in Romania	Bălan M., Vasile V.	Quality - Access to Success	English	Article	Greenhouse gas emissions; Reducing emissions from transport; Transport		The greenhouse gas emissions from transport have registered a severe increase over the years about 23% of carbon dioxide (CO_2) emissions resulted from burning fossil fuels worldwide. In this context, it is observed the increasing need to shift to sustainable transport patterns for taking into consideration a wide-scale use of alternative energy sources (e.g. bio-fuels, biogas) and also, the investments in environmental technologies research and development etc. Romania has a national transport system situated on average level in terms of conventional standards of Europe's transport system. But, it was noted that the infrastructure of roads, railways, maritime and air transport is vulnerable in terms of extreme weather conditions. Considering the indirect effects of climate change, they are manifested by deteriorating road and rail infrastructure, the paper presents some of the measures adapted by Romania to reduce the greenhouse emissions produced by the transport sector. The adaptation of the Romanian transport sector to climate change impacts should take into account the use of technologies by focusing on increased safety standards, and ensuring continuity of services. In order to implement these measures it is increased the need to invest into designing vehicles that can withstand the adverse effects of climate change. The new transport infrastructure and means of transport should be designed, beginning with the design phase, in order to be resilient to the effects of the climate change.	2	2013		
A society ill-equipped to deal with the effects of climate change on cultural heritage and landscape: a qualitative assessment of planning practices in transport infrastructure	Antonson H., Buckland P., Nyqvist R.	Climatic Change	English	Article	Adaptation; Cross-sectoral issue; Cultural heritage and landscape; Government reports; Interviews; Roads	Regional planning; Climate change risks; Continuing education; Cultural heritages; Government decisions; Qualitative analysis; Qualitative assessments; Standardised methods; Transport infrastructure; Climate change; climate change; cultural heritage; cultural landscape; planning practice; planning process; prioritization; qualitative analysis; transportation infrastructure; Sweden	This paper provides insights into the handling of climate change issues related to cultural heritage at different government decision levels dealing with physical planning, and in particular roads. Data are derived from a qualitative analysis of official reports and interviews with local and regional planners in three Swedish regions with contrasting climates. The theoretical lens of Institutional Interplay is applied to an analysis grouped into six themes: Climate threats to cultural heritage, Adaptation measures, Preparedness, Institutional preconditions, Institutional interplay, and Challenges. The results suggest that despite a strong environmental reputation internationally, Sweden is not particularly well prepared for dealing with future climate change impacts on cultural heritage and landscape. The lack of national standards and standardised methods risks regional and sectoral variation in the treatment of similar tasks, a problem which deficiencies in knowledge and continuing education are perpetuating. The degree to which discussions and cooperation occur between divisions within the same authority, between authorities, and in national networks varies considerably. Routines and criteria for prioritisation of cultural heritage mitigation, essential under conditions of limited resources, have yet to have been implemented. We conclude with five recommendations for improving the planning process with respect to climate change risks to cultural heritage. © 2021, The Author(s).	1	2021	10.1007/s10584-021-03115-y	
Alternative tourism in the biosphere reserve of vizcaino (rebivi), Mexico: Facing the impacts of climate change	Ivanova A., RamÍRez E., MontaÑO A., Serrano R.	WIT Transactions on Ecology and the Environment	English	Article	Adaptation; Alternative tourism; Mexico; Protected areas climate change		The Biosphere Reserve of Vizcaino (REBIVI) is the most extensive protected natural area in Mexico. The main economic activities are fishing, aquaculture, alternative tourism, and agriculture. The objectives of the present research are the following: a) Characterize the main alternative tourism activities in the REBIVI, b) Analyze the main impacts of climate change on the alternative tourism in the short and medium term, and c) establish measures of adaptation to these impacts. The methodology applied was: a) research in literature and web pages to locate the main tourism activities in the REBIVI, b) analyze the climate scenarios using GIS geographic information systems, d) determine the main impacts of climate change on the REBIVI, and relate them to alternative tourism activities, c) conduct consultation forums in different locations of the REBIVI to know the perception of the inhabitants on the effects of climate change on tourism resources and d) select adaptation measures and prioritize them, based on multicriteria methodology. The results show the following main threats of climate change: droughts, hurricanes, floods, and sea level rise. The scarcity of water resources can affect the maintenance of pronghorn and bighorn sheep, with relation to water availability and grazing. The recommendation is to carry out water saving programs and build small dams for pluvial water catchment. The hurricanes threaten to be more intense, which would cause change of stream channels that can affect roads and highways. We recommend not building infrastructure near these places. Waters of the Pacific Ocean and the Gulf of California surround the REBIVI, making it vulnerable to sea level rise. The recommendation is to move the infrastructure that is close to the coast and try to build the new tourist infrastructure away from the places prone to flooding. The main resource of attraction for alternative tourism in the REBIVI is the gray whale, for which there is no expected negative impact in general. However, pest's proliferation with the increase in temperature could affect the whales. © 2018 WIT Press.	1	2018	10.2495/ST180181	
An in-depth view of climate change: Addressing climate change while making a transition on the development mode	Du X.	Chinese Journal of Population Resources and Environment	English	Article	Climate change; Development mode; Ecological civilization; Resources and environment; Transition		While fossil fuels greatly contribute to human society, they pose great challenges to natural resources, the environment, and climate change. Developed countries, like the United States, formulated strategic measures to ensure their sustainable development and leading positions in the world. These measures include new green policies, development of shale gas, revitalization of nuclear power, energy independence, reindustrialization, and new low-carbon development based on a combination of Internet technology and renewable energy. Developing countries are also trying to introduce balanced strategies of poverty alleviation and sustainable development. Globally, industrial civilization is being transformed to ecological civilization and green, low-carbon development is a global trend. Addressing climate change provides new strategic factors to further this development. China should take substantial actions to realize sustainable development in a new road: China is in the critical stage of changing its development mode, so it is vital to choose an appropriate development path. This extensive development comes at the high price of consuming too much resources and scarring the environment. Mitigation and adaptation strategies for addressing climate change can help the transition of development. Based on the analysis of the development data of developed countries, the author introduces the concept of "two-type developed countries" with an understanding that not all developed countries must take the same development mode. He also holds the view that China should achieve modernization in a more energy-saving and more carbon-efficient manner compared with that of two-type developed countries. An analysis of "two competitions" that China is facing shows that changing the developing mode is urgent and China should grasp this opportunity in the next five to ten years, which is a key period for this transition. This paper discusses the low-carbon development goals and the three-step process. Low-carbon development does not necessarily restrict economic development. It, however, can expedite the transition of the development mode and this is a low-carbon and green development path. Transition of the development mode includes implementation of China's green and low-carbon energy strategies, low-carbon society construction, development of agriculture and forestry, garbage sorting and utilization, innovation of urbanization, etc. Improvement of national infrastructure construction includes water safety, environment and climate monitoring system, intelligent energy web, basic database, etc. Addressing climate change can significantly improve the nation's basic research level. In summary, it mitigates backward production capability, extensive development, and environmental damage while promoting technological advancement, scientific development, and ecological civilization. © 2015 Shandong Normal University.	1	2015	10.1080/10042857.2015.1017905	
An overview of the project Strengthening Infrastructure Risk Management in the Atlantic Area (SIRMA)	Baron E.A., Fernandes S., Matos J.C., Sousa H.S.	Life-Cycle Civil Engineering: Innovation, Theory and Practice - Proceedings of the 7th International Symposium on Life-Cycle Civil Engineering, IALCCE 2020	English	Conference Paper		Climate change; Climate models; Corrosion; Hazards; Land use; Life cycle; Reliability; Risk assessment; Atlantic Ocean; Corrosion process; Natural events; Performance; Probabilistic models; Rail infrastructure; Risks management; Road infrastructures; Transportation infrastructures; Uncertainty; Risk management	Most of the transportation of people and goods in Atlantic Area is made through rail and road infrastructures. Their performance is directly affected by extreme natural events and by the strong corrosion processes that result from proximity to the Atlantic Ocean. SIRMA project aims to develop a robust framework for the management and mitigation of such risks, by implementing immediate, medium, and long-term measures, and therefore to increase the resilience of transportation infrastructure. SIRMA's core is on long-term recovery and risk mitigation to reduce maintenance and retrofitting costs. This objective will be obtained by adjusting existing deterministic models of infrastructure resilience under the current climate, with probabilistic models considering the uncertainties of future climate and change on the land use and how it affects hazard impact on individual mode components. Thus, probabilistic models will allow for a better adaptation of infrastructure to climate change and consider the uncertainties to develop adequate predictive policies and planning tools to reduce risks of hazards. © 2021 Taylor & Francis Group, London.	1	2020	10.1201/9780429343292-164	
APEGBC professional practice guidelines-developing climate change-resilient designs for highway infrastructure in British Columbia (interim)	Harshan R., Glen Z., Michael M.	Proceedings, Annual Conference - Canadian Society for Civil Engineering	English	Conference Paper		Engineers; Highway planning; Professional aspects; Risk assessment; American Society of Civil Engineers; Climate change adaptation; Climate vulnerability; Extreme weather events; Highway infrastructure; Infrastructure design; Professional engineerings; Professional practices; Climate change	The Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) has developed professional practice guidelines that provide practice guidance and case studies to support engineers in addressing climate change and extreme weather event factors in the designs for BC Ministry of Transportation and Infrastructure (BCMoTI) owned provincial highway infrastructure. These guidelines are developed in response to the BCMoTI Technical Circular (T-06/15), which requires infrastructure design adaptation to climate change including documentation for BCMoTI projects. Highway designs already consider climatic factors, but extreme weather resiliency and climate change adaptation are being increasingly considered by professionals, based on the guidance provided by frameworks established by Engineers Canada and the American Society of Civil Engineers. These guidelines showcase the climate science as it relates to the practice of professional engineering and aims to spark a paradigm shift in engineering by supporting the development of designs based on a comprehensive climate vulnerability risk assessment and consideration of innovative approaches that include robust, flexible and low or no regret designs. © 2017Canadian Society for Civil Engineering. All rights reserved.	1	2017		
Challenges in the provision of health to the rural Bedouin population in southern Israel	Urkin J., Alsana S., Merrick J.	Bedouin Health: Perspectives from Israel	English	Book Chapter			The Bedouins in the south of Israel are in a state of transition and adaptation to nontraditional lifestyle and the abandonment of the nomadic way of life in exchange for permanent housing in small towns and authorized villages. This development has been encouraged by the government that provides infrastructure and incentives. However, about eighty thousand Bedouins do not reside in those settlements. Most of them are scattered in permanent houses, huts or tents in remote rural places. Living outside of town means no electricity, no running water, no sewage system, no paved roads, no mail address and no phone lines. Climate changes impose additional burdens on this population. The purpose of this paper is to describe the challenges and some of the solutions in providing health care to this population. © 2013 Nova Science Publishers, Inc. All rights reserved.	1	2013		
Climate extremes and their implications for impact modeling in transport	Pregnolato M., Jaroszweski D., Ford A., Dawson R.J.	Climate Extremes and Their Implications for Impact and Risk Assessment	English	Book Chapter	Climate change; Flooding; Impact; Resilience; Transport		Cities are increasingly vulnerable to damage and disruption from adverse weather events, due to their high concentration of people and assets and a changing climate. In the United Kingdom, the winter storms of 2010 cost the economy £280 million per day, and the government is set to invest £300 billion to protect infrastructure assets at risk from flooding. Improved engineering and planning decisions in the face of complex interactions between climate hazards, infrastructure, and actors within the urban system requires novel analytical tools and methodologies. This chapter addresses the impacts of climate extremes across the transportation sector, particularly in impact modeling studies. In particular, it describes how the nature of the transport system, including its multifaceted vulnerabilities, complexity, and spatially heterogeneous network criticality, places unique demands on the impacts community (e.g., reduced or lack of mobility) and poses interesting questions on suitable pathways to integration into inter-sectoral climate risk assessments. This chapter provides an overview of current knowledge of the impacts of weather and climate extremes on transport, highlighting case studies of extreme flooding impacting roads and rail. Both studies underline the necessity of systems approaches to tackle the challenges brought by urban complexity. It is demonstrated that combining flood modeling and transport networks into the impact analysis improves engineering decision-making and enables the prioritization of adaptation investments in urban areas. The findings and the methodology are of interest to academics, planners, economists, and engineers, as well as communities affected by disruptive events. © 2020 Elsevier Inc. All rights reserved.	1	2019	10.1016/B978-0-12-814895-2.00011-2	
Deep green or white hot? The future of Oxford Road Corridor in Manchester, UK	Kazmierczak A., Cavan G., Carter J., Handley J., Guy S.	COBRA 2010 - Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors	English	Conference Paper	Built environment; Climate change adaptation; Climate projections; Energy exchange model; Green space; Human comfort; Urban Heat Island	Built environment; Climate change adaptation; Climate projection; Energy exchanges; Green spaces; Human comforts; Urban heat island; College buildings; Research; Roads and streets; Surveying; Climate change	The Oxford Road Corridor (The Corridor) is a major transport link running into Manchester city centre. This densely built-up area covers 270 hectares, includes universities, hospitals, museums and theatres, and provides a workplace for around 37,000 people. The Corridor is the subject of major redevelopment efforts. One of the key aspirations is to maintain and enhance the provision of green infrastructure. However, the area is also under considerable pressure from development, which may result in loss of green spaces. One of the arguments for improved vegetation cover is adaptation to increased summer temperatures expected with climate change projections, which are further exacerbated by the Urban Heat Island effect. The EcoCities project at the University of Manchester is investigating climate change impacts on Greater Manchester, and aims to inform the development of adaptation responses for the built environment, with a particular focus on the use of green infrastructure. The Corridor is a key case study being explored by EcoCities. This paper reports on an analysis of the current and possible future changes in land cover along The Corridor. Future development scenarios associated with different amounts of green infrastructure in The Corridor were created, and run through an energy exchange model, with current and future climate projections data, in order to calculate the change in surface temperature related to different development and climate change scenarios. Conclusions are drawn relating to assessing the contribution of increasing green infrastructure in The Corridor to cooling the urban environment and assisting in adapting to climate change impacts. It is hoped that the findings will facilitate a discussion amongst relevant stakeholders about costs and benefits of different models of development in The Corridor in relation to green infrastructure provision. The project has the potential to inform adaptation of The Corridor to climate change, and therefore the creation of a more liveable environment.	1	2010		
Environmental impact of artificial snow production in the ski resorts in the Alps [Umweltauswirkungen der kunstschneeproduktion in den skigebieten der alpen]	De Jong C.	Geographische Rundschau	German	Article		adaptive management; alpine environment; climate change; environmental impact; environmental management; mountain region; strategic approach	Artificial snow production is regarded as an adaptation strategy to climate change. However, the construction of artificial snow infrastructure, With reservoirs, roads and ski runs, leads to profound and at times even irreversible environmental change. Local water resources and water quality are increasingly under stress, soils rendered erodibte, and biodiversity decreasing. Environmental labels and procedures are often intransparent. In future, environmental management plans adapted to climate change and the growing industrialization ofthe mountain environment will be necessary. © 2020 Westermann Schulbuchverlag GmbH. All rights reserved.	1	2020		

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Geo-environmental feedback of present climate change in the rajasthan state, north-west india	Chlachula J., Moharana P.C.	International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM	English	Conference Paper	Aridification; Environmental impact; Sand dunes formation; Thar Desert	Agricultural robots; Arid regions; Costs; Cultivation; Demography; Economics; Ecosystems; Environmental impact; Erosion; Feedback; Land use; Landforms; Reservoirs (water); Stream flow; Sustainable development; Vegetation; Weathering; Agricultural land use; Agricultural strategies; Anthropogenic pressures; Aridification; Environmental adaptation; Mean annual precipitation; Sand dunes; Thar Desert; Climate change	The Thar Desert is a part of the arid zone of north-western India and one of the major deserts in the subtropical belt, encompassing a total geographical area of 196 000 km2. Ongoing desertification with intense erosional actions removing unconsolidated surface cover to form desert pavement on one side, and co-acting mass sediment transfer with sand dunes formations on another side, as well as ground salinisation due to progressing regional aridification (mean annual precipitation 150–500 mm) pose major threats to the local ecosystems and occupation habitats. A broad annual temperature range (5–50°C) contributes to intensive physical and chemical weathering and, in the absence of compact vegetation cover with increased windiness, to a large-scale sediment transfer. These negative effects are responded to by new agricultural strategies contributing to the socio-economic sustainability of the western Rajasthan. The major strategic geo-environmentally-based aim is implementation of modern approaches and innovative techniques enhancing productivity of the Thar area farmlands in view to the steadily rising local demography. Innovative, effective and relatively low-cost approaches and new technologies are being applied aimed at establishment of countryside-protective plantations, wind erosion control, active sand dune stabilisation through tree plantation, artificial watershed and water retention reservoir establishment, wasteland mitigation, desert land farming systems and some other alternate land use strategies reflecting the regional natural conditions and socio-economic needs. Yet, the intensified agricultural land use with a locally excessive artificial irrigation from artesian wells together with livestock overgrazing of the sparse vegetation generate an increasing anthropogenic pressure to the fragile (semi-)desert ecosystems. This is balanced by natural remediation though the innovative crop cultivation and predominant traditional nomadic pastoralism. The current integrated geo-and bioscience research focus is on the effects of the present climate change to both the pristine and anthropogenically used (occupied) lands, 73% of which is directly exposed to wind erosion and certain (arable land) degradation, the modern relief formation as well as the present human influence to the environment. Knowledge of the acting climate variations affecting the landscape (relief and biotic) diversity and pre-determining the actual economic potential in the Thar Desert area is therefore essential in terms of documenting the most recent regional geological history and geomorphic transformations in addition to the environmental adaptations of people in the frame of sustainable development of this NW India's most arid zone. New wind-exposed archaeological sites add to the existing cultural heritage of the country. © SGEM2018.	1	2018	10.5593/sgem2018/5.2/s20.062	
Lightweight dividing walls: Adaptation to temperate climates	Mendonca P., Macieira M.	International Journal of Environmental, Cultural, Economic and Social Sustainability	English	Article	Composites; Lightweight dividing walls; Solar passive/active systems integration		This paper intends to prove that it is possible to use lightweight membranes on interior partition walls and on external façades, even in housing buildings at temperate climate regions, if their properties are well explored. The few material used, even less than conventional lightweight solutions - the most common is plasterboard with light steel frame structure - allow a lower specific embodied energy and other more favourable environmental impact indicators. Compared to conventional heavyweight solutions, such as hollow brick walls, lightweight membranes allow easier deconstruction/ reuse. In the outer skin, architectural membranes can be used as passive or active systems, for heating (promoting greenhouse effect) and cooling (shading or even evaporative cooling). Lightweight materials are more viable to be used on invariably hot or cold climates, than on temperate climates, as in this context they present problems related with its low thermal storage capacity. However, the research of new architectural membrane materials, with passive and active behavior for thermal regulation, allows extending its possibilities to interior dividing partitions in order to fulfill contemporary demands of comfort. Active and/or passive systems can be used to regulate thermal gains - for example by radiant panels and/or evaporative cooling, but also to achieve thermal inertia. In pavements, thermal storage lightweight elements, using natural Phase Change Materials, were already studied and reported on previous studies from the first author. Examples of how these systems can also be applied to lightweight membrane dividing walls are presented in this paper, and some experimental research is now under course on test cell facilities existing in University of Minho, Guimarães.	1	2011	10.18848/1832-2077/CGP/v07i02/54889	
Pavement performance specifications: Case study	D'Amours L., Carrier J.	TAC/ATC 2009 - 2009 Annual Conference and Exhibition of the Transportation Association of Canada: Transportation in a Climate of Change	English	Conference Paper		Pavements; Specifications; Frost susceptibility; Life Cycle Maintenance; Pavement performance; Performance criterion; Public private partnerships; Structural capacities; Surface distress; Technical constraints; Climate change	In a context in which many projects have been executed in public-private partnership (PPP) mode in recent years, it makes sense to explore the various pavement performance criteria used by agencies for recent road projects developed in Canada. After describing the various types of criteria used for pavements, such as ride quality, rutting, surface distress, skid resistance, structural capacity and frost susceptibility, their individual target values are reviewed. Adaptations of the performance criteria to enhance the effectiveness of the specifications for each of the parties concerned are suggested. Finally, the impact of the criteria and target values on the intervention cycles is analyzed in terms of technical constraints and life cycle maintenance cost aspects.	1	2009		
Projecting heat waves temporally and spatially for local adaptations in a changing climate: Washington D.C. as a case study	Zhang Y., Ayyub B.M.	Natural Hazards	English	Article	Climate change; Cool roofs; Green roofs; Heat waves; Reflective pavements; Urban heat island effect	adaptive management; climate change; heat island; heat wave; spatial variation; temporal variation; District of Columbia; United States; Washington [District of Columbia]	Heat waves are posing rising threats to the environment and society due to climate change, urban sprawl, and aging population. To help identify and reduce the vulnerability of cities to extreme heat, this study projects the spatial and temporal variation of heat waves in the twenty-first century and evaluates the performance and cost-effectiveness of heat wave mitigation strategies under future climate conditions. The heat-related condition of Washington D.C. is investigated for such purpose using the high-resolution weather research and forecasting model and the representative concentration pathway 8.5 climate scenario. Results indicate that by the end of the century, the amplitude of heat waves may grow by 5.7 °C, and frequency and duration may increase by more than twofold. The urban heat island effect plays an important role in heat wave growth even though global climate change dominates the variation. Deploying cool roofs and green roofs in Washington D.C. can effectively reduce the amplitude and duration of heat waves, whereas using reflective pavements has relatively little impact. From an economic perspective, cool roofs are more cost-efficient than green roofs and reflective pavements. © 2020, Springer Nature B.V.	1	2020	10.1007/s11069-020-04008-6	
Quantitative steep creek risk assessment, district of North Vancouver, British Columbia	Holm K., Jakob M., Weatherly H., Dercole F., Bridger S.	23rd Canadian Hydrotechnical Conference, Held as part of the Canadian Society for Civil Engineering Annual Conference and General Meeting 2017	English	Conference Paper		Climate change; Debris; Engineering geology; Floods; Hazards; Human resource management; Risk perception; Storm sewers; Storms; Climate change adaptation; Economic risks; Hazard mitigations; Inspection programs; Management programs; Risk reductions; Storm-water managements; Vancouver , British Columbia; Risk assessment	The District of North Vancouver (DNV) has a long history of managing geohazards. Starting in the 1990s, and updated approximately every 10 years, DNV has retained geotechnical and geoscientist consultants to assess debris geohazard (i.e., debris floods and debris flows) risks and make recommendations for reducing risk to tolerable levels. In 2015-2016, we completed comprehensive flood, debris flood- and debris-flow risk assessments for 35 steep creeks within the District using a variety of custom-tailored methods described in this contribution. While most creeks' headwaters are in forested and largely undeveloped terrain, the lower reaches flow through municipal areas containing over 20,000 buildings and a network of roads, utilities, and stormwater management infrastructure. The objectives of the assessment were to assess debris geohazards including their frequency, magnitude, extent, and potential to result in blockage and overflow of DNV stormwater management infrastructure; estimate the risk posed by these hazards to buildings and persons within buildings, prioritize locations for risk reduction planning; and develop risk control options and costs. Based on the results of the assessment, DNV staff are developing a 10-year work plan that will be integrated with the District's asset management, GIS-based inspection program, climate change adaptation and hazard mitigation plans. The work presented herein is an example of a pro-active science-based creek management program aiming to optimize funds for public safety and economic risk reduction. © 23rd Canadian Hydrotechnical Conference, Held as part of the Canadian Society for Civil Engineering Annual Conference and General Meeting 2017. All rights reserved.	1	2017		
Strategies for the Safety Management of Road Transportation Infrastructure under Severe Weather Conditions in China	Wang W., Chen H., Zhou J.	ICTE 2015 - Proceedings of the 5th International Conference on Transportation Engineering	English	Conference Paper	Adaptation strategies; Management; Road transportation infrastructures; Security; Severe weather conditions.		Observed records provide clear evidence of global climate change, especially for severe weather events. The study presented addressed strategies for safety management of road infrastructure under Severe Weather Conditions (SWC), aims to consolidate transportation infrastructures' adaptation to severe weather change. On the basis of reviewing security and management strategy, we analyze the impact of Road Transportation Infrastructure (RTI) in severe weathers. Moreover, strategy development for managing highway safety under SWC is discussed based on the risk assessment, the precaution mechanisms, the emergency rescue and the traffic organization. Lastly, we briefly discusses guarantee measures for implementation. The study demonstrated that the reasonable adaptation strategy for safety management of RTI under SWC can effectively enhance the responsiveness of the traffic administrative department, in addition, which is of great social significance to reduce the loss of accidents to SWC, to maintain social stability and the protection of people's life and property safety. © ASCE.	1	2015	10.1061/9780784479384.370	
Strengthening Africa's Adaptive Capacity to Climate Change: African Union Law and Implications of China's Belt and Road Policy	Addaney M.	Climate Change Management	English	Book Chapter	Adaptation; Adaptive capacity; African union; Belt and road initiative; Infrastructural development		People in Africa are particularly vulnerable to the adverse effects of climate change due to factors such as agro-based economies, poor infrastructure, low technology and industrialization. This phenomenon has weakened Africa's adaptive capacity to climate change. In an interconnected global economy, effective and inclusive development demands effective partnerships. On the other hand, the Belt and Road Initiative (BRI) adopted by the Chinese Government propagates infrastructural investment in participating countries and logistic connectivity. This chapter discusses the strategic goals and scope of the BRI in relation to Africa's priority adaptation sectors such as agricultural modernization, industrialization, energy and infrastructural development. It argues that the BRI has huge potential in promoting agricultural modernization, infrastructural development and industrialisation in Africa which will strengthen the continent's adaptive capacity. In conclusion, it suggests that the African Union and African governments must develop and/or revise their multi-sectoral climate change adaptation policy frameworks to tap into the opportunities that the BRI offers. © 2020, Springer Nature Switzerland AG.	1	2020	10.1007/978-3-030-37425-9_25	
Tools to evaluate the vulnerability and adaptation of infrastructure to climate change	Felio G.	Proceedings, Annual Conference - Canadian Society for Civil Engineering	English	Conference Paper		Cost effectiveness; Cost engineering; Decision making; Potable water; Public risks; Risk assessment; Civil infrastructures; Climate change adaptation; Climate change impact; Coastal infrastructure; Economic impacts; Electrical transmission; Engineered systems; Operations and maintenance; Climate change	It is clear that climate change represents a significant risk to the performance of engineered systems and to public safety in Canada. As such, engineers, asset managers and decision-makers must address climate change adaptation as part of their primary mandate - the protection of the public interest, which includes life, health, property, economic interests and the environment. Vulnerability and risk assessment form the bridge to ensure climate change is considered in engineering design, operations and maintenance of civil infrastructure. Identifying the components of the infrastructure that are highly vulnerable to climate change impacts enables cost-effective engineering, operations and policy solutions to be developed. This paper puts future climate risks in the context of the current condition of Canada's infrastructure and the impacts of climate change. It presents a high level overview of some of the tools available to decision-makers and infrastructure practitioners to consider climate change impacts, from planning to operations and maintenance. The article focuses on processes and methodologies that have been used by public agencies and municipalities in Canada to identify and quantify risks, as well as develop climate change adaptation solutions. Engineers Canada's PIEVC Protocol, a methodology used in more than 40 projects across Canada to evaluate the vulnerability of infrastructure is described in more details. The Protocol has been applied to a wide spectrum of infrastructure: roads, highways, bridges and associated structures; potable water, wastewater and storm water systems; electrical transmission infrastructure and dams; buildings; airports; and coastal infrastructure. The applications cover all regions of Canada.	1	2015		
Vulnerability assessment of climate change impact on critical oil/Gas infrastructure: A decision-maker's perception in the Niger Delta	Udie J., Bhattacharyya S., Ozawa-Meida L.	International Journal of Climate Change: Impacts and Responses	English	Article	AHP; Climate change; Infrastructure; Niger delta; Vulnerability assesment		The impacts of climate change arising from flooding, the intrusion of high saline tidewater, rising temperature, wind storms, and rising Atlantic level are exacerbating significant threats to oil and gas critical installations in the Niger Delta. Understanding the hierarchies of vulnerable critical infrastructure could help assets managers in the industry to adopt sustainable adaptation measures against the looming impacts of climate change-induced stress on systems. In this article, the analytic hierarchy process (AHP) is implemented in prioritising vulnerable critical oil and gas infrastructure in the Niger Delta for effective and sustainable adaptation planning and response. A mix of an exploratory investigation involving interdisciplinary participants' engagement in focus groups were conducted in four multinational oil companies in the Niger Delta to elicit data for analysis. Participants in the study compared seven selected critical installations using an AHP questionnaire. A MI-AHP spreadsheet analysis of stakeholders' perceptions revealed infrastructure vulnerability in hierarchical form: pipelines, terminals, roads/bridges, flow stations, loading bays, transformers/high voltage cables, and wellheads. The study shows that the vulnerability in the region is influenced by exposure, the presence of climate burdens, and proximity to inundated coastal areas below 4.5 meters above sea level. It also shows that critical systems are vulnerable due to interdependence and level of linkages that exist between directly vulnerable and non-directly vulnerable assets. Results also show that vulnerability in the region is due to critical perception, age and obsolescence, and weak adaptive capacity. This study furnished decision-makers in the oil and gas sector with information on which infrastructure is to be protected in terms of adaptation planning, investment, and implementation with particular attention on climate change. © Common Ground, Justin Udie, Subhes Bhattacharyya, Leticia Ozawa-Meida.	1	2018	10.18848/1835-7156/CGP/v10i04/25-39	
Adaptation to Climate Change - Task Group under CEDR	Petkovic, G; Thordarson, S	TRANSPORT RESEARCH ARENA 2012	English	Proceedings Paper	Climate change adaptation; National Road Administration; national policies; risk assessment; road planning; road maintenance		Conference of European Road Directors, CEDR, initiated work on studying the effects of climate change on roads. The work belongs to Strategic Plan 2 (2009-2013), Thematic Domain Operation and is organised as twin tasks dealing with adaptation on one hand (task 16) and mitigation of climate change on the other hand (task 17). This paper describes the work within task group 16 on adaptation to climate change, from the initiation of the work to the publishing of the report to CEDR, October 2011. The mandate of the adaptation group can be summarised as follows: Show the consequences of climate change for infrastructures, and propose actions towards adapting the road network and management procedures to climate change. The work started by performing two surveys in road administrations in the participating countries: a survey of risks related to climate change, and a survey of ongoing adaptation work. The report to CEDR consists of a summary of the results of the surveys, and is followed by a more detailed examination of the effects of climate change on the road network. Suggestions for adaptation work are offered and criteria for prioritising possible actions are proposed. A thematic collection of examples demonstrating adaptation work in the participating countries is integrated in the report. Some of the examples refer to R&D programmes. Others describe current practice in one country that may be useful and relevant for application in another country. The report also suggests topics for future research, including opportunities for trans-European joint research programmes. (C) 2012 Published by Elsevier Ltd. Selection and/or peer review under responsibility of the Programme Committee of the Transport Research Arena 2012	0	2012	10.1016/j.sbspro.2012.06.1226	
Climate Change Adaptation Strategies for Canadian Asphalt Pavements; Part 1: Adaptation strategies	Swarna, ST; Hossain, K; Mehta, YA; Bernier, A	JOURNAL OF CLEANER PRODUCTION	English	Article	Climate change; Adaptation strategies; Pavement performance; AASHTOware ME design; Pavement design		There is strong evidence for climate change leading to a rise in temperatures and a change in precipitation trends. These environmental changes pose a threat to pavement infrastructure worldwide. Therefore, it is necessary to modify pavement design procedures to consider climate change. In addition, it is necessary to consider suitable pavement materials for future climate. The objective of this study is to develop a framework for selecting an appropriate adaptation strategy to mitigate climate change impact. To fulfill this, the influence of climate change on long-term pavement performance in Canada has been quantified over sixteen Canadian pavement sections located over various provinces in Canada. In addition, the fundamental causes of pavement deterioration due to climate change were determined using ten different climate change models. Various adaptation strategies such as upgrading asphalt binder grade, increasing the thickness of asphaltic concrete layer, increasing the base layer thickness, and using stabilized base layers were analyzed to reduce pavement deterioration and to extend the service life of the pavement. Unlike the other studies, pavement temperatures were determined using Enhanced Integrated Climate Model (EICM) to determine the change in binder grade for the future climate in the adap-tation process. The study found that by 2070 all examined locations will require an upgrade in binder grade and the majority will require an upgrade in mixture gradation. Furthermore, the east and west coast will be more vulnerable to climate change and require additional measures in comparison to Central Canada. Newfoundland and Prince Edward Island are the only locations that will need to consider a change in asphalt thickness while British Columbia is the only location eventually requiring a stabilized base. This study emphasizes the necessity of climate change adaptation strategies for Canadian asphaltic concrete pavements.	0	2022	10.1016/j.jclepro.2022.132313	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
A sustainable and resilient approach to managing flooding, water quality, and ecosystems for rivers and streams	Schmidt M.F.	WEFTEC 2016 - 89th Water Environment Federation Annual Technical Exhibition and Conference	English	Conference Paper	Adaptation; Best management practices (BMPs); Cumulative impacts; Floodplain and floodway protection; Green infrastructure; Integrated stormwater management; Resiliency; Stormwater harvesting; Sustainable; Volume-time detention method	Aquifers; Banks (bodies of water); Buffer storage; Climate change; Ecosystems; Engineering geology; Erosion; Flood control; Food storage; Oils and fats; Quality control; Recharging (underground waters); River control; Storm sewers; Storms; Sustainable development; Water quality; Water supply; Adaptation; Best management practice (BMPs); Cumulative impacts; Flood plains; Green infrastructure; Resiliency; Storm-water managements; Stormwater harvesting; Sustainable; Volume-time detention method; Floods	Rivers and streams provide stormwater conveyance and storage, habitat, food, navigation, recreation and aesthetic beauty. For these reasons, many of the largest and most populous cities in the world lie along rivers and coasts, and healthy productive waters are key to public health and prosperity. Over time, development has encroached on wetland, riparian buffer and floodplain areas causing cumulative impacts. Many systems are experiencing issues with increased flooding and erosion; adverse impacts to water quality from excess levels of nutrients, sediments, bacteria, oils and grease, and metals; and loss of habitat and declining health of flora and fauna. Cumulative impacts are often a result of inadequate site runoff requirements and standard floodplain management policies that allow floodplain filling to raise structures. Buildings, roads and conveyance channels are also allowed to be filled, allowing as much as a one-foot increase in protected floodways. These practices often lead to snowballing impacts, and ultimate flood stage increases can be significantly greater than one foot, especially in flat areas and floodplains. Integrated stormwater, riparian buffer and floodplain management programs offer sustainable opportunities to protect and enhance rivers and streams by considering all water as a resource to be managed rather than disposed. This approach provides multiple benefits and cost savings in a resilient manner to protect systems and support adaptation for climate change. Benefits include riverine and tidal flood control, erosion control and reduced sedimentation, water quality improvement, increased aquifer recharge, stormwater harvesting and alternative water supply, shoreline and ecosystem restoration, and public parks and amenities. This paper presents a sustainable approach from more than 32 years of comprehensive stormwater and river management program experience, including existing system retrofits, new development and redevelopment controls. It includes discussion of lessons learned and the refinement of standards and criteria over that timeframe. It includes references to multiple ongoing programs and with an example case study. The approach is founded on three key elements working together to leverage the benefits of each: • Protection of onsite storage, floodplain storage and floodways • Protection and management of onsite vegetation, riparian buffer zones and stream habitat • Integrated stormwater management approaches for stormwater quantity and quality. Copyright ©2016 Water Environment Federation.		2016	10.2175/193864716819713790	
Adaptation of the Road Infrastructure to Climate Change	Auerbach M., Herrmann C.	Materials and Infrastructures 2	English	Book Chapter	Adaptation strategies; AdSVIS projects; Climate change; International cooperation; Road infrastructure	International cooperation; Motor transportation; Risk assessment; Roads and streets; Wind; Adaptation strategies; AdSVIS projects; Climate projection; Climatic parameters; Engineering structures; Global challenges; Road infrastructures; Road network data; Climate change	Various climate projections predict changing climatic parameters such as temperature, precipitation and wind speed for Germany. This could have severe impacts on road transport infrastructure as well as road traffic itself. At the Federal Highway Research Institute (Bundesanstalt für Straßenwesen), a strategy was developed to adapt roads and engineering structures to the impacts of climate change. The strategy "Anpassung der Straßenverkehrsinfrastruktur an den Klimawandel/Adaptation of road traffic infrastructure to climate change (AdSVIS)" currently comprises about 15 projects. On the basis of the identification of the hazards and the combination of the climate and road network data, the road transport infrastructure that might be affected is to be determined. Adaptation measures are to be developed for the identified risk areas and consequently their effectiveness has to be assessed. Special attention is given to international cooperations since climate change is a truly global challenge. © ISTE Ltd 2016. All rights reserved.		2016	10.1002/9781119318613.ch14	
Adaptation to climate change in design-SH16 causeway upgrade	Bettington S.H., MacKintosh D.J.	Australian Coasts and Ports 2015 Conference	English	Conference Paper	Climate change; Overtopping; Sea level rise; Seawall	Budget control; Causeways; Complex networks; Contractors; Cost effectiveness; Design; Embankments; Ports and harbors; Retaining walls; Sea level; Adaptation to climate changes; Coastal infrastructure; Construction methodology; Cost-effective solutions; Design and construction; Geotechnical conditions; Overtopping; Sea level rise; Climate change	As part of the NZ Transport Agency's motorway network upgrade in Auckland, a causeway across the western edge of Waitemata Harbour and bridge over the Whau River are being significantly improved. This project is part of the Western Ring Route, a Road of National Significance (RoNS) to New Zealand. Combined with the adjacent Waterview Connection Project and other highway upgrades these works will provide a significantly improved motorway connections though western Auckland. The Causeway Alliance was commissioned to undertake design and construction of the SH16 Causeway Upgrade Project and is comprised of the NZ Transport Agency with Fulton Hogan, Leighton Contractors, AECOM, Coffey, and Jacobs (formerly Sinclair Knight Merz). The project includes raising the existing carriageway and causeway embankment up to 1.5m to prevent flooding during peak tides and accommodate future sea level rise to 2100, widening the embankment to accommodate four eastbound lanes five westbound lanes, bus shoulders, improved facilities for cyclists and walkers and improved treatment of stormwater runoff. In this age of increasingly tight constraints on infrastructure budgets set against the need to minimise environmental damage and social impacts; all while addressing rising sea levels, design decisions have become increasingly complex. This project offers a range of lessons for designers and agencies alike. This paper aims to draw out some of these lessons as they apply to coastal infrastructure and in particular the design process. Areas of focus will include: • How to approach climate change in design. • Importance of open discussion and collaboration between clients, contractors and designers to develop cost effective solutions (what really matters in cost control; where should the design effort be applied). • Complex geotechnical conditions that impact design decisions and construction methodology. • Issues relating to selection of suitable rock armour. A key area of discussion relates to the design approach to climate change and the adaptations adopted. The practical approach New Zealand agencies have adopted actively provides for prudent design and construction, yet allows for severe climate change induced sea level rise. In comparison the conservative or haphazard approaches of other jurisdictions can lead to poor engineering and possibly overdesign, which in turn leads to a reactive political environment.		2015		
Adapting pavement infrastructure to flood risk under climate change-A review of adaptation strategies	Donghui L., Susan T., Wei-Chau X.	6th International Disaster Mitigation Specialty Conference 2018, Held as Part of the Canadian Society for Civil Engineering Annual Conference 2018	English	Conference Paper		Disasters; Global warming; Pavements; Sea level; Adaptation decisions; Adaptation framework; Adaptation strategies; Climate change adaptation; Extreme weather events; Intense precipitation; Pavement performance; Pavement systems; Floods	Flooding is one of the most common natural hazards in Canada. Climate change is expected to increase flood risk caused by frequent and intense precipitation, and rise of sea level. The implications of climate change influence the planning, design, construction, and management of pavement infrastructure due to flooding risk. In order to live better with the consequence of global warming, appropriate actions should be taken to prevent or minimize pavement damage, and to ensure a satisfactory pavement performance. Climate change adaptation helps to reduce pavement vulnerability to extreme weather events, and thus to offset the effects of global warming. This paper reviews adaptation strategies for managing pavement flooding risk from various aspects. Research literature, current inventories, policies, and adaptation framework and plans from Canada and other developed nations are reviewed. An adaption framework and technical adaptation strategies are developed, which serve as a reference for researchers, pavement managers, and other stakeholders to make better adaptation decisions and to increase pavement system resiliency. © 6th International Disaster Mitigation Specialty Conference 2018, Held as Part of the Canadian Society for Civil Engineering Annual Conference 2018. All rights reserved.		2018		
Best-practice guidelines for adaptation of roads to climate [Guía de buenas prácticas para la adaptación de las carreteras al clima]	De La Peña González E., López Valiente M.	Carreteras	Spanish	Article	Adaptation; Climate; Climate change; Design; Environment; Life cycle; Planning; Resilience	Design; Highway planning; Life cycle; Planning; Transportation routes; Adaptation; Best practice guidelines; Climate; Engineering practices; Environment; Planning and design; Resilience; Road infrastructures; Climate change	There has always been a close relationship between climate and road infrastructure; however, the accelerated changes that have happened recently mean that the historical climate data used to date are not sufficient for an adequate management of the current infrastructure. If the planning and design of roads are still carried out only in accordance with the usual engineering practices and with the existing historical data, they will probably not be able to respond to the climatic events of recent years and that, predictably, will continue in the future. The Best Practices Guidelines for the Adaptation of Highways to Climate, published by CAF - development bank of Latin America, aims to generate knowledge about the importance of defining infrastructures adapted to the climate throughout their life cycle, as well as to show examples, actions and measures of good practices that could be useful to apply to highway projects. © 2019 Asociacion Espanola de la Carretera. All rights reserved.		2019		
Challenges and solutions in the provision of health to the rural bedouin population in Southern Israel	Urkin J., Alsana S., Merrick J.	Climate Change and Rural Child Health	English	Book Chapter			The Bedouins in the south of Israel are in a state of transition and adaptation to nontraditional lifestyle and abandonment of the nomadic way of life into a change to permanent housing in small towns and authorized villages. This development has been encouraged by the government that provides infrastructure and incentives. However, about eighty thousand Bedouins do not reside in those settlements. Most of them are scattered in permanent houses, huts or tents in remote rural places. Living outside of town means no electricity, no running water, no sewage system, no paved roads, no mail address and no phone lines. Climate changes impose additional burden on this population. The purpose of this chapter is to describe the challenges and some of the solutions in providing health care to this population. © 2011 Nova Science Publishers, Inc. All rights reserved.		2011		
Climate change and coastal transport infrastructure—How do we keep Australia moving?	Fisk G., Tonmoy F., Rissik D.	Lecture Notes in Mechanical Engineering	English	Book Chapter			Transport infrastructure across the spectrum of airports, seaports, road and rail involves assets that are long-lived, and what is designed today must be done so in the context of expected increases in the intensity of extreme weather events. Much of Australia's transport infrastructure is located close to the coast and is vulnerable to sea level rise and its associated processes (e.g. erosion, inundation), and other climate change-related extremes storms, heatwaves, droughts and floods. Faced with the uncertainties of the timing and severity of climate change, decisions about what, where and how to build new coastal transport infrastructure as well as maintaining existing ones will become more and more challenging in the future. This paper summarises the risks to coastal infrastructure from climate change and the key drivers that owners and operators of transport infrastructure in Australia should consider to help them adapt to the effects of coastal climate change and extreme weather events. This includes both the siting and design of new infrastructure as well as strategies to build resilience of current infrastructure to future impact. Showcasing the National Climate Change Adaptation Research Facility's (NCCARF) on-line adaptation decision support tool, CoastAdapt, the paper outlines guidelines and information available to infrastructure owners and operators to build resilience and adapt to future climate risks including a recent case study undertaken with North Queensland Airports. © Springer Nature Switzerland AG 2019.		2019	10.1007/978-3-319-95711-1_17	
Climate change and infrastructure: Decision making issues and adaptation measures	Ethans D.	Climate Change and Infrastructure: Decision Making Issues and Adaptation Measures	English	Book			According to the National Research Council (NRC) and others, infrastructure such as roads and bridges, wastewater systems, and National Aeronautics and Space Administration (NASA) centers are vulnerable to changes in the climate. Changes in precipitation and sea levels, as well as increased intensity and frequency of extreme events, are projected by NRC and others to impact infrastructure in a variety of ways. When the climate changes, infrastructure-typically designed to operate within past climate conditions-may not operate as well or for as long as planned, leading to economic, environmental, and social impacts. This book examines the impacts of climate change on roads and bridges, wastewater systems, and NASA centers; the extent to which climate change is incorporated into infrastructure planning; factors that enabled some decision makers to implement adaptive measures; and federal efforts to address local adaptation needs, as well as potential opportunities for improvement. © 2014 by Nova Science Publishers, Inc. All rights reserved.		2014		
Climate change and post-harvest agriculture	Chegere M.J.	Agricultural Adaptation to Climate Change in Africa: Food Security in a Changing Environment	English	Book Chapter			This chapter looks at the role of post-harvest losses (PHL) in adaptation to climate change in sub-Saharan Africa. An estimated 10%-20% of the total grain produced in that region is lost before the food reaches consumers. This loss is valued in billions of dollars a year and could meet the annual calorie needs of 48 million people. PHL also waste labor, land, water, fertilizer and energy, and generate unnecessary greenhouse gas emissions, when resources are used to produce, process, and transport food that will not reach consumers. Losses occur during post-harvest activities, such as drying, storing, and transporting grain. PHL can be quantitative (e.g., bags of grain break and spill, or pests eat the grain) and qualitative (e.g., loss in nutritional value due to spoilage). A number of causes of PHL will be exacerbated by hotter average temperatures, greater rainfall variability, and more frequent extreme weather events. These factors are compounded by inadequate post-harvest handling practices and inadequate facilities and infrastructure. PHL can be reduced by investing in cold and dry storage, rural roads, rural and wholesale market facilities, and processing facilities. Training of farmers on proper practices and use of strategies such as hermetically sealed bags can reduce PHL. © 2018 Environment for Development (EfD) Initiative.		2018	10.4324/9781315149776	
Climate change and the highway system: A project level adaptation approach	Lennon J.M., Dorney C.L.	World Environmental and Water Resources Congress 2013: Showcasing the Future - Proceedings of the 2013 Congress	English	Conference Paper	Adaptation; Climate Change; Climate Uncertainty; Infrastructure vulnerability	Bridges; Cost benefit analysis; Costs; Economic analysis; Floods; Safety engineering; Sea level; Sewage treatment; Urban transportation; Water resources; Adaptation; Adaptive design process; Climate Uncertainty; Design and evaluations; Future climate projections; Infrastructure vulnerabilities; Sewage treatment facilities; Transportation infrastructures; Climate change	Climate change implications and the associated risk and uncertainty in the design and evaluation of infrastructure is an increasing concern facing system owners and engineering design professionals. This paper provides a discussion of a project-level adaptation design process that provides a context for inclusion of climate change uncertainty. The adaptive design process proposed is for the analysis of infrastructure affected by precipitation, runoff, and flooding, but the basic framework can also be used to evaluate other climate hazards such as sea level rise, urban heat islands, etc. The process in this paper focuses on the flooding of transportation infrastructure, in particular a bridge crossing. However, the process can also be readily modified to analyze other forms of infrastructure including sewage treatment facilities, levees, dams, etc. The adaptive design process is a site-specific, detailed evaluation that relies upon the testing of different project alternatives. Multiple alternatives are to be developed and tested for a range of peak discharges associated with future climate projections and/or error margins in historic precipitation data. The process analyzes each project alternative using hydrologic damage curves that relate asset failure thresholds (and their costs) to specific discharge levels. The damage curves are to be developed by planners, economists, and design professionals based upon sound engineering judgment and an analysis of the implications of failure. The adaptive design process can be utilized as a tool to evaluate the uncertainty in system hydrology due to projected climate changes and/or the error margins in the historic climate record. The adaptive design process concludes with a cost-benefit economic analysis. The economic analysis provides the basis for cross-comparison among the adaptation alternatives. The project alternative with the highest benefit/cost ratios across the range of climate scenarios tested should receive strongest consideration for final design. © 2013 American Society of Civil Engineers.		2013	10.1061/9780784412947.201	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Climate change engineering vulnerability assessment of transportation infrastructure in British Columbia Phase II	Nyland D., Nodelman J.R., Nodelman J.Y.H.	2011 Conference and Exhibition of the Transportation Association of Canada - Transportation Successes: Let's Build on Them, TAC/ATC 2011	English	Conference Paper		Climate change; Exhibitions; Highway planning; Laws and legislation; Risk assessment; Standards; Adaptation strategies; Climate change adaptation; Highway infrastructure; Infrastructure vulnerabilities; Ministry of environments; Public infrastructures; Transportation infrastructures; Vulnerability assessments; Transportation	In December of 2009 the BC Provincial government put into place a BC Climate Adaptation Strategy. The Strategy calls on ministries to consider climate impacts, where relevant, in service and business plans, projects, legislation, regulations, and approvals. The goal of the Strategy is that B.C. be prepared for unavoidable climate change and its impacts. Many of these potential climate impacts are directly relevant to government business. In accordance with the BC Climate Change Adaptation Strategy, the BC Ministry of Transportation and Infrastructure considers potential climate change and impacts, in planning, projects, policies, legislation, regulations and approvals. Ministry areas affected include: Operational Programs (Transit, Cycling, Avalanche), Engineering Programs (design standards and guidelines), and Maintenance Programs (considerations based on climate predictions). In response to potential climate issues, the Ministry of Transportation, Chief Engineer's Office, is engaged in case studies to examine climate risk to BC transportation infrastructure and what engineering adaptation is required for a 50 to100 year planning horizon. The Ministry is engaged with other national, provincial and academic organizations in developing experience and expertise in this field. To date our partners include: Engineers Canada (Public Infrastructure Engineering Vulnerability Committee - PIEVC), the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria, and the BC Ministry of Environment. Climate risk case studies have been completed for sections of the Coquihalla Highway 5 and Yellowhead Highway 16 in BC using the Climate Change Infrastructure Vulnerability Assessment Protocol (PIEVC). The results from examining forecast climate and infrastructure interactions including findings and recommendations and any required remedial action will be addressed. These studies assist the Ministry in planning for potential climate change. The results from these studies of the Coquihalla and Yellowhead Highways will provide background guidance in reviewing design standards for highway infrastructure in British Columbia.		2011		
Climate smart development in Asia: An overview	Srinivasan A., Ling F.H., Mori H.	Climate Smart Development in Asia: Transition to Low Carbon and Climate Resilient Economies	English	Book Chapter			Global climate change is perhaps one of the most serious challenges facing humanity. It is no longer just an environmental issue but one with enormous socio-economic and geopolitical implications. The 4th assessment report of the Intergovernmental Panel on Climate Change (IPCC) concluded that climate change is unequivocal and that human influence on the global climate system through anthropogenic greenhouse gas (GHG) emissions over the past 150 years is substantial (IPCC 2007). For example, the atmospheric concentration of carbon dioxide (CO from pre-industrial levels of 280 parts per million (ppm) to 390 ppm in 2010. If the effect of other GHGs is included, the concentration is at the equivalent of 430 ppm. The IPCC concluded that the average global temperature increased by 0.74 °C between 1905 and 2005 due to human-induced climate change, and that temperatures would rise by another 1.1 to 6.4 °C by the end of this century. In order to stabilize the climate, the IPCC concluded that GHG emissions must peak before 2020 and be reduced by 40 to 70 percent by 2050 (IPCC 2007). However, when we consider that both world energy use and associated GHG emissions are expected to grow nearly 50 percent by 2030, an average rate of 1.7 percent per year, the enormity of the challenge becomes obvious. Indeed, the current emissions trajectory may result in an atmospheric GHG concentration of 650 ppm or more by the end of this century (Flavin 2008). As many countries in Asia have entered the most carbon-and energy-intensive stages of their development and some are now experiencing high rates of deforestation and forest degradation, Asia's share in global GHG emissions is expected to increase substantially. If no major changes are made, Asia may contribute as much as 45 percent of global energy-related GHG emissions by 2030 (IEA 2011). The continued heavy reliance on fossil fuels to meet Asia's growing energy needs, espe- cially in its industrial and transport sectors, will further worsen air pollution and dramatically increase social costs. Unchecked growth in GHG emissions will increase the likelihood of abrupt climatic change, leading to devastating effects on ecosystems, industries, agriculture, and transportation systems (Solomon et al. 2009). The impacts of climate change are already evident in many parts of Asia in the form of increased frequency and intensity of extreme climate events, including floods and droughts (IPCC 2007). Due to historical build-up of GHG in the atmosphere, such adverse impacts will continue to be felt in the foreseeable future, even if GHG mitigation efforts pick up momentum. Therefore, adaptation to enhance the climate resilience of economic, social, and environmental systems is crucial. The Stern Review on the Economics of Climate Change estimated that the cost of inaction on climate change could be as high as 5 to 20 percent of gross domestic product (GDP) while the cost of action could be less than 1 percent of global GDP (Stern 2007). The transition from a "carbon-intensive climate-sensitive" development para- digm to a "low carbon climate resilient" economy (LCE) is an enormous challenge that will require significant restructuring of economies in both developed and developing countries. Indeed, the efforts to restrain GHG emissions to date have mostly been a combination of technology and policy solutions by developed countries, which are not necessarily always appropriate in developing countries in Asia. Evidence to date suggests that such interventions have had positive but limited impacts on GHG concentrations. Therefore, more proactive approaches to the design and implementation of climate smart road maps are needed. Likewise, the reactive and unplanned measures to cope with adverse impacts of climate change have consumed enormous financial resources without much improvement in climate resilience. Developing countries in Asia, therefore, have to take a more proactive role in addressing this issue in a way that is most appropriate to their national circumstances and capabilities. Stabilizing the climate will require considerable effort, namely, a broad trans- formation of the various sectors of the economy - energy, transport, agriculture, forestry and others - so that economic output can be raised without substantial increases in GHG emissions. Decarbonizing energy systems will require both a decrease in energy demand and promotion of technologies that reduce fossil fuel consumption. Likewise, promoting climate-friendly urban development strategies and environmentally sustainable transport systems is vital. Further efforts to enhance carbon sequestration through sustainable land use and forest management, including reduced emissions from deforestation and forest degradation (REDD), are crucial. Many countries realize the need to halve global GHG emissions by 2050 by intensifying efforts to follow climate smart pathways for development. The 15th Conference of Parties (COP-15) to the United Nations Framework Convention on Climate Change (UNFCCC), held in December 2009, produced a clear letter of political intent in the form of the "Copenhagen Accord" to constrain carbon and respond to climate change. The accord included a goal of limiting global mean temperature rise to below 2°C above pre-industrial times. More than 140 countries indicated their support to the accord so far. Of them, 42 developed countries and 41 developing countries, which together account for more than 80 percent of global GHG emissions, pledged nationally appropriate mitigation targets and actions (UNFCCC 2010a and 2010b). Several countries in Asia also pledged mitigation actions, with China committing to reduce GHG emissions per unit of GDP by 40 to 45 percent below 2005 levels by 2020 (Table 1.1). Although a global agreement is yet to be reached, member states agreed to the establishment of a "Green Climate Fund, " with a goal to mobilize $100 billion per year by 2020 to assist developing countries in migitation and adaptation. A GHG mitigation-only pathway is not sufficient to attain LCE, however, as some degree of climate change and its impacts are inevitable. Climate risks and resilience should be integrated into sectoral development planning (Chapter 9) and appropriate adaptation measures in different sectors - agriculture, energy, water, health, tourism, and others - must be promoted. Adjustments to agricultural practices, changes in the design of energy, water and tourism infrastructure, and developing defenses against new diseases and epidemics are also critical. © 2012 selection and editorial material, Ancha Srinivasan, Frank Hiroshi Ling and Hideyuki Mori; individual chapters, the contributors.		2013	10.4324/9780203141564-10	
Climate-resilient roads in Paraguay; Mapping the risks and advising adaptive mitigation measures [Routes résistantes au climat dans le Paraguay: Cartographie des risques et avis sur des mesures d'atténuation adaptées]	Elkadi A.S., Woning M., Bles T., Abraham G., Casares A., Sethi K., Flor L.	17th European Conference on Soil Mechanics and Geotechnical Engineering, ECSMGE 2019 - Proceedings	English	Conference Paper	Adaptation; Climate change; Resilient infrastructure; Risk Assessment; ROADAPT	Agricultural robots; Climate change; Geotechnical engineering; Hazards; Motor transportation; Network security; Precipitation (meteorology); Project management; Roads and streets; Soil mechanics; Deleterious effects; Growth and development; Higher frequencies; Mitigation measures; Pilot projects; Pilot studies; Road infrastructures; Transport infrastructure; Risk assessment	Transport infrastructure plays a crucial role in growth and development of economies and thriving communities. In Paraguay, the economy depends heavily on (agricultural) export; mainly through road network. Climate-related hazards such as extreme weather threaten the availability of the road infrastructure. Such hazards are expected to increase in the future with changing rainfall amounts and intensities, posing chance of higher frequency for events like precipitation induced floods and landslides. This can have a deleterious effect on transport infrastructure, such as road networks and railways, with large negative economic, social, environmental, and security aftermaths. In this paper, a case study from a World Bank funded pilot project is presented. In this project, Deltares and CSI Ingenieros have been working with the Government of Paraguay (GoP), through its Ministry of Transport and Communications (MOPC), on developing a strategy to assess climate change related risks on the road network and on how improve their resilience. The ROADAPT approach (Roads for today, adapted for tomorrow) was applied for assessing the risk and vulnerability of a part of the road network (pilot study area of over 300 km) and mitigation measures were suggested. © The authors and IGS: All rights reserved, 2019		2019	10.32075/17ECSMGE-2019-0494	
Cool pavements for climate change adaptation	Freire C.A., Grau J.S., Ayerra J.L.	Transportation Research Procedia	English	Conference Paper	climate change; cool pavements; GHG emission; lighting level; low noise; urban heat island		Whitin the framework of road infrastructures, CHM has led a study that investigates construction materials in order to reduce accumulated and released heat on urban surfaces, such as asphalt, especially in summer, seeking to minimize the "urban heat island". This project is the result of having developed reflective pavements that has passed through laboratory level, manufacture on an industrial scale and their testing on a small scale to ensure proper implementation, as well as their implementation by means of a large-scale demonstrator, on 24,000m2 of pavement in the city of Murcia (LIFE HEATLAND). This asphalt has several benefits with respect to conventional asphalt, it improves the urban environment and life quality of the citizens around the implantation, and which are mainly:•Energy savings in lighting system: Air conditioning system and public light•Energy savings and materials saving.•Natural improvement: Air quality and lower noise.•Improvement quality of life: comfort and pedestrian•Economics and ambiental benefits Until today, the demonstrator has been monitored and the following conclusions have been obtained, validating this type of pavement as a mechanism to reducing the urban heat island effect:•Initial luminance of reflective pavement 2.5cd / m2 under the lamppost, 150% higher than the conventional asphalt street.•Solar reflectance of 30%, almost four times higher than that of conventional asphalt.•Average surface temperature with reflective pavement 7-11C lower than that of the conventional pavement surface.•Areas of the asphalt where rubber has been deposited from the tires as a result of the rolling of vehicles are heated 1-3C more than the clean areas.•Lower environmental lower noise level of the area: 3 dB (A). © 2021 Elsevier B.V.. All rights reserved.		2021	10.1016/j.trpro.2021.11.073	
Economic and Environmental Analysis of Adaptation Strategies to Mitigate Impact of Climate Change on Pavements	Sharma M., Inti S., Tandon V.	Lecture Notes in Civil Engineering	English	Conference Paper	Adaptation; Climate change; Environmental analysis; LCC; Pavements	Cost benefit analysis; Costs; Earth (planet); Life cycle; Pavements; Adaptation; Adaptation strategies; Adaptive measures; Anthropogenic activity; Climate parameters; Economic benefits; Economics analysis; Environmental analysis; Highways agency; Level of Service; Climate change	The earth's climate is continuously changing due to anthropogenic activities. The predicted change in climate parameters adversely affects the service life of roadways. The paper focuses on evaluating economic benefits to highway agencies and users if adaptive measures are taken to mitigate the impact of climate change. For this study, a location within Texas was selected to cover the variability of climate within the state. Pavement sections were selected based on the variability of location, traffic, and level of service, and these sections are analyzed under variable future climatic conditions. The analysis of pavement sections was performed using AASHTO Pavement ME Design software. Adaptation strategies were implemented to sustain the serviceability of roadways. The effects of these strategies on the performance of pavements were analyzed along with changes in total life cycle cost (LCC) and environmental (emissions) benefits of roads. Additional costs and emissions incurred were derived by comparing the LCC under present climate and projected future climate scenarios. The combined analysis indicates that considering future weather changes early into design reduces emissions as well as costs incurred by the users. © 2022, The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd.		2022	10.1007/978-981-16-9921-4_11	
Effect of climate change on performance WSUD treatment devices	Lam E.C., Gribler M.	2018 Hydrology and Water Resources Symposium, HWRS 2018: Water and Communities	English	Conference Paper		Climate models; Forecasting; Highway planning; Hydrology; Pollution; Rain; Stochastic systems; Time series; Urban transportation; Water resources; Water supply; Climate change adaptation; Flow duration curve; Global climate model; Regulating authorities; Standard requirements; Storm-water managements; Transport infrastructure; Water sensitive urban design (WSUD); Climate change	Water Sensitive Urban Design (WSUD) or Water Sensitive Road Design (WSRD) are the standard requirements for new urban and transport infrastructure in Australia. MUSIC models using long term (10 years or more) 6-minute time step rainfall data are a commonly used tool to assess if the WSUD satisfies the pollutant reductions required by the regulating authority. The long-term rainfall time series are typically historical records which are representative of the long-term average rainfall and also contains representative dry and wet periods within the time series. Different authorities may have different designated time periods adopted as a representative rainfall period for assessment. Similarly, the climate change adaptation is an emerging issue which requires an assessment of the performance of stormwater management infrastructure under future climate conditions. The future climate change prediction is usually based on the Global Climate Model (GCMs). However, the GCMs predictions are usually on annual average basis and the accuracy of the sub-annual prediction is questionable (DELWP 2016). (DELWP, 2016) suggested several approaches such as flow duration curve scaling and stochastic data generation for water supply assessment. (Burge et. al 2015) employed a stochastic method to modify rainfall time series for WSUD assessment. This paper developed a simpler but more approximate method to modify the standard 6-minute time series. This time series was used to assess the effect of climate change on WSUD performance and it was found that the WSUD performance is generally reduced. In addition, an attempt was also made to identify which type of WSUD pollutant reduction is more sensitive to climate change. © CURRAN-CONFERENCE. All rights reserved.		2018		
Evaluation of water-related adaptation measures in Nationally Determined Contributions of Belt and Road countries [一带一路"沿线国家的自主贡献中水资源相关适应措施评估]	Yu F., Cui H.-J., Ge Q.-S.	Climate Change Research	Chinese	Article	Adaptation c; Belt and Road; Global warming; National Determined Contribution (NDC); Water resources		Belt and Road (B&R) countries have been suffering from various climate risks for a long time, including water related problems, such as water shortage and flood hazard. By evaluation of water-related adaptation measures proposed in the Nationally Determined Contributions (NDCs) submitted by B&R countries, it's found that the risks related to climate change and water resources have been widely concerned, and most countries have put forward targeted adaptation measures more or less such as optimizing water resources management, improving water resources utilization efficiency, improving risk early warning capabilities and infrastructure construction. However, there are still a few problems including that the lack of adaptation related content in the NDCs of some B&R countries, which are mainly composed of Central and Eastern Europe (CEE) countries; The scope of risk concerns in West Asia/the Middle East and Central Asia is not comprehensive enough to assess and plan for future potential flood risks; In Central Asia, South Asia and the Middle East, where water disputes are prominent, there is a lack of appropriate international cooperation mechanisms. There is a lack of attention to the water environment in most countries. In order to improve the adaptation capacity of B&R countries, and build a sound climate adaptation system, it is necessary to improve NDC report, establish an international cooperation mechanism, and increase the attention and investment in climate change research, ensuring the green and sustainable development of the Belt and Road Initiative. imatechange. © 2021 by the authors.		2022	10.12006/j.issn.1673-1719.2021.054	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Governing innovation for sustainable technology: Introduction and conceptual basis	Nilsson M., Rickne A.	Paving the Road to Sustainable Transport: Governance and innovation in low-carbon vehicles	English	Book Chapter			Innovation as one solution to the challenge in line with Schumpeter's bequest to economic strategy and policy, we today view innovation as key to a knowledge-based society and its economic growth (Schumpeter, 1934). Indeed, innovation in its various forms - technological, market-related, organizational, etc. - is often what outlines the competitive edge for firms as well as for countries. In addition to the economic rationale, innovation is also seen as a key to achieving more sustainable development worldwide (Norberg-Bohn, 1999; Pearson et al., 2004). Indeed, achieving sustainable development depends on technological and social innovations coupled with organizational and institutional change geared towards environmental sustainability. One salient example is the climate change issue, in particular in relation to 'post2012' discussions, where in the light of global difficulties in reaching political agreement, technology is nowadays widely considered the key solution to the dilemma of getting national governments to agree to ambitious carbon reductions while at the same time safeguarding economic development and welfare. Great hopes are also attached to the promise of sustainable technology innovation in other fields of resource use and environmental impact, such as, for instance, non-renewable and renewable resource use, energy conversion and chemicals. Indeed, some of that promise has also been delivered in certain domains. Any innovation process involves a multitude of activities necessary to bring products and services to the market, where an underlying invention is only a partial aspect of the process. Important activities may comprise scientific work, technology and product development, design, market development, changes in organization, social practices, regulations, building industrial networks, infrastructure and culture (Ashford, 2004). This implies that innovation processes involve the creation, absorption and transmission of knowledge and are highly interactive in character in that they involve continuous learning cycles. The previous view of linearity and the focus on a presumed static event of novelty creation are no longer valid. A departure point in modern innovation studies is that the technological, sectoral, spatial, institutional, organizational, social and economic domains of innovation are highly related and cannot be meaningfully separated in the real world (Ashford, 2004). Sometimes, learning loops can be concentrated within an individual or a limited number of people, but the rule is more often that a multitude of individuals and organizations are involved, holding various resources and tasks. The complex and multidisciplinary character of most innovation processes implies that resources, skills and competencies can seldom reside within an individual, or even within a single organization. Cooperation, knowledge exchange and learning become key. It is the combination of complementary resources and competencies - be it knowledge, capital, facilities, etc. - that may bring the creation of new things: innovation. For any specific organization, such as a firm, recombination of resources and knowledge may take place within the borders of the company in a vertically integrated organizational manner. More often, innovation requires not transactions with external partners, but rather intertwining of organizational processes for innovation to come about. Partners include other firms, customers, suppliers, competitors, research organizations, financiers, policy organizations, bridging actors, etc., locally, nationally or in other countries. Such exchange gives access to resources of various kinds, including equipment, proven laboratory methods, blueprints, development tools, etc. Also, discussions may lead to novel ideas, solutions to technical problems or organizational changes such as suggestions for product or process improvement. Often, interaction is direct and facilitated by face-to-face meetings, being set up as bilateral or multi-partner collaboration on scientific development and copublication, shared platforms for prototype testing, common market efforts, and so on. Sometimes, learning from others comes about through observation rather than by interaction, including, for example, reverse engineering, studying publications, patents or prototype releases at market fairs. In addition, the mobility of people is a main mechanism of knowledge transfer. To underline this inherently social, interactive learning process of creating innovations, a systems approach to innovation has been put forward under the terminology of 'innovation systems' (ISs) (Lundvall, 1992; Nelson, 1993; Edquist, 1997). Such studying of innovation helps us understand both how and why new patterns of organization, technology, production and consumption come about, and provides guidance on how these patterns can be induced or accelerated. An IS may be defined as 'the groups of organizations and individuals involved in the generation, diffusion and adaptation, and use of knowledge of socio-economic significance, and the institutional context that governs the way these interactions and processes take place' (Hall et al., 2003: 3). Thus, in this school of thought a set of structural elements and their interconnections are the focus - a set of knowledge areas and artefacts (e.g. technology, intellectual property, products), innovating and innovation-related actors and the inherent knowledge flows and networks between these, as well as the underlying institutional framework (Carlsson and Stankiewicz, 1991). Firms in various parts of the value chain are often the main innovating actors. Research and educational organizations, including universities, are important providers of new knowledge, human capital, etc., but are also intensively engaged in several other activities throughout the innovation process. In addition, there are organizations giving innovation support of various kinds: public organizations and authorities setting conducive policies and institutional arrangements, trade associations, incubators and venture capitalists. An important feature of any innovation system is thus the institutional features setting the rules of the game for the actors and artefacts. The institutions - laws, rules, norms and routines - function as key ordering devices shaping behavioural patterns, and therefore ISs within differing institutions display different patterns of interaction, prevalence of corporate spin-outs, propensity to share knowledge between universities and firms, etc. Innovation processes often include development of a shared vision by dominant actors in a network and evolutions of the institutional landscape in ways that make it open for change (Kaijser, 2001; Kemp et al., 1998). As highlighted above, ISs are networks of organizations and individuals, working under a common institutional set-up (laws, practice, etc.), within which the creation, dissemination and exploitation of new knowledge and innovations occur (Cooke et al., 2004). While it is acknowledged that innovation processes are often global, where the connected knowledge formation, resource accumulation and diffusion processes span regions and nations, there are also spatially delimited aspects of innovation. In fact, one of the ways by which the IS approach helps us to understand such dynamics is by focusing on the institutional specificities of various ISs. Clearly, institutions differ between countries - and even within countries - and they differ between knowledge areas (e.g. between various technological settings) or sectors. Therefore, in the analysis of ISs, one draws a border around the specific system, thereby including or excluding actors, artefacts, networks and institutions or being central to the system or not. To some extent all such delineation is by necessity arbitrary, but nevertheless necessary to do a useful analysis. The literature also		2012	10.4324/9780203119716-7	
How can your water utility benefit from a climate change risk assessment? City of calgary case study	Marcy S., Wright I., Shiskowski D., Olson D., O'driscoll J., Murray K., Lapp D.	American Water Works Association Annual Conference and Exposition 2012, ACE 2012	English	Conference Paper		Calgary; Climate change impact; Climate change risks; Climate condition; Climate effects; Climate variability; Engineering practices; Extreme events; Knowledge base; Municipal infrastructure; Pilot studies; Public infrastructures; Risk-based; Roads and bridges; Waste water systems; Water research; Water supply infrastructures; Water supply management; Water utility; Watershed management; Engineers; Exhibitions; Knowledge based systems; Public risks; Research; Soil conservation; Standards; Water conservation; Water management; Water supply; Water supply systems; Climate change	While most municipal infrastructure systems should be sufficiently robust to handle small changes in base-line climate conditions over the next few decades, certain infrastructure components may be at risk if there is a significant increase in climate variability and the occurrence of extreme events. To determine the nature and predict the level of risks faced by the impacts of climate change on infrastructure components, the Public Infrastructure Engineering Vulnerability Committee (PIEVC) of Engineers Canada has developed a broad and systematic approach (Protocol) that can be applied to a variety of municipal infrastructure systems. The risk-based Protocol has been applied to buildings, roads and bridges, storm and wastewater systems and complex potable water supply systems. Complementary to the Water Research Foundation's (WRF) efforts to study climate change impacts on long-term water utility planning and standards adaptation, Engineers Canada has conducted several pilot studies to develop and test the Protocol and continues to conduct case studies, providing its tool for use within Canada and internationally. The City of Calgary, in partnership with Engineers Canada, undertook a comprehensive project to test the PIEVC Protocol and gain an understanding of relevant climate effects and their interactions with the water supply infrastructure - from watershed management to treatment and distribution - that may pose negative impacts. The results of these case studies are being incorporated into a national knowledge base and analyzed to develop recommendations around reviews of codes, standards and engineering practices. The paper presents an overview of the PIEVC initiative and development of the Protocol through case studies undertaken across Canada and internationally. The impacts of predicted climate change to the City of Calgary's water supply system are highlighted. Recommended actions for the key potential vulnerabilities to the water supply management and infrastructure components, as identified through the use of the Protocol, are provided as an example of what other water utilities across North America (Canada and the USA) could encounter. 2012 © American Water Works Association.		2012		
Hybrid combination of waste plastics and graphene for high-performance sustainable roads	Venturini L., Mantecca P., Perucca M., Rizzi L.G.	Plastic Waste for Sustainable Asphalt Roads	English	Book Chapter	Graphene; Life cycle assessment (LCA); Recycled waste plastic; Trial sections		The development of the European road infrastructure is part of the European Action Plan that finances sustainable growth. The European regulation establishes the criteria for determining whether an investment can be considered eco-sustainable and it sets precise and clear environmental objectives that are indispensable for achieving eco-sustainability: the mitigation and adaptation to climate change, the transition to a circular economy, the prevention and reduction of pollution, and the sustainable use of water and marine resources. The development of innovative technologies is fundamental to pursue sustainability objectives in the road infrastructure. The Ecopave Project, funded by the European Union and the Lombardy region, allowed studying and developing a new supermodifier for asphalt mixtures. The modifier, which has two patents (one for the composition and one for the production method), was made of recycled waste plastic, usually destined to incineration, 100% pure graphene, and other components (i.e., the functional base). The final product is a Graphene-Based Supermodifier (GBSm) for asphalt concrete that improves the service life and reduces the need for maintenance of road pavements with the goal of abating environmental impacts. © 2022 Elsevier Ltd All rights reserved.		2022	10.1016/B978-0-323-85789-5.00010-1	
IET Seminar on Impact of Climate Change and Sustainable Development on Asset Management	[No author name available]	IET Seminar Digest	English	Conference Review			The proceedings contain 10 PowerPoint presentations. The topics discussed include: climate change: UK impacts and adaptation overview of government policy; approaches to adaptation a comparison between scenarios and vulnerability approaches; climate change adaptation and mitigation - some challenges for asset managers; climate change and sustainable development - a regulator's perspective; regulator's perspective on the challenges for the energy sector; resilience to flooding; resilience to flooding on the strategic road network; the Gloucestershire experience - resilience to flooding; the IAM's sustainable infrastructure initiative; and sustainable development of asset infrastructure - an NWL example.		2008		
Impact Assessment of Climate Change in Texas Pavements and Resiliency Strategy	Sharma M., Inti S., Tandon V.	Sustainable Civil Infrastructures	English	Conference Paper	International Roughness Index (IRI); North American Regional Climate Change Assessment Program (NARCCAP); Pavement Design; Pavement Performance; Pavement Section	Geotechnical engineering; Pavement overlays; Sustainable development; Extreme weather events; Future climate scenarios; Pavement performance; Pavement structures; Planning and design; Precautionary measures; Regional climate changes; Temperature patterns; Climate change	Changing climate can cause extreme weather events, and variations in hydrologic, storm and temperature patterns. These changes have an adverse impact on the performance of pavement system in Texas. It is of extreme importance to estimate the possible effects of climate change on the performance of the pavements. These estimates will help transportation officials in making decisions to accommodate the climate change into planning and design of pavement systems. The objectives of this study are to document anticipated change in climate and its impact on the performance of the pavements and to present various precautionary measures that can be adopted in current pavement design to withstand the anticipated climate change. In this study, future climate data is selected from North American Regional Climate Change Assessment Program (NARCCAP) databases. Pavement Mechanistic-Empirical (ME) Design software is used for analysis of the pavement performance with historical climate as well as predicted future climate data. Comparing the pavement performance with historical climate and predicted future climate data revealed that the distresses in the pavement structure is increasing with the future climate scenario. Various adaptation approaches of pavement design to survive the future climate change are recommended through this study. © 2019, Springer International Publishing AG, part of Springer Nature.		2019	10.1007/978-3-319-95750-0_4	
Impact Assessment of Climate Change on Coastal Transport Systems in the Greater Thessaloniki Area	Papagiannakis A., Ntafos K.	Advances in Intelligent Systems and Computing	English	Conference Paper	Climate change impact assessment; Sea level rise; Thessaloniki coastline; Transport infrastructure vulnerability; Transport resilience	Land use; Motor transportation; Population statistics; Risk perception; Roads and streets; Sea level; Climate change adaptation; Extreme weather conditions; Greater Thessaloniki Area; Intergovernmental panel on climate changes; Long term planning; Sea-level rise scenarios; Transport infrastructure; Worst case scenario; Climate change	Long-term planning and operation of transport systems should more than ever consider climate change and extreme weather conditions. There are multiple risks such as coastal and urban floods, sea level rise, very high and extremely low temperatures, drought and wind. The aim of this article is to assess the impacts of sea level rise so as to identify the transport infrastructure vulnerabilities in the Greater Thessaloniki area, in a coastal zone of 60 km long and 2 km wide from the seashore, which is located within five different municipalities. Based on cartographic data obtained from Climate Central's Surging Seas Risk Zone Map, land use data from Corine Land Cover and population data from Hellenic Statistical Authority, two sea level rise scenarios of 0.5 and 1 m were simulated using GIS. According to the most likely scenario introduced by Intergovernmental Panel on Climate Change of the United Nations, that is 0.5 m rise, until 2100 1.87% of the total length of the coastal road network will be covered by the sea, while in the worst-case scenario of the 1 m, the percentage will be 3.07%. At the same time, the interruption of the road access to the airport in both scenarios, the vulnerability of some parts of the port, and their potential inability to operate are highlighted. The research findings indicate the need to plan and construct resilient transport systems as well as to coordinate and implement specific climate change adaptation measures for transport infrastructures in Thessaloniki coastline. © 2021, The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG.		2021	10.1007/978-3-030-61075-3_73	
Improving pedestrian thermal comfort by pavement-watering during intense heat events	Hendel M., Colombert M., Diab Y., Royon L.	30th International PLEA Conference: Sustainable Habitat for Developing Societies: Choosing the Way Forward - Proceedings	English	Conference Paper		Climate change; Ecosystems; Climate change adaptation; Climate index; Daily effects; Equivalent temperature; Mean radiant temperature; Paris , France; Stress reduction; Urban heat island; Pavements	From the late 19th until the mid-20th Century, pavement-watering was used to prevent dust cloud from forming. This practise has since been lost, but is now stirring new interest as a tool for urban heat island mitigation, climate change adaptation and pedestrian thermal stress reduction. To evaluate the potential of pavement-watering, two daytime watering methods were tested over the summer of 2013 in Paris, France: the pavement and sidewalk of a N-S street and the pavement of an E-W street. The effectiveness of the method was measured according to mean radiant temperature (MRT) and Universal Thermal Climate Index (UTCI) equivalent temperature reductions, determined by a statistical analysis. MRT and UTCI reductions were observed at both sites. While daily effects were highest at the N-S site, highest maximum hourly cooling was observed at the E-W site, reaching 2.9°C for MRT and 1.2°C for UTCI. Overall, hourly cooling was most often statistically significant at night and at the N-S site. © 2014 30th International PLEA Conference: Sustainable Habitat for Developing Societies: Choosing the Way Forward - Proceedings. All rights reserved.		2014		
Increasing the Resilience of European Transport Infrastructure	Boukas K., Amditis A., Wellharter R., Ramesh V., Soto M.Á.T., Heredia G., Belsito L., Camarinopoulos S., Fraundorfer F.	Lecture Notes in Civil Engineering	English	Conference Paper	Bridges; Extreme events; Mitigation; Prevention; Resilience; Response; Risk management; Seamless mobility; Tunnels	Climate change; Deterioration; Extreme weather; Inspection; Risk analysis; Risk assessment; Risk management; Extreme weather conditions; Extreme weather events; Mobility solutions; Structural vulnerability assessments; Transport infrastructure; Transport networks; Transport operations; Vulnerability assessments; Structural health monitoring	Extreme weather conditions, climate change, damages to the infrastructure (caused by natural and man-made hazards) and traffic impediments negatively impact the reliability of mobility solutions. Risk analysis, adaptation measures and strategies that enable minimizing the impact of both natural and man-made extreme events on seamless transport operation, protect the users of the transport network in case of extreme conditions, as well as provide optimal information to operators and users of the transport infrastructure, need to be developed. Road transport is vulnerable to extreme weather events, while bridges and tunnels are among the most critical land transport structures. A large number of bridges and tunnels have been in operation for more than 50 years and there are widespread signs of deterioration. They need inspection, vulnerability assessment and, when needed, appropriate interventions. Inspection, though, in inaccessible areas, or structures with high volumes of traffic, is expensive, time-consuming, and potentially dangerous. At the same time, structural/vulnerability assessment is also a lengthy process which is especially painful after extreme events. The overall goal of RESIST (RESilient transport InfraSTructure to extreme events) a RIA H2020 project funded by the EU commission with grant number 769,066 is to increase the resilience of seamless transport operation to natural and man-made extreme events, protect the users of the European transport infrastructure and provide optimal information to the operators and users of the transport infrastructure. In the context of RESIST, robotics for visual and contact inspection of structures, structural vulnerability assessment, infrastructure risk management as well as mobility continuity applications considering stress levels of the drivers are being developed towards a high level of resilience of the transport infrastructure. © 2021, The Author(s), under exclusive license to Springer Nature Switzerland AG.		2021	10.1007/978-3-030-74258-4_48	
International Conference on Advances in Construction Materials and Management, ACMM 2021	[No author name available]	Lecture Notes in Civil Engineering	English	Conference Review			The proceedings contain 48 papers. The special focus in this conference is on Advances in Construction Materials and Management. The topics include: Analysis of "Integrated Exhibition-Cum-Convention Centre, Pragati Maidan, New Delhi", Using ETABS; greenhouse Gases Emission from Municipal Solid Waste in Thanjavur; evaluation of Meteorological Drought Impact Using Drought Indices; the Freezing Point of Soils and the Factors Affecting its Depression; Blast Loads and Their Effects on Structures; Study on Irregular Tall RC Structure and Composite Structure by Pushover Analysis; feasibility Study on Subgrade Stabilization of Pavement Using Lime and Fly Ash as Admixtures; treatment of Seawater Using Electrochemical Mediated Desalination; assessment of Energy Dissipation Capacity of Steel Moment Resisting Frames Under the Effect of Earthquake; assessing the Role of Nature-Based Solutions in Urban Resilience and Climate Change Adaptation; assessment of Ground Water Quality in Industrial Area of Thiruvallur, Tamil Nadu; ground Water Modelling of Poondi Micro-Watershed, Thiruvallur, Tamil Nadu; Analysing the Effect of Enzyme-Induced Stabilization (EIS) in Improving the Strength Characteristics of Weak Soils; Constructed Wetland (CW) Technique as an Effective Sustainable Treatment for Wastewater: A Review; Comparative Statistical Analysis to Determine the Impact of COVID-19 Lockdown on PM2.5 Concentration in Chennai City, India; comparison of Nutrient Removal Efficiency, Growth Characteristic and Biomass Cultivation of Two Microalgal Strains Provided with Optimal Conditions in Agricultural Wastewater; revealing the Design of Energy-Efficient Techniques to Enhance the Building Performance; behaviour of Battered Pile Subjected to Lateral Load; modelling Residential House Pricing Using Regression Analysis; an Ant Colony-Based Optimization Model for Resource-Leveling Problem.		2022		

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Keeping climate impacts at bay in Boston	Filosa G., Stahl L., Miller S., McArthur K.	Public Roads	English	Article		climate effect; extreme event; hazard assessment; road; transportation infrastructure; transportation planning; tunnel; vulnerability; Boston; Massachusetts; United States	The Massachusetts Department of Transportation (MassDOT) is faced with the challenge of adapting infrastructure to the changing climate and extreme weather events. To address this challenge proactively, MassDOT is developing a program that is focused on evaluating the vulnerability of statewide transportation assets to climate-related hazards and creating tools to facilitate resilient highway designs. Current projects in this resiliency program include a coastal and a statewide assessment of transportation vulnerability and a tool for mapping that vulnerability. In addition, MassDOT published a report in 2015 assessing the risks to Boston's Central Artery/Tunnel. The Central Artery/Tunnel, known to locals as the Big Dig, is a critical link in the regional transportation network and a vitally important asset to Boston and the surrounding communities. In the event of a disaster, the Central Artery is an indispensable route for evacuation, emergency responses, and recovery services. In 201072011 and in 201372015, FHWA partnered with State DOTs and metropolitan planning organizations to conduct a number of assessments of the vulnerability of transportation infrastructure to climate change and extreme weather. The purpose of these pilots was to help DOTs and metropolitan planning organizations identify vulnerable assets and analyze options for adapting and improving their resiliency to the impacts of climate change. Following the pilot study, MassDOT developed the Mapping Our Vulnerable Infrastructure Tool (MOVIT), a Web-based application that compiles and displays information on the locations and assets that have experienced weather-related problems. To identify specific locations that might require adaptations, the MassDOT assessment team used a hydrodynamic model that employs mathematical representations of tides, waves, winds, storm surge, sea level rise, and wave setup the increase in water level caused by wave runup. The team used the Advanced CIRCulation (ADCIRC) model to simulate storm formation in the Atlantic Ocean.		2016		
Life cycle engineering for roads (LCE4ROADS), the new sustainability certification system for roads from the LCE4ROADS FP7 project	Bustamante E.G., Flores R.F.	Life-Cycle of Engineering Systems: Emphasis on Sustainable Civil Infrastructure - 5th International Symposium on Life-Cycle Engineering, IALCCE 2016	English	Conference Paper	Certification system; LCA; LCE; Roads; Sustainability	Climate change; Cost effectiveness; Cost engineering; Sustainable development; Transportation; Certification systems; Cost effective; European levels; ISO standards; Life cycle engineering; On currents; Road infrastructures; Roads; Life cycle	This paper aims to show the results achieved on the development of a new sustainability certification system for roads named "LCE4ROADS", as part of the FP7 project "Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures (GA No 605748)". The certification system developed is based on current EN and ISO standards for sustainability in construction (EN15804) and LCA and LCC (ISO 14040-44 and ISO15686) and considers previous developments from other research projects like MIRAVEC, EVITA or COST 354. Key aspects at European level like the adaptation and resilience to Climate Change and the implementation of freight corridors (the so called TEN-T) are considered. © 2017 Taylor & Francis Group, London.		2017		
Potential Impact of Climate Change on Porous Asphalt with a Focus on Winter Damage	Kwiatkowski K., Stipanovic Oslakovic I., Hartmann A., Ter Maat H.	Materials and Infrastructures 2	English	Book Chapter	Climate change impact; Freeze-thaw cycles; Porous asphalt; Rijkswaterstaat; Winter damage	Asphalt; Climate models; Freezing; Highway planning; Noise abatement; Roads and streets; Thawing; Climate change impact; Freeze-thaw cycles; Porous asphalts; Rijkswaterstaat; Winter damages; Climate change	This chapter investigates the impact and adaptation options of climate change on porous asphalt (PA) roads, specifically for the case of winter weather (freeze-thaw cycles) and road damage in the Netherlands. Changes in weather patterns pose a threat to the serviceability and long-term performance of roads, as up to half of road maintenance costs are attributable to weather stresses. PA is of particular concern in the Netherlands, where its use has become mandatory, primarily for environmental (noise reduction) concerns. In recent winters, ravelling and pothole damage have increased the discussion about cold weather performance of PA and the potential challenges of changing winter weather patterns. Current climate change impact research often produces results on a systemic, macroscale, and less is known about the regional impact to specific road types. To address this, we examine the correlation between historic winter weather and PA pavement performance, which is particularly sensitive to the freezing/thawing phenomena. That relationship is combined with Dutch regional climate models and used to analyze the potential physical and economic impacts of adapting to future climate change. This has implications on maintenance, design, and long-term planning of the road network in the Netherlands. © ISTE Ltd 2016. All rights reserved.		2016	10.1002/9781119318613.ch12	
Preface: Natural hazard impacts on technological systems and infrastructures	Petrova E., Bostenaru Dan M.	Natural Hazards and Earth System Sciences	English	Article		accident; building; climate change; dam construction; hydrometeorology; ice thickness; landslide; natural hazard; transportation; transportation infrastructure; tsunami	Projected changes to design ice thickness as quantified in the study by Jeong et al. (2019) will be useful information for the development of climate-resilient design standards, codes, and guides for buildings and infrastructure. Caution in designing for ice loads at latitudes higher than 40 N is warranted due to projected increases in extreme ice thickness. As the results show, it is important to examine changes in the future probability of extreme ice loads occurring simultaneously with extreme wind load in northern NA because the compounding effect may lead to an increase in load larger than the increase in ice load or wind load alone. The methodology proposed by Fluixá-Sanmartín et al. (2019) allows a detailed quantification of the effect of climate change on dam safety, which is one of the main concerns of the managers and technicians of this critical infrastructure for water supply and energy production worldwide. It can serve as a useful guide for dam owners and dam safety practitioners in the analysis of other study cases by encompassing different models and data sources. This would eventually allow a more efficient planning of dam safety investments in the long term and even the adaptation of existing dam exploitation rules. Sayão et al. (2020) also deal with dam safety but from a seismic hazard point of view. They introduce the issue of the visualization of databases, while Petrova (2020) and Frolova et al. (2020) also deal with databases of natural hazard impacts on infrastructure, providing useful tools for further research. Williams et al. (2020) conclude that the fragility functions show a trend of lower tsunami vulnerability (through lower probabilities of reaching or exceeding a given damage level) for road-use categories of potentially higher construction standards; bridges are more vulnerable to the impacts of tsunamis than roads; however, bridges are better designed to withstand the forces of tsunami loading and have a lower level of vulnerability at all hazard intensities (inundation depth) compared to buildings; culverts represent particularly vulnerable sections of roads. The topographic setting is also shown to affect the vulnerability of transportation assets in a tsunami. Braud et al. (2020) proposed the methodology that is robust, relevant, and generic enough to evaluate a nonquantitative method of runoff hazard mapping using localized runoffrelated proxy data. The results from their case study confirm that the susceptibility maps produced by the IRIP model provide relevant information related to runoff and that they can be used to design risk management strategies, as illustrated in the railway context. Among all the identified types of natural hazards in the study by Petrova (2020), hydrometeorological hazards such as heavy snowfalls and rains, floods, and ice phenomena, as well as dangerous exogenous slope processes including snow avalanches, debris flows, landslides, and rock falls, were revealed as having the largest contributions to transport accidents and disruptions. The most dangerous is the combination of heavy precipitations and strong winds. Regional differences in the risk of transport accidents between Russian federal regions were found and analyzed. Toma-Danila et al. (2020) and Mossoux et al. (2019) deal with the vulnerability of the transport infrastructure and, more precisely, the road network. This is important in emergency management in the case of a natural disaster (earthquake and volcanic eruption) in order to access such infrastructure as hospitals. Chen et al. (2019) consider the effects of human engineering in increasing landslide susceptibility and effects on infrastructure, providing case studies of two landslides in the vicinity of bridges. If the analysis of transport infrastructure may lead to better planning by providing new road segments and new infrastructure, then in the case of human engineering, land use change, a nonstructural measure, can also be undertaken to provide better land use through regional plans. Looking at the lessons learned from the database and information visualization papers which promote the conversion of data to information – and thus the digital humanities – as well as at the urban, regional, and mobility plans which are necessary to better manage transportation networks and human engineering activities, how other disciplines can contribute to natural hazard research is also highlighted. © 2020 Copernicus GmbH. All rights reserved.		2020	10.5194/nhess-20-2627-2020	
Regional-scale investigation of pile bearing capacity for Canadian permafrost regions in a warmer climate	Faki A., Sushama L., Doré G.	Cold Regions Science and Technology	English	Article	Active layer; Adfreeze force; Bearing capacity; Climate change; Convection-permitting resolution; Permafrost; Pile foundation	Bearing capacity; Cements; Climate change; Climate models; Pile foundations; Piles; 'current; Active Layer; Adfreeze force; Climate change simulations; Convection-permitting resolution; Engineering systems; Multi-scale simulation; Permafrost region; Pile bearing; Ultrahigh resolution; Permafrost	Climate change is being experienced particularly intensely in the Arctic and therefore adaptation of engineering systems for this region cannot be further delayed. However, one of the major barriers to studies focused on adapting northern engineering systems is the lack of information at the spatial and temporal scales required for engineering applications. This study investigates pile bearing capacity for selected pile configurations for the Canadian permafrost regions (Nunavut and Northwest Territories), for current and future climates, using the very first ultra-high resolution (4 km) climate change simulation developed for the region using the Global Environmental Multiscale (GEM) model, for a high emission scenario. Comparison of the ultra-high-resolution GEM simulation, driven by reanalysis, with available observations confirms the model's ability in representing near-surface permafrost and related climate variables. The estimated adfreeze contribution to the total bearing capacity, for current climate, informed by the reanalysis-driven GEM simulation, for a 5-m cement pile, is found to be of the order of 15% for regions with shallow bedrock and 80% for regions with deeper bedrock. Application of the GEM climate change simulation outputs, for RCP8.5 scenario, suggest decreases to adfreeze contribution in the 5–30% range by 2040, with the largest differences noted for regions with deeper bedrock. For steel piles of same configuration, although the adfreeze contributions are only about 70% of that for cement piles, the projected relative changes are of similar magnitude. Further downscaling to 250 m resolution using the land model of GEM for the Slave Geological-Grays Bay corridor, where future developments are planned, including an all-season road, enables better estimation of bearing capacity for realistic pile scenarios such as those for bridges (in thick layer of sediments) used for river crossings. Due to the wide variation of pile materials, lengths and installation methods, site specific information can be developed from the framework developed in this study. The results of this study, including the ultra-high resolution climate change information, will thus form the basis for additional detailed investigations on climate-infrastructure interactions and climate resiliency studies. © 2022 Elsevier B.V.		2022	10.1016/j.coldregions.2022.103624	
Risk Assessment of Road Infrastructures as Key for Adaptability Measures Selection	Arango E.L., Sousa H.S., Matos J.C.	Lecture Notes in Civil Engineering	English	Conference Paper	Adaptability measures; Extreme events; Risk assessment; Road infrastructures	Climate change; Decision making; Motor transportation; Roads and streets; Decision making support; Extreme weather events; Future climate; Natural events; Risk assessment methodologies; Road infrastructures; Single decision; Transport networks; Risk assessment	Road infrastructures are crucial for societies daily life due to the dependency of other critical infrastructures upon it. Therefore, society expects an uninterrupted availability of the road network. However, maintain this constant availability is often a difficult task as, in the last decades, climate change has significantly affected transport networks, especially due to the occurrence of extreme natural events leading to their disruption. Those events include floods, wild fires, landslides and others, and all of are varying both in frequency and intensity presently and in the coming years. Therefore, there is a clear need for timely adaptation. Regarding these adaptability measures, an important step is needed to quantify how the transport network is directly and indirectly affected by extreme weather events, which can be obtained within a risk assessment. Nonetheless, there are many questions and variability about this topic such as uncertainties in projections of future climate, cause-effects assessment, and how it can be an integration of all these aspects into a single decision-making process. In that scope, this work describes a risk assessment methodology having account the cause, effect, and consequences of extreme events in road networks to identify the major risks and therefore the assets that may be suitable to be analyzed within a selection of adaptation measures aiming at a holistic decision-making support tool. © 2021, The Author(s), under exclusive license to Springer Nature Switzerland AG.		2021	10.1007/978-3-030-73616-3_52	
Strategie issues - European union	Sellick J.	Environmental Law and Management	English	Article		architectural design; biodiversity; building construction; climate change; European Union; floodplain; habitat loss; introduced species; maintenance; trafficking; water management; Estonia	There are several strategic issues that the European Union (EU) is facing. Such as floodplain management, EU plan against wildlife trafficking, indicator assessment on use of freshwater resources, and many more. In January, the EEA published a report on flood risks exploring the synergies between floodplain restoration, water policies and thematic policies. The report concludes that ecosystem based adaptation, nature-based solutions and green infrastructure are essential to ensure cost-effective approaches since they may delay or avoid lock-ins to classic infrastructure-building water management. The European Parliament has adopted a resolution in respect of the mid-term review of the Biodiversity Strategy to 2020. Existing EU measures will be improved through enhanced cooperation between agencies, training, and target priority setting at EU level with Europol support. The EEA has published a detailed analysis specifically focused on the state of Europe's forest ecosystem. It identifies the top four challenges facing the ecosystem as habitat loss and degradation, invasive alien species, pollution and climate change. The Commission has published two new voluntary construction related criteria sets on office building procurement and road building design, construction and maintenance management. Meanwhile, Estonia has been issued with a reasoned opinion for failing fully to implement Directive 91/676/EEC in respect of establishing an action program for zones where water is vulnerable to nitrates pollution.		2016		
Sustainable Streetscape - Greenest Street in America – Blue Island Avenue and Cermak Road, Chicago	Leopold D.	86th Annual Water Environment Federation Technical Exhibition and Conference, WEFTEC 2013	English	Conference Paper		Carbon footprint; Climate change; Ecodesign; Roads and streets; Adaptation strategies; Chicago; Cutting edges; Department of Transportation; Integrating technology; Public rights; Urban ecosystem; Sustainable development	This presentation will highlight the Chicago Department of Transportation's (CDOT) recently completed "greenest street in America," the first phase of a two-mile stretch of Blue Island Avenue and Cermak Road in the Pilsen neighborhood that is an unprecedented demonstration of how cutting-edge sustainable design and "complete streets" principles can be implemented in the public right of way. The project demonstrates a full range of sustainable design techniques that improve the urban ecosystem, promote economic development, increase the safety and usability of streets for all users, and build healthy communities. It provides both mitigation and adaptation strategies by reducing its carbon footprint and integrating technologies that allow the infrastructure to address and adapt to climate change. Copyright © 2013 Water Environment Federation. All Rights Reserved.		2013	10.2175/193864713813716174	
The canadian federation of earth sciences scientific statement on climate change – its impacts in canada, and the critical role of earth scientists in mitigation and adaptation	Burn C.R., Cooper M., Morison S.R., Pronk T., Calder J.H.	Geoscience Canada	English	Article		Carbon dioxide; Carbon dioxide process; Decay (organic); Decision making; Deterioration; Earth atmosphere; Erosion; Fires; Floods; Fossil fuels; Geology; Geotechnical engineering; Glaciers; Greenhouse gases; Ice; Permafrost; Project management; Sea level; Thawing; Atmospheric concentration; Development project; Engineering practices; Exploration and development; Extreme weather events; Research activities; Residential development; Standards and guidelines; Climate change; adaptive management; climate change; climate effect; exploration; fossil fuel; geological record; global climate; greenhouse gas; mitigation; permafrost; residential development; Canada	The Canadian Federation of Earth Sciences (CFES) has issued this statement to summarize the science, effects, and implications of climate change. We highlight the role of Earth scientists in documenting and mitigating climate change, and in managing and adapting to its consequences in Canada. CFES is the coordinated voice of Canada's Earth Sciences community with 14 member organizations representing some 15,000 geoscientists. Our members are drawn from academia, indus-try, education, and government. The mission of CFES is to ensure decision makers and the public understand the contri-butions of Earth Science to Canadian society and the econo-my. Climate change has become a national and global priority for all levels of government. The geological record shows us that the global climate has changed throughout Earth's history, but the current rates of change are almost unprecedented. Over the last 70 years, levels of common greenhouse gases (GHGs) in the atmosphere have steadily increased. Carbon dioxide (CO2) concentration is now 418 parts per million — its highest of the last three million years. The chemical (isotopic) composition of carbon in the atmosphere indicates the increase in GHGs is due to burning fossil fuels. GHGs absorb energy emitted from Earth's surface and re-radiate it back, warming the lower levels of the atmosphere. Climatic adjust-ments that have recently occurred are, in practical terms, irre-versible, but further change can be mitigated by lowering emissions of GHGs. Climate change is amplified by three important Earth system processes and effects. First, as the climate warms evapora-tion increases, raising atmospheric concentrations of water vapour, itself a GHG — and adding to warming. Second, loss of ice cover from the polar ice sheets and glaciers exposes larg-er areas of land and open water — leading to greater absorp-tion of heat from the sun. Third, thawing of near-surface permafrost releases additional GHGs (primarily CO2 and methane) during decay of organic matter previously preserved frozen in the ground. Some impacts of climate change are incremental and steadily occurring, such as melting of glaciers and ice sheets, with consequent sea level rise. Others are inter-mittent, such as extreme weather events, like hurricanes — but are becoming more frequent. Summer water shortages are increasingly common in western Canada as mountain snow-packs melt earlier and summer river flows decline. In northern Canada, warming and thawing of near-surface permafrost has led to deterioration of infrastructure and increased costs for buildings that now require chilled foundations. Other consequences of unchecked climate change include increased coastal erosion, increases in the number and size of wildfires, and reduction in winter road access to isolated northern com-munities. Reductions in net GHG emissions are urgently required to mitigate the many effects of further climate change. Industrial and public works development projects must now assess the effects of climate change in their plan-ning, design, and management. Cities, municipalities, and rural communities need to plan new residential development care-fully to avoid enhanced risk of flooding, coastal erosion, or wildfire. Earth Science knowledge and expertise is integral to exploration and development of new metals and Earth materials required for a carbon-neutral future, and in the capture and storage of CO2 within the Earth. Earth Science is also central to society's adaptation to new climatic regimes and reduction of risks. This includes anticipation, assessment, and management of extreme events, development of new standards and guidelines for geotechnical and engineering practice, and revi-sion to regulations that consider climate change. Geoscientists also have an important role in the education of students and the public on the reasons for necessary action. Canada is uniquely positioned with its strong global geoscientific leader-ship, its vast landmass, and its northern terrain to effectively leverage research activities around climate change. Geoscience tools and geoscientists' skills will be integral to Canada's prepa-ration for climate change. © 2021 GAC/AGC*.		2021	10.12789/geocanj.2021.48.173	

Article Title	Authors	Source Title	Language	Document Type	Author Keywords	Keywords Plus	Abstract	Cited Reference Count	Publication Year	DOI	
Unlocking the Potential of Permeable Pavements in Practice: A Large-Scale Field Study of Performance Factors of Permeable Pavements in The Netherlands	Veldkamp T.I.E., Boogaard F.C., Kluck J.	Water (Switzerland)	English	Article	climate change; climate extremes; full-scale infiltration tests; hydraulic performance; hydrological field experiments; maintenance; permeable pavements; stormwater harvesting; urban water management	Climate change; Infiltration; Pavements; Urban planning; Water management; Climate extremes; Field experiment; Full-scale infiltration test; Hydraulic performance; Hydrological field experiment; Hydrological fields; Infiltration tests; Permeable pavements; Stormwater harvesting; Urban water management; Maintenance	Infiltrating pavements are potentially effective climate adaptation measures to counteract arising challenges related to flooding and drought in urban areas. However, they are susceptible to clogging causing premature degradation. As part of the Dutch Delta Plan, Dutch municipalities were encouraged to put infiltrating pavements into practice. Disappointing experiences made a significant number of municipalities decide, however, to stop further implementation. A need existed to better understand how infiltrating pavements function in practice. Through 81 full-scale infiltration tests, we investigated the performance of infiltrating pavements in practice. Most pavements function well above Dutch and international standards. However, variation was found to be high. Infiltration rates decrease over time. Age alone, however, is not a sufficient explanatory factor. Other factors, such as environmental or system characteristics, are of influence here. Maintenance can play a major role in preserving/improving the performance of infiltrating pavements in practice. While our results provide the first indication of the functioning of infiltrating pavement in practice, only with multi-year measurements following a strict monitoring protocol can the longer-term effects of environmental factors and maintenance actually be determined, providing the basis for the development of an optimal maintenance schedule and associated cost–benefit assessments to the added value of this type of climate adaptation. © 2022 by the authors. Licensee MDPI, Basel, Switzerland.		2022	10.3390/w14132080	
Vulnerability of french road infrastructure to climate change, elements of adaptation	Yazoghli-Marzouk O., Haussard S.	Safety, Reliability, Risk and Life-Cycle Performance of Structures and Infrastructures - Proceedings of the 11th International Conference on Structural Safety and Reliability, ICOSSAR 2013	English	Conference Paper		Adaptation methods; Bituminous pavement; Experience feedback; Geographical zones; Road infrastructures; Socio-economic impacts; Structural durability; Transport networks; Rain; Reliability; Risk management; Roads and streets; Safety engineering; Transportation routes; Climate change	Road infrastructures are affected by climate change. The variation of temperature and the modification of rainfall constitute stress that affected structural durability of bituminous pavements. In this paper, the vulnerability of road infrastructures to climate change was treated as a risk management question. The vulnerability is traduced in physical and socio-economical weakness points. The risk is a function of climate parameters and sensitivity of constitutive elements of the road to those parameters. The methodology used is "Top-Down" method. The scenario used in this evaluation is A2. The considered climate parameters are temperature and rainfall. Physical and socio-economic impacts are based on experience feedback and bibliography research. The results show that there are various curative and preventive adaptation methods to climate change. A graphical analysis which superposes geographical zones, climatic zones and structuring roads may help the operator of transport network to select the priority sections. © 2013 Taylor & Francis Group, London.		2013		