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TRL THE FUTURE OF TRANSPORT

STATE OF KNOWLEDGE REPORT

Adaptation for Transport Resilience to Climate Change (AfTR-CC) for LICs in Africa and South Asia

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HVT047 – University of Birmingham

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Abstract
This report explores the current state of knowledge of climate change adaptation for transport infrastructure resilience in low-income countries (LICs) in Africa and South Asia. This was achieved through reviewing literature and undertaking stakeholder interviews and capability assessments of policies, tools and frameworks. The report explores the impacts of weather and climate on transport infrastructure in these LICs, the current ambitions of LICs in delivering climate change adaptation, the level of understanding of the issues according to transport stakeholders, the challenges and barriers LICs face in achieving their adaptation goals, and ways in which LICs can be supported to take steps towards increased transport resilience.

Keywords	climate change, adaptation, transport resilience, LICs, Africa, South Asia, climate resilience
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CONTENTS

Executive Summary vi

1. Project introduction and research overview 1

1.1 Overview 1
1.2 Purpose of this document 1
1.3 Project approach 1
1.4 Methodology 2
1.4.1 Primary data collection 2
1.4.2 Secondary data collection 5
1.4.3 Case studies 7
1.5 Conclusion 7

2. Setting the scene: climate change and transport resilience in Africa and South Asia 9

2.1 Overview 9
2.2 Current and projected climate change 9
2.2.1 Observations 9
2.2.2 Climate projections 11
2.2.3 Vulnerabilities in LICs 12
2.3 Transport resilience in the context of climate change adaptation 13
2.3.1 Measuring resilience 13
2.3.2 Interdependencies 14
2.4 Impacts of climate change to transport infrastructure 14
2.4.1 Infrastructure damage 15
2.4.2 Costs 16
2.4.3 Socio-economic impacts 17
2.5 Benefits of climate change adaptation for transport infrastructure 19
2.6 Mechanisms to support climate change adaptation 20
2.6.1 Policy and strategy 20
2.6.2 Standards 23
2.6.3 Adaptation tools and frameworks 23
2.7 Conclusion 27

3. Ambitions to achieve transport resilience in LICs in Africa and South Asia 29

3.1 Overview 29
3.2 The magnitude of required ambition and actions 29
3.3 Commitments on climate change adaptation 29
3.3.1 Transport adaptation NDC commitments in LICs in Africa and South Asia 29
3.4 Current adaptation policy and strategy 30
3.4.1 Assessment of national adaptation plans, strategies and plans of action 30
3.4.2 Transport sector incorporation 34
3.5 Current understanding of transport adaptation and activities 35
3.5.1 Weather patterns as a result of climate change 35
3.5.2 Impacts of climate change on transport, society and the economy 36
3.5.3 Transport resilience and infrastructure adaptation 37
3.5.4 Capacity building and financing 41

3.6 Conclusion 42
4. Challenges and barriers in achieving transport resilience 43
4.1 Overview 43
4.2 Broad challenges identified through the literature review 43
4.2.1 Weather and climate data 43
4.2.2 Institutional arrangements 44
4.2.3 Financing 46
4.2.4 Crossovers in climate change adaptation and disaster risk reduction 49
4.2.5 Transboundary partnerships 50
4.2.6 Impacts of COVID-19 50
4.3 Specific challenges identified through stakeholder interviews 51
4.3.1 Financial and economic challenges 51
4.3.2 Social and political challenges 51
4.3.3 Technical challenges 51
4.3.4 Institutional and regulatory challenges 52
4.4 Specific challenges identified through evaluating policy 52
4.5 Specific challenges identified through evaluating tools 53
4.6 Conclusion 53
5. Addressing knowledge gaps and needs to facilitate transport resilience 55
5.1 Overview 55
5.2 Identified knowledge gaps and needs 55
5.2.1 Government coordination 55
5.2.2 Capacity building 56
5.2.3 Stakeholder engagement 58
5.3 Channels and options to facilitate LICs' needs 58
5.3.1 Progressing national adaptation planning and mainstreaming into policy 59
5.3.2 Resource utilisation 61
5.4 Conclusion 63
6. Report summary and future directions 65
7. References 67

APPENDICES

Appendix A: Project research question reference table 80
Appendix B: Stakeholder interview questions 86
Appendix C: List of national adaptation documents assessed 93
Appendix D: Reference guide for policy capability assessment 94
Appendix E: List of tools and frameworks assessed 96
Appendix F: Reference guide for tools and frameworks capability assessment 99

TABLES

Table 1: Countries shortlisted for interviews, with their current income class and CRI ranking 3
Table 2: Overview of stakeholder respondents and their organisation type 5
Table 3: Parameters of the literature search 5
Table 4: Examples of potential impacts of climate change on transport systems 15
Table 5: List of SDG targets for which transport resilience has the strongest impact 19
Table 6: Classification of adaptation tools and frameworks for transport 24
Table 7: NDCs by LICs in Africa that mention adaptation measures in the transport sector (102) 30
Table 8: Extent of engagement in NAPs and NAPAs regarding transport sector adaptation 34
Table 9: Extent of design specifications mentioned in interviews by country and transport mode 39
Table 10: Extent of operational plans mentioned in interviews by country and transport mode 40
Table 11: Respondent suggestions: What would make the biggest difference to climate resilience? 41
Table 12: LIC needs in order to overcome key barriers in achieving transport resilience to climate change 55

FIGURES

Figure 1: Summary of interview process with stakeholders 4
Figure 2: Present and projected Köppen-Geiger climate classifications for Africa 10
Figure 3: Present and projected Köppen-Geiger Climate Classifications for South Asia 11
Figure 4: Sectoral interdependencies and their relationships 14
Figure 5: Total score of tools and frameworks according to the six criteria designed by Cash et al. (11) 24
Figure 6: Mean scores of criteria by purpose of tools and frameworks 25
Figure 7: Mean scores of criteria by target group (left) and functionality (right) of each tool or framework 26
Figure 8: Mean scores of criteria by tool or framework's adaptation planning steps 26
Figure 9: Warming projections up to 2100 based on pledges and current policies (101) 29
Figure 10: Score of each NAP and NAPA assessed according to the five ISO 14090 criteria 31
Figure 11: Score of each NAP and NAPA assessed according to the ISO 14090 criteria, by year of publication 31
Figure 12: Range of scores of each NAP and NAPA assessed according to five of the ISO 14090 criteria 32
Figure 13: Mentions of types of infrastructure damage in interviews 37
Figure 14: Extent of weather and climate impact monitoring by proportion of respondents 37
Figure 15: Multilateral climate adaptation funds approved by LICs in Africa and South Asia, 2003–2020 47
Figure 16: Multilateral climate adaptation funds relative to total GDP in 2020[5] 47
Figure 17: Score of each NAP and NAPA against ISO 14090 criteria, by extent of engagement regarding transport 53
Figure 18: Example stakeholder groups and institutions for transport adaptation consultation 59
Figure 19: Framing of adaptation from process based to normative 61

ABBREVIATIONS/ACRONYMS

°C	degree Celsius
AfTR-CC	Adaptation for Transport Resilience to Climate Change
COP	Conference of the Parties
CRGE	Climate-Resilient Green Economy
CRI	Climate Risk Index
EDRI	Ethiopian Development Research Institute
EIA	environmental impact assessment
ENSO	El Niño Southern Oscillation
FCDO	Foreign, Commonwealth & Development Office
FRACTAL	Future Resilience for African Cities and Lands
G20	Group of Twenty nations
GDP	gross domestic product
GGGI	Global Green Growth Institute
GHG	greenhouse gas
HIC	high-income country
HVT	High Volume Transport
ICT	information communication technology
IMC	IMC Worldwide Ltd
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ISF	InsuResilience Solutions Fund
ISO	International Organization for Standardization
ITCZ	intertropical conversion zone
LEG	Least Developed Countries Expert Group
LIC	low-income country
LMIC	lower-middle-income country
MCA	multi-criteria analysis
MIC	middle-income country
NAP	national adaptation plan

NAPA	national adaptation programme of action
NDC	nationally determined contribution
NGO	non-governmental organisation
NIC	National Infrastructure Commission
ODA	Official Development Assistance
PAG	project advisory group
PIANC	World Association for Waterborne Transport Infrastructure
PIARC	World Road Association
PPCR	Pilot Program for Climate Resilience
RAI	Rural Access Index
RCP	Representative Concentration Pathway
ReCAP	Research for Community Access Partnership
RIMA	Resilience Index Measurement and Analysis
SDG	Sustainable Development Goal
SERS	Subjective self-Evaluated Resilience Score
SIDS	small island developing states
TRL	Transport Research Laboratory
TUMI	Transformative Urban Mobility Initiative
UIC	International Union of Railways
UK	United Kingdom
UNFCCC	United Nation's Framework Convention on Climate Change
V20	Vulnerable Twenty nations
WMO	World Meteorological Organisation
WRCCA	Weather Resilience and Climate Change Adaptation

EXECUTIVE SUMMARY

This report explores the current state of knowledge of climate change adaptation for transport infrastructure resilience in low-income countries (LICs) in Africa and South Asia. It documents research undertaken by the project "Adaptation for Transport Resilience to Climate Change (AfTR-CC) in African and South Asian LICs" (reference: HVT047). The project combined primary and secondary data to characterise the current interest, challenges and barriers pertinent to improving the resilience of transport to climate change in these countries. Additional outcomes of this project are a policy guide, intended for providers of transport in LICs in Africa and South Asia, and at least one scholarly paper based on topics within this report, in order to extend the research findings and recommendations to a wider audience.

This report contains six sections. Each section begins with an overview statement that introduces the section's content and ends with a conclusion of the content presented and discussed.

In **Section 1**, the project and research methodologies are introduced. The project research questions fitted broadly into four themes:

- Future weather patterns as a result of climate change;
- The impacts of climate change on transport, society and the economy;
- Transport resilience and infrastructure adaptation;
- Capacity building and financing projects.

The findings presented in this report were drawn from the following research activities:

- Interviews with transport stakeholders;
- Capability assessments of tools and frameworks relevant to transport and/or climate change adaptation;
- Capability appraisals of policies through assessments national adaptation plans (NAPs) and national adaptation programmes of action (NAPAs) in Africa and South Asia;
- Literature review of peer-reviewed publications, grey literature and online resources.

Section 2 provides context on the situation facing LICs in Africa and South Asia pertaining to transport resilience and climate change adaptation. The climate is already changing in these regions and climate change projections indicate they are likely to face more severe consequences of climate change than other parts of the world. Increasing the resilience of transport infrastructure is therefore important because weather-related disruption can have severe socio-economic impacts on communities who depend on it. Reducing transport disruption also links to numerous Sustainable Development Goal (SDG) indicators. LICs in Africa and South Asia are highly dependent on rain-fed agriculture. A resilient transport infrastructure is connected to food security and access to local and international markets, supporting their competitiveness. Furthermore, the sooner LICs are able to implement adaptation, the less it will cost in terms of gross domestic product (GDP) in the long term.

There are many practical mechanisms to support climate change adaptation including policies, strategies standards, tools and frameworks. This section introduces these mechanisms and assesses relevant tools and frameworks. While they have similar concepts and goals, it may be difficult for LICs to select the most appropriate methods due to lack of capacity.

The existing ambitions of LICs in Africa and South Asia in terms of climate change adaptation are presented in **Section 3**. The extent of current policies and pledges around the world to reduce greenhouse gas (GHG) emissions may not be sufficient to keep mean global surface temperatures beneath a level that reduces the risk of irreversibility in the climate system. Adaptation is therefore essential. An assessment of national adaptation documents revealed the climate change adaptation ambitions of LICs, while transport stakeholder interviews determined current levels of knowledge, plans and actions.

The 2015 Paris Agreement invites Parties to submit nationally determined contributions (NDCs) that include their intentions to build adaptive capacity. LICs in Africa and South Asia all mention adaptation in their most recent submissions. In parallel, more LICs have recently submitted NAPs. However, these plans do not always explicitly address transport-specific actions and from the transport stakeholder perspective, the level of

understanding of climate change and its impacts on transport infrastructure is low, often due to a lack of knowledge and/or technical capacity.

Section 4 identifies the challenges and barriers to implementing transport resilience, based on the literature and capability assessments, and stakeholder interviews. The literature suggests there are gaps in relevant weather and climate data, both observations and projections, as well as the capacity of LICs to interpret them. Institutional arrangements at national and local levels, and among ministerial departments, require changes in order to address capacity challenges. Complexities regarding financing projects and crossovers in climate change adaptation and disaster risk reduction are exacerbated by the geography of some LICs and impacts of the COVID-19 pandemic.

The project's interviews with stakeholders identified transport-specific challenges that have four themes:

- **Financial and economic:** Difficulties in accessing funding because maintenance costs are increasing and timely interventions are challenging, both of which are compounded by resource issues that affect infrastructure assessments;
- **Social and political:** Stakeholders mention low awareness of transport-specific issues among ministries and agencies, and are conscious that the profile of climate change needs raising by mainstreaming into public and political debate;
- **Technical:** Lack of data and knowledge, and a need for technical support as well as financial support;
- **Institutional and regulatory:** Primarily regarding inadequate or lack of design standards and guidance and the monitoring and reporting of weather impacts and transport vulnerability.

Section 5 focusses on the needs of LICs in Africa and South Asia and channels to address them. The main gaps and needs of LICs when it comes to improving transport resilience are in: government coordination between national and local levels; capacity building to improve climate and technical knowledge; access to finance; crossovers in climate change adaptation and disaster risk reduction; and stakeholder engagement. There are opportunities to address these gaps and needs through: signposting the ways to progress national adaptation plans; utilising existing resources such as tools and frameworks; innovations in data and transport infrastructure design; and collaboration activities.

Finally, **Section 6** summarises the report's key findings.

The appendices in this report provide responses to the project's key research questions, the interview questions and the material and scoring guide for the capability assessments of policies and of tools and frameworks.

In summary, this report suggests three areas of action for improving transport resilience to weather and climate in LICs:

- **Improved government coordination:** Improving the relationships between national and local government and among ministries and sectors for aspects such as sharing knowledge, facilitating data sharing and downscaling NAP implementation to the local level;
- **Capacity building:** Upskilling by increasing technical knowledge to improve awareness of climate change, the impact of weather on infrastructure and the tools and resources available; improving financial knowledge and access to data; mobilising under-utilised sectors of society and the private sector; and streamlining processes where climate change adaptation and disaster risk reduction cross over;
- **Stakeholder engagement:** Increasing the participation of all groups affected by the impacts of climate change on transport, enabling them to contribute to adaptation options and decisions, leading to sustainable implementation and effective monitoring and evaluation.

LICs in Africa and South Asia require support and guidance to take steps towards transport resilience for climate change adaptation. This highlights the importance of local, national and international collaboration, the sharing of knowledge and ideas, and iterative processes to drive change that is gradual and incremental, but ultimately transformational.

1. Project introduction and research overview

1.1 Overview

This section describes the purpose and approach of this report, and the methodologies used for the research activities.

1.2 Purpose of this document

The High Volume Transport (HVT) Applied Research Programme is a five-year research programme, funded by UK Aid from the Foreign, Commonwealth & Development Office (FCDO). It was launched in 2017 in order to increase access to transport services, more affordable trade routes and safer, lower carbon transport in low-income countries (LICs) (1). The HVT Applied Research Programme is being undertaken in partnership with the World Road Association (PIARC) and the Transformative Urban Mobility Initiative (TUMI).

The HVT Applied Research programme seeks to update technical best practice for transport infrastructure in LICs and actively disseminate it to LIC national authorities in a way that can be understood and put into practice. It will expand and develop new technologies and solutions and will learn from and adapt existing transport technologies, materials, designs, planning and methods from high- and middle-income countries.

The HVT programme supports policy, engineering and technical research to improve transport for all and reduce its impact on the environment. HVT research will support African and Asian countries to develop strategic, cost-effective, safe and low carbon passenger and freight transport services (1). The priority research areas include:

- Climate mitigation and adaptation;
- Inclusion, gender and road safety;
- Policy and regulation;
- Technology and innovation;
- Fragile and conflict-affected states;
- Research uptake and capacity building.

The University of Birmingham was selected to lead the research for the project “Adaptation for Transport Resilience to Climate Change (AfTR-CC) in African and South Asian LICs” (reference: HVT047), which in this report is referred to as “the project”. The project aimed to ascertain the current state of knowledge of climate change adaptation for transport infrastructure resilience, with a focus on LICs in Africa and South Asia. This report, which is one of the project outcomes, highlights the current state of the art and identifies the challenges and gaps in existing knowledge that need addressing to ensure future mobility in LICs in Africa and South Asia.

The project and this report support the United Nation’s Sustainable Development Goals (SDGs), particularly SDG Target 9.1 to “Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all” (2). More broadly, the project and this report support SDG 13 to “Take urgent action to combat climate change and its impacts” (3). They also support Article 7 of the Paris Agreement on adapting to climate change (4).

1.3 Project approach

The primary focus of this project in the scope of HVT priority research areas was climate adaptation, covering multiple transport modes such as road, rail, urban and waterway transport. It used primary research in the form of stakeholder interviews to provide a review of the knowledge, interest, challenges and barriers pertinent to LICs in Africa and South Asia. It also used secondary data gathered from a desk-based review of existing literature, tools and policies and relevant case studies. In addition to this report, the project's outputs include a policy guide, intended for providers of transport in LICs in Africa and South Asia, and at least one

scholarly paper based on topics within this report, in order to extend the outputs of the research to a wider audience.

The FCDO has prioritised 34 countries in seven priority areas (including climate and biodiversity) to receive bilateral Official Development Assistance (ODA) from the United Kingdom (UK) in the 2021-2022 budget (5,6). These include most of the countries considered in the project.

The project comprised 25 research questions, which fitted broadly into four categories:

- Future weather patterns as a result of climate change;
- The impacts of climate change on transport, society and the economy;
- Transport resilience and infrastructure adaptation;
- Capacity building and financing projects.

These categories underpin all sections of this report and the research activities undertaken throughout the project cut across all of them. Therefore, the report structure does not address each research question individually. Instead, the table in Appendix A shows where the evidence answering each research question can be found within the report.

This report contains six sections:

- **Section 1:** Introduces the project and describes the methodology of all project research activities undertaken to produce this report;
- **Section 2:** Justifies the need to adapt transport to increase its resilience to the impacts of climate change and analyses the mechanisms available to enable this, in the context of LICs;
- **Section 3:** Explores the current and proposed ambitions of LICs in Africa and South Asia to adapt to climate change within the transport sector, in particular through policy-led communication;
- **Section 4:** Outlines the challenges and barriers LICs in Africa and South Asia face in achieving transport resilience through climate change adaptation, based on the project's research activities and information presented in Sections 2 and 3;
- **Section 5:** Identifies the knowledge gaps for capacity building opportunities in LICs in Africa and South Asia, based on the project's research activities, which informs the policy guide;
- **Section 6:** Summarises the main findings of the project.

A project advisory group (PAG) supported the project, helping to steer and guide the research activities. The 10 PAG members were from a range of organisations with extensive experience in transport resilience and climate change adaptation worldwide, including developing countries. Their contributions to the project included provision of additional literature, contacts for interviews and ideas to consider and develop in specific research activities.

1.4 Methodology

The project focused on the current state of knowledge, interest and capacity to implement climate change adaptation for transport resilience. It applied primary research to gain insight into the situations among LICs in Africa and South Asia. This primary research provided a review of the challenges, barriers, interest and gaps in knowledge and/or capacity building related to climate change adaptation for transport resilience, supported by a literature review and relevant case studies.

1.4.1 Primary data collection

Interviews were undertaken with various organisations across LICs in Africa and South Asia, including government bodies and infrastructure operators. This captured the current extent of climate change adaptation for transport resilience in these countries and provided an in-depth understanding of their need and ambition for improvements, and their capabilities.

1.4.1.1 Selected countries for interview

One aim of this project was to develop policy guidance for LICs. To do so, it drew on the knowledge of stakeholders within both LICs and lower-middle-income countries (LMICs). Including LMICs offers several benefits. Firstly, it allowed evaluation and validation of the differences in activity by LMICs to identify if these would offer benefits to LICs. Secondly, LMICs may face similar climate vulnerabilities to LICs from a transport perspective, so there is value in incorporating them, particularly when looking at a transport mode as whole. Finally, Afghanistan is the only LIC in South Asia, so the project captured a broader range of information on the region by engaging LMICs as well. Given the political situation in Afghanistan, the project team agreed it would also not be appropriate to make any contact with stakeholders for input into the project.

Countries were selected for interview based on their vulnerability to extreme weather events and climate change. This included a ranking criteria according to countries' membership of the Climate Vulnerable Forum (7) and their Climate Risk Index (CRI) score – where the lower the number, the greater the climate risk to the country (8). Stakeholder engagement was initiated through existing contacts in these countries by the project team or PAG members. Table 1 lists the countries that were shortlisted for interviews at the start of the project, including their income classification by the World Bank (9).

Table 1: Countries shortlisted for interviews, with their current income class and CRI ranking

Country	Region	Income class	CRI ranking[1] 2019
Ethiopia	Africa	LIC	72
Ghana	Africa	LMIC	42
Kenya	Africa	LMIC	25
Madagascar	Africa	LIC	29
Malawi	Africa	LIC	5
Mozambique	Africa	LIC	1
Rwanda	Africa	LIC	42
South Sudan	Africa	LIC	8
Tanzania	Africa	LMIC	67
Uganda	Africa	LIC	31
Zimbabwe	Africa	LMIC	2
Afghanistan	South Asia	LIC	6
Bangladesh	South Asia	LMIC	13
India	South Asia	LMIC	7
Nepal	South Asia	LMIC	12
Pakistan	South Asia	LMIC	15
Sri Lanka	South Asia	LMIC	30

[1] The lower the CRI ranking, the greater the climate risk to the country.

The research questions for this project covered a wide range of topics (see Section 1.3). Interviews were conducted with a range of stakeholders to capture a cross-section of perspectives, enabling the project to answer the research questions comprehensively. These stakeholders were classified as:

- Ministry of Environment (or equivalent);
- Ministry of Transport (or equivalent);
- Infrastructure practitioner (such as road authorities, transport owners or railway operators);
- Urban planning/urban transport authority.

1.4.1.2 Interview questions

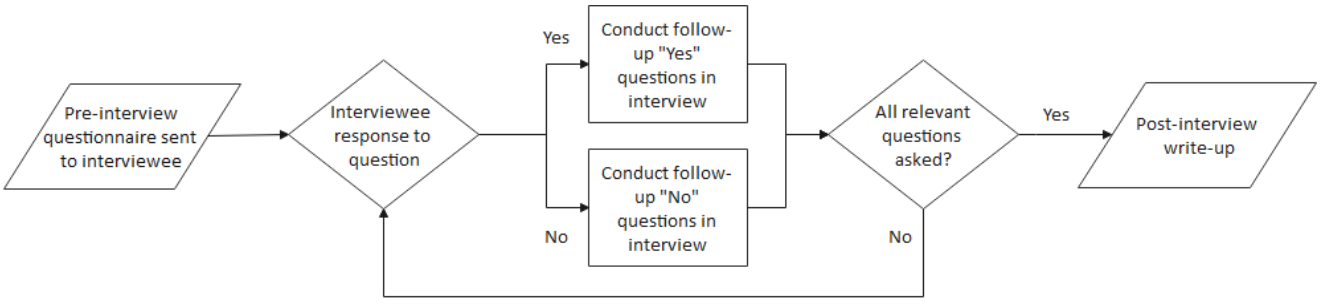
The project research questions were grouped into four themes (see Section 1.3) and the interview questions were designed to align with them. Each structured question started with an overarching opening question, primarily with a “yes” or “no” response, followed by a number of related questions for either response. (See Appendix B for breakdown details of the interview questions.) Due to the number and range of research questions, each respondent received a different subset of interview questions, selected to be most appropriate to their organisation. The interview questions were arranged in four different ways, based on the four organisation types listed above in Section 1.4.1.1.

Before the oral interview, respondents received the structured opening questions as a written questionnaire. Asking some questions in advance allowed the time available for the interview to be used to discuss any complex or nuanced topics. In addition, answers to the questionnaire could be used to guide the direction and content of the interview.

The first respondents received a version of the questionnaire as a Microsoft® Excel® spreadsheet. This later developed into a web-based questionnaire, facilitated by an online survey platform for improved efficiency. Respondents received the questionnaire approximately one week before their scheduled interview. Not all respondents responded to the questionnaire before their interview; if they did, the interview questions were adjusted to optimise the discussion.

The interviews were semi-structured, with discussion around the opening questions and further follow-up questions or prompts depending on the respondent’s answers to the questionnaire. Figure 1 illustrates the process for each structured question and response.

Figure 1: Summary of interview process with stakeholders



1.4.1.3 Interview conduct

All interviews took place virtually, in English, via Zoom or Microsoft Teams®, between July and September of 2021. Most interviews took approximately 45 to 60 minutes, but some interviews took longer – up to 80 minutes – if the respondent had not completed the pre-interview questionnaire. Thirteen interviews took place in total; these are summarised in Table 2.

For consistency, a write-up format was designed prior to conducting the interviews. Each respondent was sent the write-up of their interview to confirm accuracy and allow them to add any more relevant information. In the event that this follow-up referred to any documents or material mentioned by the respondents, they were added to the compiled literature (see Section 1.4.1.2).

Table 2: Overview of stakeholder respondents and their organisation type

Country	Organisation	Sector
Bangladesh	Ministry of Environment	Road
Bangladesh	Infrastructure practitioner	Road
Ethiopia/Djibouti	Infrastructure practitioner	Rail
Ghana	Infrastructure practitioner	Road
India	Infrastructure practitioner	Rail
Kenya	Infrastructure practitioner	Road
Madagascar	Infrastructure practitioner	Road
Nepal	Infrastructure practitioner/Ministry of Transport	Road
Nepal	Urban planning/transport authority	Road
Pakistan	Infrastructure practitioner	Road
Tanzania/Zambia	Infrastructure practitioner	Rail
Uganda	Infrastructure practitioner	Road
Zimbabwe	Infrastructure practitioner	Road

1.4.2 Secondary data collection

Secondary data was obtained through four methods: literature review; capability assessment of policies; capability assessment of tools; and case studies.

1.4.2.1 Literature review

A systematic review of literature took place in June and July 2021, collecting information on the state of knowledge relating to climate change adaptation and transport topics, with a focus on LICs in Africa and South Asia. By not limiting the literature review to those countries given in Table 1, a greater amount of relevant information for both regions was collated for analysis.

Table 3 shows the parameters of the literature search. Document titles and abstracts and/or executive summaries were screened for relevance. If deemed relevant, the publication was saved and recorded in a compendium of project resources for the project team and PAG members. The literature search mainly focused on the last 10 years of publications: however, earlier literature was considered where relevant.

Table 3: Parameters of the literature search

Literature sources	Literature search methods	Databases accessed	Keywords
Peer-reviewed journal articles Grey literature (e.g. non-governmental organisation reports) Government publications/policy Online media (e.g. websites)	Keyword search Snowballing[2] Recommendations (PAG, key experts) Interview references	Web of Science Google Scholar ResearchGate Connected Papers	climate change adaptation, transport, Africa, South Asia, government policy, transport resilience, climate change, extreme weather, low-income countries

[2] "Snowballing" in terms of this report is defined as searching for relevant literature according to a document's reference list, or the literature that references it.

1.4.2.2 Capability assessment: policy

To understand the appetite of LICs in Africa and South Asia for transport resilience and climate change adaptation, the project undertook evaluations of individual countries' policies and the tools currently available to them.

The project carried out a desk-based review of government documents published by LICs in Africa and South Asia and by those LMICs shortlisted as part of the primary data collection (see Table 1). After a review of the available documents, the countries' NAPs or NAPAs were selected for the assessment of their policy capability. These are key documents that cover climate change adaptation at country level and thus should include consideration of transport. Eighteen NAPs or NAPAs, published in English, were assessed (see Appendix C).

The NAPs and NAPAs were assessed using criteria given in ISO 14090 "Adaption to climate change – Principles, requirements and guidelines" (10). This 2019 standard outlines the principles, requirements and guidance on preparing for climate change adaptation and is considered best practice internationally. Within the ISO 14090 standard, clauses 6 to 10 describe how any organisation should implement climate change adaptation; these clauses formed the basis of the evaluation criteria for the capability assessment.

A multi-criteria analysis (MCA) was used to rate each NAP and NAPA on a scale of 1 (low) to 5 (high) on its level of content and understanding of each clause. A score of 5 indicates the NAP includes a comprehensive coverage of aspects within the respective ISO 14090 clause's guidance. A score of 1 shows the NAP has no coverage related to that clause. The focus of evaluation is the inclusion of "shall" statements, as this indicates a requirement, as opposed to a recommendation, permission, possibility or capability. The criteria, or clauses, evaluated were:

- **Impact analysis:** The assessment of impacts of climate change;
- **Adaptation plan:** The plan of adaptation activities and the plan's components;
- **Implementation plan:** The processes to deliver the adaptation plan, including accountabilities;
- **Monitoring and evaluation:** The methods outlined to monitor the implementation and inform future developments;
- **Reporting and communication:** The clarity of communication to external parties.

A reference guide was developed to provide a generic description for each of the scores. This reference guide enabled the NAPs and NAPAs to be evaluated systematically and consistently (see Appendix D for the scoring system's highest and lowest score descriptors). In addition to the MCA, a second evaluation identified the extent to which transport was considered in each NAP or NAPA:

- **It is not mentioned:** Transport as a sector, or a specific mode of transport, cannot be found;
- **It is mentioned:** Transport as a sector, or a specific mode, is considered (such as in the context of another analysis or sector) but is absent of analysis or discussion;
- **It is discussed:** There is evidence of analysis or consideration of transport, or a specific mode explored in depth, and it is part of the adaptation plan.

1.4.2.3 Capability assessment: tools

The project included a desk-based review of the different types of tools and knowledge platforms that exist to support policymakers in LICs. The review focused on tools related to climate change adaptation that are transport specific. Due to the variability in content of these tools, a standardised approach was developed that was not specific to any theme (e.g. transport). This allowed all relevant tools to be evaluated and cross-referenced, regardless of scope or content. In total, 35 tools were assessed (see Appendix E).

An MCA was used to rate tools in accordance with the principles designed in a study by Cash et al. (11). This study suggests that efforts to mobilise science and technology for sustainability are "more likely to be effective when they manage boundaries between knowledge and actions in ways that simultaneously enhance the salience, credibility and legitimacy of the information they produce". Therefore, the content of each tool was rated on a scale of 1 to 5, based on the following three criteria, as defined by Cash et al.:

- **Salience:** The relevance to the needs of transport stakeholders in LICs in Africa and South Asia;
- **Credibility:** The scientific adequacy of the technical advice and arguments;
- **Legitimacy:** The perception that the production of information has been respectful of the values and beliefs of transport stakeholders in Africa and South Asia, and unbiased in its conduct.

How effective a user (in this case, a transport stakeholder) finds this content is dependent on three functions, listed below. These functions help bridge the boundaries between knowledge and action, allowing the user to make sense and genuine use of the information the tool provides. Therefore, the tools were also rated on a scale of 1 to 5 for these three functions:

- **Communication:** The extent of open and inclusive communication towards transport stakeholders, including the level of transparency, if applicable;
- **Translation:** The extent to which language, jargon, experiences and presumptions are clear and can be understood (or not understood) by transport stakeholders;
- **Mediation:** The extent of transparency, holistic perspectives, provision of rules of conduct and establishing criteria for transport stakeholders.

Similar to the policy capability assessment, a reference guide was developed to provide a generic description for each of the evaluation criteria and the scoring system (see Appendix F for detailed descriptions of the scoring system's highest and lowest scores).

1.4.3 Case studies

The case studies were selected following a review of the primary and secondary data collected for the project. These focused on examples of good practice or where there were valuable learnings in governments and organisations in any relevant aspect of climate change adaptation and transport resilience. The case studies in this report are:

- **Case study 1:** Leadership-driven national policy design in Ethiopia;
- **Case study 2:** Iterative climate change adaptation processes in the transport sector: Network Rail's Weather Resilience and Climate Change Adaptation Plans;
- **Case study 3:** Why does Burkina Faso's NAP score so highly?;
- **Case study 4:** Multilateral funding for transport adaptation: Mozambique's Roads and Bridges Management and Maintenance Program;
- **Case study 5:** City-to-city knowledge transfer through FRACTAL: Future Resilience for African Cities and Lands.

1.5 Conclusion

This project examined the current state of knowledge of, interest in, and capacity to implement climate change adaptation for transport resilience in LICs in Africa and South Asia, with the aim of using the information to develop a policy guide to support these countries in moving towards better transport resilience through climate change adaptation. This report documents the project's findings based on analysis of primary and secondary data, and reviews the barriers, interest and knowledge gaps pertinent to LICs in Africa and South Asia.

The themes that underpin the research questions answered throughout this report are:

- Future weather patterns as a result of climate change;
- The impacts of climate change on transport, society and the economy;
- Transport resilience and infrastructure adaptation;
- Capacity building and financing projects.

The primary research for this project comprised interviews with stakeholders from LICs and LMICs in Africa and South Asia across four organisation types: Ministry of Environment (or equivalent); Ministry of Transport

(or equivalent); infrastructure practitioner (i.e. transport owner or operator); and urban planning/urban transport authority. The secondary data collected comprised:

- Literature review of peer-reviewed journal articles, grey literature, government publications and online media;
- Capability assessments of policies and tools, in structured formats based on existing, robust guidance.

2. Setting the scene: climate change and transport resilience in Africa and South Asia

2.1 Overview

This section describes the climate and infrastructure challenges faced by LICs in Africa and South Asia, and the benefits of adapting transport to climate change. It also discusses the range of mechanisms and resources available to them to support transport resilience and climate change adaptation.

2.2 Current and projected climate change

Since the industrial revolution, fossil fuel combustion and land use change have been the primary contributors to anthropogenic emissions of GHGs. This has resulted in the atmospheric GHG concentration reaching record high levels – and it continues to rise. Therefore, the impact of humans upon global natural systems and energy balance has unequivocally led to climate change (12). This, in turn, means the continents of Africa and Asia are facing severe, high-impact weather events due to the change in the global climate system (13).

2.2.1 Observations

Global anthropogenic emissions are estimated to have caused an increase of approximately 1 degree Celsius (°C) in global mean surface temperature since pre-industrial times (12). The rate of increase is not homogenous around the world and is typically greater on land. Similarly, precipitation change is also variable globally. Most land areas are experiencing more heavy precipitation events, but instances of drought are more likely in some regions (14).

Africa and Asia have already experienced extreme weather incidents in recent years (13). Wetter weather in the eastern regions of Africa has led to instances of very extensive flooding and India recently experienced one of its two wettest monsoon seasons since 1994. Southern Africa continues to experience a long-term drought, but with some localised heavy rainfall.

2.2.1.1 Observed trends in Africa

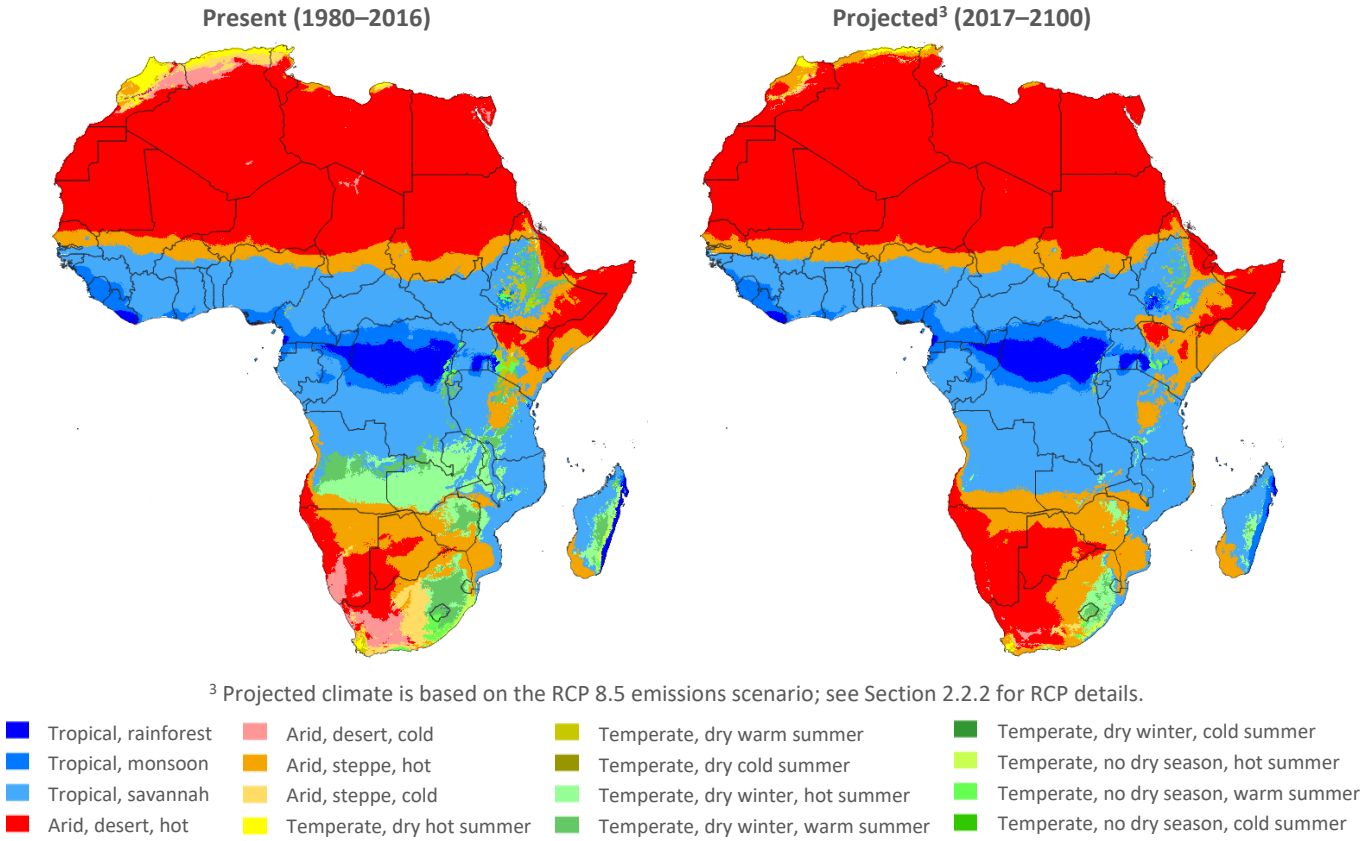
The continent of Africa has clearly defined, almost latitudinal climate zones across a large part of its surface. As shown on the left in Figure 2, the northern region is primarily characterised by arid desert, with a transitional zone to its south (arid, steppe, hot) and then a large, tropical savannah zone. The equatorial region is a rainforest zone, halfway down the continent. To the east and the south of Africa, the climate zones are smaller, including a range of temperate zones in the south, which are also areas of greater land elevation.

The continental trade winds from Asia result in lower levels of precipitation across the eastern coast of Africa. The intertropical conversion zone (ITCZ) movements through the central parts of Africa influence the two predominant seasons per year: rainy and dry.

In recent decades, temperatures in Africa have risen at a rate comparable to those of other continents (15). Compared with a 1910–2000 baseline period, the whole of Africa has experienced positive temperature anomalies every year since 1977. The warmest year on record was 2010 and eight of the 10 warmest years have been since 2010 (16).

Precipitation records, on the other hand, exhibit sharp geographical contrasts. In 2019, southern Africa and west of the High Atlas Mountains recorded rainfall that was remarkably below average, while central and east Africa recorded above-average rainfall (15). In 2020, the African monsoon season extended farther north than usual (13). To the west, such as in Guinea-Bissau, there have been three temporal trends in precipitation since 1950: prevalence of wet years from 1950 to 1970; prevalence of dry years from 1970 to 1990; and marked shifts between wet and dry years since 1990 (17).

Figure 2: Present and projected Köppen-Geiger climate classifications for Africa



[3] Projected climate is based on the RCP 8.5 emissions scenario; see Section 2.2.2 for RCP details.

Source: Adapted from Beck et al. (18) and Pope (19)

The El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) phases correlate with eastern and southern African climate variability; a positive ENSO phase can lead to more rain in eastern Africa but less rain in southern Africa, and a positive IOD can lead to more rain in eastern Africa. Both may also affect the timing of floods across Sub-Saharan Africa, by up to three months depending on their phase (20).

Sea level rise also exhibits regional variability, with the western African region in particular experiencing a rate of sea level rise slightly above the global mean (15).

2.2.1.2 Observed trends in South Asia

Compared with Africa, the climate zones in South Asia are more diverse and distributed differently. As shown on the left in Figure 3, four climate zones dominate the majority of its land: hot, arid desert to the west; temperate in the north-east; tropical monsoon in the south; and hot, arid steppe through the centre. The northern parts of the region, which border the Himalayas, are most varied.

South Asia's temperature and precipitation characteristics differ from Africa, with a much greater temperature range and typically more climate zones per country. Afghanistan and Pakistan, in particular, receive less rainfall than other South Asian countries. The rainy monsoon season is responsible for most of the region's annual rainfall; this occurs annually, starting in the east around the Bay of Bengal and moving westwards between June and September.

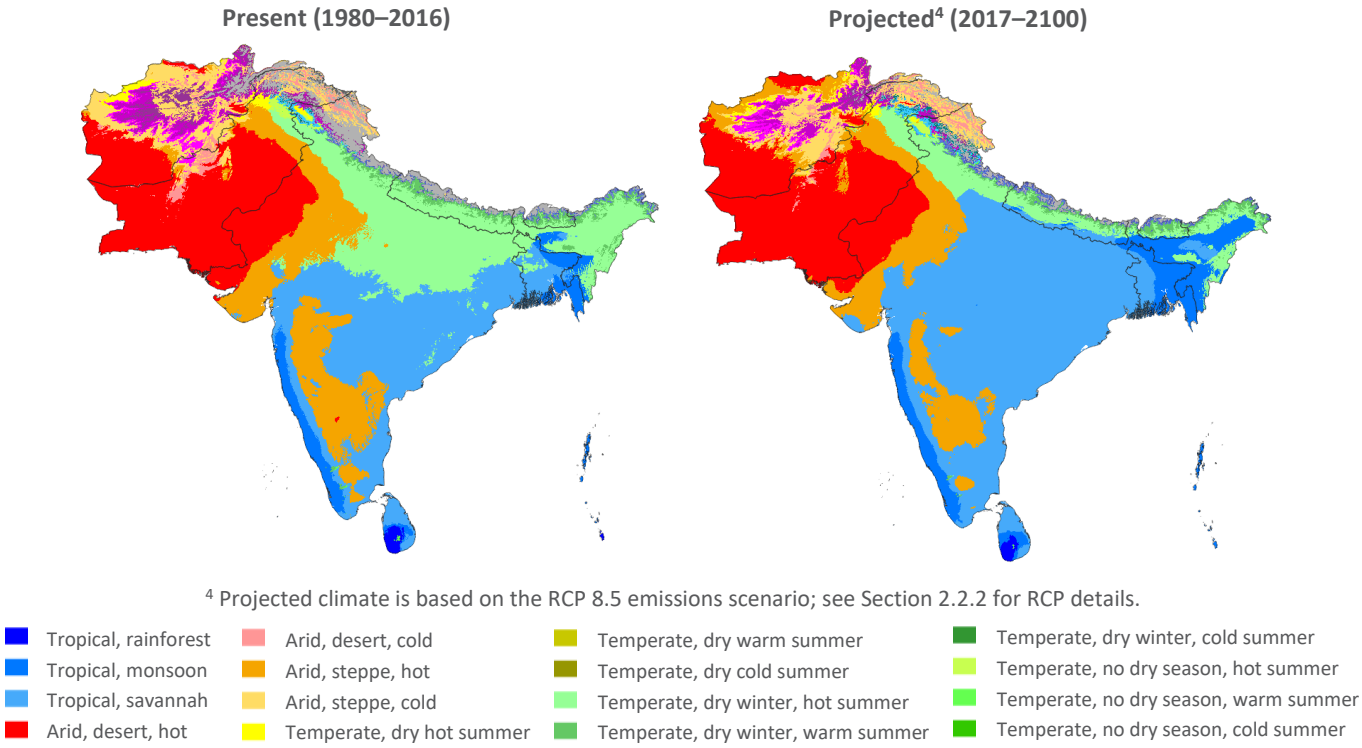
The temperature across Asia as a whole has risen in recent decades (21), with 2020 its warmest year on record. Positive temperature anomalies have occurred every year since 1988. Seven of the warmest years occurred in the last 10 years (22). There has also been an overall increase in the number of hot days and warm nights, but there is insufficient evidence to suggest that any trends in increased frequency or intensity of heatwaves have occurred (23).

There have been variations in precipitation levels across South Asia across many decades, with the trend being an overall decline. However, the frequency of heavy precipitation events has increased, and the

frequency of light precipitation events has decreased (24). In 2020, the monsoon-influenced regions of the world, including South Asia, experienced unusually high levels of precipitation (13).

In some instances, there have been significant decreases in the number of wet days due to delays in the monsoon season, such as in Sri Lanka (25). There have also been increases in flooding and drought across different regions of India (26). Records show that Afghanistan has experienced the most drought events in South Asia in the last 30 years; however, drought is not well documented across the whole region (27).

Figure 3: Present and projected Köppen-Geiger Climate Classifications for South Asia



[4] Projected climate is based on the RCP 8.5 emissions scenario; see Section 2.2.2 for RCP details.

Source: Adapted from Beck et al. (18) and Pope (19)

2.2.2 Climate projections

The Intergovernmental Panel on Climate Change (IPCC) regularly assesses the scientific basis of climate change, which includes future risks. Its assessments are used to develop methods to project global climate change. The fifth Assessment Report, which is the most recent (2014; the sixth is due in 2022), adopted four scenarios that represented different levels of global GHG emissions, known as Representative Concentration Pathways (RCPs). The RCPs have become the primary basis of academic studies into projected climate change.

The lowest scenario, RCP 2.6, is one in which global emissions reduce significantly, resulting in global surface temperatures that do not exceed 2°C above pre-industrial levels by 2100. This is the basis of the Paris Agreement (4). The remaining scenarios – RCP 4.5, RCP 6.0 and RCP 8.5 – all result in further warming, with RCP 8.5 indicating that global surface temperature warming may be 4°C or more. Surface temperature warming has consequences for global biogeochemical processes, leading to impacts on, for example, sea level, the water cycle, ocean acidification and the cryosphere (sea and land ice extent).

For Africa and Asia, many of the concerns associated with projected climate change are related to precipitation (14). This includes shifts, extensions and intensification of monsoon seasons, increased rainfall from landfall cyclones and prolonged drought events. Many LICs have a high dependency on agriculture and farming, and transport is vital for sustaining their food supplies. Therefore, the projected changes in precipitation present a significant risk.

2.2.2.1 Climate projections in Africa

It is very likely that all of Africa will get warmer during the 21st century (14) and at a greater rate than the global average (23), with regional differences. In tropical west Africa, the rate of warming is likely to be higher

earlier in the century than elsewhere in Africa due to its pre-existing natural climate variability, which is small. High warming rates are projected in southern Africa (23); this may lead to the loss of its temperate climate zones, which may become arid, hot desert or steppe zones, as shown on the right in Figure 2.

The projected trends in precipitation vary across Africa. In the east, there may be increased short rain events due to the pattern of Indian Ocean warming (28), although this translates to little change in mean precipitation (14). However, the west of Africa is expected to experience an enhanced summer monsoon period, possibly with a slight delay to the rainy season, and intensification of rain at the end of the season. In the south, precipitation is expected to reduce and there is increased risk of soil moisture drying under the high emissions climate scenario (RCP 8.5) (28).

River systems may also be highly sensitive to climate change (29). The impacts are potentially very large, although there are uncertainties due to the potential changes in precipitation (30). For example, in the Greater Horn of Africa, to the east, the streamflow response to climate change may result in large sub-regional variation; long-term mean flow may decrease in Ethiopia, whereas the equatorial region may see an increase (31). Projected drying of river systems may become dominant as increased temperatures lead to evapotranspiration losses, but also any decisions about development on a river system will have consequences (30).

2.2.2.2 Climate projections in South Asia

There is high confidence in the projected rise in temperature across South Asia (14). However, its extent is predicted to vary by country and by season. Faster rates of warming are projected at different times of year across the region. For example, the projected winter season warming is more rapid in Bangladesh and Pakistan, whereas more rapid warming is projected in the spring and summer in Afghanistan, and in the dry months for Nepal (32).

The increases in temperature are predicted to be greatest in the north-west of South Asia; namely Afghanistan, northern Pakistan and the northernmost part of India (33). In areas of higher elevation, there may be a relatively higher increase in temperatures in the highest altitudes (mountains) compared with lower ones (hills), and the impacts are likely to be more significant in the mid-to-late 21st century than in the first half of the century (34). Warming has different implications for different areas, due to topography. For example, warming in the high mountain regions, such as those around Nepal, would result in rapid glacial melting, affecting the flow of snow-fed rivers. This, in turn, could erode the riverbanks in mid-hill regions downstream. Coupled with changes in precipitation, this could lead to more disasters such as floods, landslides and drought (35).

In future, precipitation may increase in the regions of South Asia that are currently humid (33). Additionally, there is a medium level of confidence in summer monsoon precipitation increasing across the region (14), such as northwards as shown on the right in Figure 3.

Drought events are also likely to increase across South Asia in all GHG emissions scenarios. Significant drought conditions may occur over the north-west, both in duration and intensity, as well as parts of the south-west and northern central areas (33), due to the predicted increases in evapotranspiration rates.

Even under a low emissions scenario, small island developing states (SIDS) such as the Maldives and low-lying coasts such as the Bangladeshi delta could still face greater exposure to sea level rise (36).

2.2.3 Vulnerabilities in LICs

The IPCC defines “vulnerability” as the “propensity or predisposition to be adversely affected” by climate change (12). However, the term comprises a range of concepts and elements (such as sensitivity/susceptibility to harm or lack of capacity to cope and adapt), so it is difficult to generalise or to quantify using a standardised measure or metric. More specifically for transport, its vulnerability is “a function of the potential impact of climate change – based on location and thus its exposure and sensitivity to climate change – and its adaptive capacity, broadly defined to include both providers and users” (37,38).

Observed trends and projections of the future climate across Africa and South Asia highlight that LICs currently face, and are likely to continue facing, a wide range of climate-related disasters. Many of these

countries have been evaluated as having a high level of vulnerability and low level of readiness to combat climate change, in terms of their ability to utilise investments for adaptation actions (39).

Transport vulnerability in LICs is not just limited to the direct effects of climate change and any vulnerability can have far-reaching consequences. The wider environment and social, economic and political factors all need to be considered. For example, a transport system with low resilience may require higher maintenance in future due to more intense and frequent precipitation (37). Without the funds to facilitate this, it impairs the ability of people to access essential services such as jobs, schools and hospitals. Ultimately, this has an impact on wider development if not addressed. LICs have not necessarily undertaken vulnerability assessments in their transport sectors, so the risks have not been quantified (40).

Another factor that could cause infrastructure to be vulnerable is limited planning relating to any migrant influx and the resultant growth in population in need of services (41). An example relevant to LICs is rapid urbanisation. If climate change accelerates migration out of more vulnerable regions, pressures on existing transport networks could propagate, disrupting the provision of services.

2.3 Transport resilience in the context of climate change adaptation

Transport resilience, according to the IPCC's definition of resilience (12), infers a transport system's capacity to cope with a hazardous event or disturbance, responding or reacting in such a way that it retains its essential function. Hazardous events can take many forms, but in the context of climate change, these are largely the consequences of extreme weather events and, for coastal regions, sea level rise.

2.3.1 Measuring resilience

The term "resilience" can be used as a measure of the resistance, robustness and flexibility of complex systems. It is difficult to define, however, as it can mean different things when considering different groups or places. Metrics can help, as they aim to quantify the otherwise abstract, qualitative concept of resilience. Many existing resilience metrics that achieve this focus on food availability and economic factors such as the Resilience Index Measurement and Analysis (RIMA) (42) or the Subjective self-Evaluated Resilience Score (SERS) (43).

For transport, resilience metrics are limited. However, there are some measurable characteristics of national infrastructure systems that can be applied to transport. The UK's National Infrastructure Commission (NIC) identified six aspects of resilience (44):

- **Anticipate**: Actions to prepare in advance to respond to shocks and stresses: for example collecting data on the condition of transport assets such as vehicles or structures;
- **Resist:** Actions taken in advance to help withstand or endure shocks and stresses to prevent an impact on transport infrastructure and services, such as building flood defences;
- **Absorb:** Actions that, accepting there will be or has been an impact on transport infrastructure and services, aim to lessen that impact, such as building redundancy through railway timetabling or additional highway routes;
- **Recover:** Actions that help quickly restore expected levels of service following an event: for example procedures to restart services following an event such as a nationwide loss of power, or the provision of rail replacement bus services;
- **Adapt:** Actions that modify the system to enable it to continue to deliver services in the face of changes, for example placing signalling equipment on raised platforms to prevent damage from floodwaters;
- **Transform:** Actions that regenerate and improve infrastructure systems: for example transforming infrastructure to meet the net zero target.

In terms of climate change adaptation, different approaches are required to facilitate physical versus operational resilience. Where physical resilience typically benefits from hard infrastructure measures, such as flood defences or increased drainage capacity, operational resilience may require "softer" approaches, such as timetabling, intermodal transport hubs, improved staff availability and communication.

2.3.2 Interdependencies

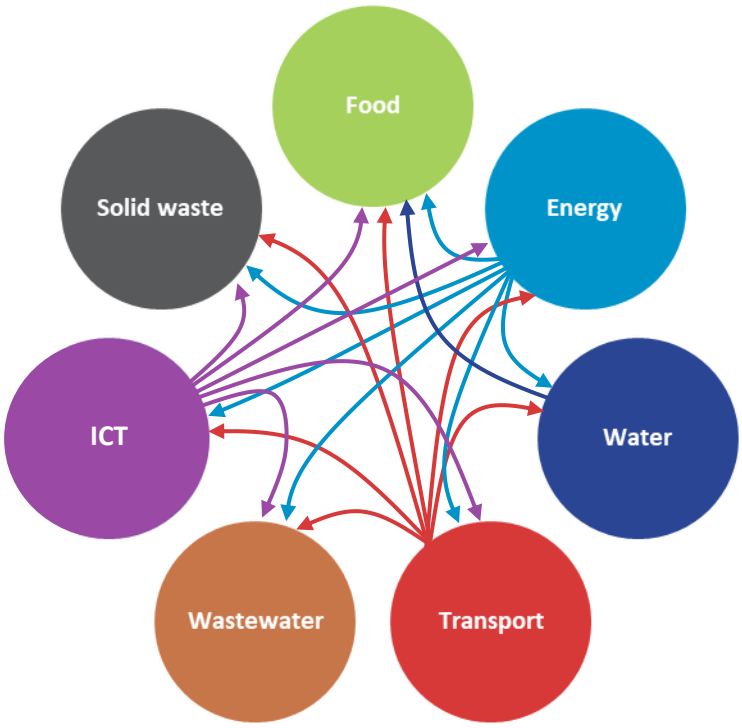
Transport is one of many infrastructure sectors; others include energy, water, waste and information communication technology (ICT). Together, these make up a complex "system of systems" infrastructure.

Today, these sectors rely heavily on each other to deliver their services, creating interdependencies. Although the infrastructure of each sector was independently designed and built, they have become increasingly interconnected. As a result, when one part of this system of systems stops working, it has knock-on effects on others.

In the context of climate change, these infrastructure interdependencies are an additional vulnerability. They amplify existing climate risks (45) and emphasise the need to consider resilience as being a cross-sector, system-scale issue (46).

Transport sector interdependencies are far-reaching across sectors, as shown in Figure 4, **Transport infrastructure is highly connected to all other infrastructure sectors**, primarily because it provides a direct supply link (47). Similarly, energy and ICT directly affect transport, as they are necessary for its operation. For LICs in Africa and South Asia, the road network is the primary mode of transport for goods, services and commuters. Road disruption may therefore create major choke points in passenger and freight traffic, with knock-on effects on an already vulnerable area.

Figure 4: Sectoral interdependencies and their relationships



Source: Adapted from C40 (48)

2.4 Impacts of climate change to transport infrastructure

Weather can affect transport infrastructure in multiple ways, and it is widely accepted that any consequences are likely to be negative. A lot of the research into the impact of climate change on transport has focused on the infrastructure in more developed countries, such as high- and middle-income countries (HICs, MICs). Therefore, there is a lack of studies focussed on Africa and South Asia. These regions experience weather events such as monsoons and cyclones that require greater research focus, as they can have particularly severe impacts for LICs, compounded by their vulnerabilities.

Studies of weather and transport failure have often focussed on accidents and behaviour. However, there is a growing need to focus on physical models of infrastructure performance in extreme weather and cascading failures and interdependency analysis linked to other infrastructure sectors, such as energy (49).

2.4.1 Infrastructure damage

Damage to transport infrastructure due to climate change can vary by climate hazard, as well as by transport mode. The extent of any impact may also differ between urban and rural areas, transport types, infrastructure age and maintenance practices.

Table 4 gives examples of how different climate hazards can affect transport infrastructure. Some of the impacts on infrastructure affect multiple transport modes. The infrastructure damage is what leads to disruption, with knock-on effects for other sectors that depend on transport, such as agriculture and emergency services.

Table 4: Examples of potential impacts of climate change on transport systems

Climate hazard	Infrastructure impact
Sea level rise, storm surge and flooding	• Port infrastructure damage and disruptions to shipping traffic; • Loss of coastal waterway systems and/or disappearance of barrier islands; • Damage to, or inaccessibility of, low-lying coastal infrastructure; • Increased dredging requirements; • Aggravated coastal flooding as storm surges build on a higher base, reaching further inland and impacting more transport infrastructure.
Strong winds and storms	• Greater likelihood of infrastructure failure and disruption to operations; • Increased threats to bridges and auxiliary infrastructure; • Dynamic force of water generated by waves onto infrastructure; • Coastal defence overtopping; • Damage to overhead lines for railways, power supply, signs and lighting features, and increased tree fall leading to the closure of railway tracks and roads; • Delays and cancelation of flights and unreliable air travel services; • Damage to cranes and terminal facilities; • Poor visibility and safety hazards for vehicles.
Increasing precipitation intensity	• Flooding of roads, railways and tunnels causing traffic disruption and closures; • Slope failures and landslides; • Washout of gravel and earth roads and railway tracks; • Increased seepage and infiltration into pavements and subgrade; • Erosion and scouring or washout of bridges; • Increased sediment loading of drainage works leading to increased maintenance; • Poor visibility and safety hazards for vehicles.
Change in mean precipitation	• Increased drought, reducing the navigability of inland waterways; • Impact of soil moisture levels, affecting road structural integrity; • Adverse impacts of standing water on road bases; • Subsidence of infrastructure and road beds due to increased aridity or lower water table affecting the base stability; • Consecutive drought days increasing susceptibility of wildfires or mortality of roadside vegetation; • Susceptibility to mudslides in areas deforested by wildfires.

Climate hazard	Infrastructure impact
Higher mean temperatures, extreme heat events	• Increased pavement deterioration caused by softening, including cracking, rutting and bleeding; • Rail track deformation and buckling; • Reduced asset lifetime; • Shorter maintenance windows; • Thermal expansion of bridge joints; • Increased energy consumption due to refrigeration of transported goods and use of air conditioning; • Increased forest fires resulting in land infrastructure closure and failure; • Transport payload restrictions due to reduced lift during aircraft take-off; • Decreased runway traction; • Occupational health and safety issues during transport operation.

Source: Adapted from World Bank (37,50) and UNECE (51)

Generally, flood damage is easier to quantify than other weather hazards (such as heat) due to the physical nature of such events; the extent of a flood event is measurable, and it is likely to be easier to identify causality between flood damage and its impact on infrastructure. The highest percentile impacts are most important to consider, as they are likely to translate to the most severe flood damage (compared with damage caused by changes in mean precipitation levels). For roads in particular, flooding and precipitation has a direct link with traffic safety, increasing the likelihood of more frequent accidents (52). In LICs, there is a high dependency on road infrastructure and vehicle use is growing rapidly. However, this is not necessarily matched by corresponding improvements in regulations, standards or infrastructure capacity (53) and this therefore exacerbates the risks due to flooding and heavy precipitation.

On the other hand, temperature-related hazards are far-reaching geographically compared with floods. Some of the consequences include accelerated degradation of assets, which has an impact on the maintenance required. This, in turn, may make it necessary to revise the design thresholds for civil infrastructure. For example, if temperatures begin to exceed maximum design temperatures, asset materials such as steel joints and fixtures could expand, leading to road and rail closures. Furthermore, design thresholds may vary between countries, so the exposure risk may be worse in countries with inferior standards.

2.4.2 Costs

The financial performance of infrastructure assets can be strongly linked to climate impacts. Broadly speaking, the impacts of climate change can increase construction costs at the design and construction phase; then during operation, they may cause an increase in loss both of asset value and operation and maintenance costs. They impacts may also result in decreases in revenue and/or economic return and changes in cash flow variability (54).

Rectifying infrastructure damage incurs costs from a range of activities necessary to get transport networks or systems up and running again. The level of infrastructure maintenance relative to economy size in LICs, such as road networks in Africa, is comparatively high, while still considered low when compared with other developing countries (55). LICs face challenges in accessing or raising the necessary funds to cover the potential increase in costs. This presents a risk of an escalating problem caused by a feedback loop between accelerated damage to infrastructure and accelerated deficiency in funding to maintain the infrastructure.

2.4.2.1 Maintenance costs

Climate change presents the risk that the cost of maintaining transport infrastructure will increase due to the greater frequency of extreme weather and subsequent damage. There can be delays to infrastructure maintenance in LICs due to lack of funds, resulting in required activities being tantamount to reconstruction, which may ultimately result in higher direct and indirect costs (55). Urban areas in particular, having a larger amount of infrastructure (and thus vulnerable to a greater compound effect caused by interdependencies), may require more maintenance.

Examples of the potential need for increased maintenance due to climate change include the repair of roads, bridges, drainage assets and earthworks following an extreme heat event or heavy flooding. Longer-term changes in climate variables may lead to an accelerated degradation of asset materials, necessitating earlier or more frequent replacements. For LICs, the cost of maintaining an existing road network, for example, may be so high that it is equivalent to double or triple the original cost of building those roads (56). The longer adaptation is delayed, the greater the incurred costs are likely to be (57). In some cases, the resources allocated to the transport sector have increased but maintenance remains underfunded; if this is not addressed, the underfunding of maintenance may worsen as new assets are added to the network (58).

2.4.2.2 Infrastructure modification

In some instances, transport infrastructure may require modification or even replacement in order to adapt to climate change. For example, higher temperatures may necessitate longer runways at airports (40) and greater cooling capacities on trains (59), increased precipitation variability may require trialling of more climate-resistant road materials (50) and increased periods of drought may mean that existing landing facilities for inland waterways are extended to deeper waters (53).

These types of changes can be mandated by revising regulations or enhancing standards. Implementing enhanced design standards can result in reduced maintenance and improve the cost–benefit ratio. However, this approach can cost more upfront (57) and raising the required funds may be a challenge for LICs. Furthermore, it may take a long time to change design standards and get them approved.

2.4.2.3 Operational costs

One of the ways in which transport infrastructure may need to be adapted is to meet comfort requirements for workers and customers. Higher temperatures, for example, may increase the demand for cooling, including through installation of air conditioning (45). Similarly, there may be higher demand for cooling when transporting perishable goods, such as fresh produce, to prevent them spoiling. This would increase operational costs due to higher energy demands. Pertinently, an additional consequence would be an increase in GHG emissions.

2.4.3 Socio-economic impacts

A large proportion of LIC populations live below the poverty line. Accessing opportunities to escape poverty and increase quality of life are dependent on access to an infrastructure that can facilitate this. Lack of access to transport means people cannot commute to work, which is directly linked to loss of economic opportunities and productivity. It also can result in restricted access to social services and facilities such as health and education.

2.4.3.1 Economic impacts

In rural areas, there is a high need for transport as communities are widely distributed. Rural areas also often have a high dependency on agriculture and farming. Transport is essential to move resources and produce, so any loss of access to transport due to an extreme weather event could have major consequences from a livelihood perspective. On the other hand, in urban areas and regions with a high population density, any disruption to transport has a great effect on more people, leading to wider-felt disruption and possibly larger-scale financial consequences. Service hubs become less accessible and economic impacts are greater than in rural areas.

In relation to transport, many LICs depend on imports, such as fuel or produce from other countries. It is therefore in the best interests of LICs to have well-maintained transport networks in order to avoid serious financial losses. Coastal areas with ports or connecting transport infrastructure are particularly at risk, as their role in the global trading system is significant – more than 80% by volume and 70% by value of global merchandise is traded by shipping (60). This is a critical threat for SIDS as they could face severe coastal flooding even under a low emissions scenario by 2030 (61). Furthermore, given the concentration of population, infrastructure and services in coastal areas associated with ports, the scale of impacts from weather and climate change could result in large economic losses. These losses may be higher in coastal countries across sub-Saharan Africa, as their total trade, as a share of GDP, is higher than those inland and compared with other coastal countries worldwide (62).

According to calculations by the World Bank, under a future drier climate, LICs in Africa and South Asia face large economic losses in GDP, but this may be regularly distributed over time. For example, in Ethiopia, this is expected to be 6% to 10% of GDP (63). In contrast, under a wetter climate, GDP losses accelerate after 2030 because of the costs of coping with climate impacts. South Asia may face higher costs of adaptation compared with sub-Saharan Africa under a dry climate scenario (63). Therefore, the economic impacts on LICs are potentially diverse dependent on how the climate changes and the differentiated vulnerabilities.

Cascading effects from transport into other sectors and geographies (interdependencies; see Section 2.3.2) may also magnify the broader economic damage of climate-related disasters (54).

2.4.3.2 Social impacts

Migration

There are strong links between human and natural systems. In response to extreme weather events or longer-term shifts in weather patterns caused by climate change, the movement of people via migration or displacement is likely to increase (23). Drought is a particular hazard for rural populations dependent on rain-fed agriculture. The response of agricultural workers to drought, for example, may be to seek similar work in a similar or neighbouring area, or to find new work opportunities elsewhere, such as in a city – whether temporarily, seasonally or permanently. Ultimately, this presents a significant risk of lost agricultural productivity and a reduction in associated employment (23). Lost agricultural productivity reduces food security for those who are unable to migrate, such as the elderly (64) or other vulnerable groups, and any employment reduction can negatively impact GDP. Migration can also put pressure on both local transport systems and those in the areas to which they migrate, particularly when migration is sudden or affects many people.

Gender inequality

In LICs, climate change is unlikely to affect all members of all communities equally. Women's contributions to work and familial duties differ from those of men, for example. Some of these responsibilities may include maintaining household food security and caring for the elderly or sick (65). As a result, women's travel behaviours also differ from those of men. Women are more likely to work closer to home and/or have more complex journey patterns due to taking children to school, shopping or visiting clinics (66). When women's access to transport is compromised, they may lose access to resources and services such as food and medicine, which can have significant societal consequences and may also affect women's safety. Climate adaptation can be an option to address these structural inequalities.

Public health

Public health infrastructure in LICs is often overburdened. Any loss of transport infrastructure exacerbates the challenges people face in accessing health services, particularly for emergency service callouts.

Extreme weather events increase the risk of injury or accidents, and it is likely that people will face additional climate hazard exposures in the event of disruption to public services. For example, if an extreme weather event causes public services to be suspended, the only alternative may be to walk. This may elevate heat exposure during a heatwave or increase exposure to water-borne diseases in the event of a flood.

Such risks extend beyond commuters. These events can also have health and safety implications for staff, such as heat-induced fatigue of infrastructure maintenance workers or drivers, which in turn increases the likelihood of accidents (67).

Education

If children's access to school is negatively impacted, it disrupts their education. Roads greatly influence where schools are built (66) and school attendance is therefore affected if disruption to transport is severe or recurring. Those in poor and rural areas, due to isolation by distance, terrain and poverty, are more likely to be adversely affected, as their transport services are already limited.

2.5 Benefits of climate change adaptation for transport infrastructure

There are predicted long-term benefits for LICs if they adapt to climate change. The Global Commission on Adaptation names the main multiple benefits of adaptation as the "triple dividend" (68):

- **Avoided losses:** The ability of the investment to reduce future losses;
- **Economic benefits:** Through reducing risk, increasing productivity and driving innovation through the need for adaptation;
- **Social and environmental benefits: H**arder to quantify but are non-market benefits of adaptation such as the protection or enhancement of other habitats, particularly through nature-based solutions.

The successful implementation of a resilient transport infrastructure supports the achievement of many indicators of the SDGs, as shown in Table 5. One of the measurable SDG indicators most relevant to the transport sector for LICs in Africa and South Asia is 9.1.1: the "proportion of the rural population who live within 2km of an all-season road" (2). This is measurable using the Rural Access Index (RAI), which is a percentage in terms of the SDG indicator 9.1.1. It is a strong, clear and consistent indicator across countries. The RAI scores among the 18 countries in Africa and South Asia assessed by the World Bank range from 11.4 (Madagascar) to 86.7 (Bangladesh) (69).

An economic example for sub-Saharan Africa estimated that the costs of adaptation were 0.6% to 0.7% of GDP between 2010 and 2020, falling to about 0.5% of GDP in 2040 to 2050 (63). Modelling also suggests that delaying infrastructure resilience actions is likely to increase costs (70). The challenge remains that the developing world faces a deficit in investment in infrastructure that is greater than the level of available global foreign assistance, and this is not expected to change significantly in future (71). Furthermore, if sufficient investment was made in the maintenance of this infrastructure (in both resources and operations), substantial savings would be possible – amounting to up to a 50% reduction in the total lifecycle cost of transport infrastructure (72,73).

More resilient transport systems may also support LICs in driving down poverty. Rain-fed agriculture is a major part of LIC economies and is linked to their food security, so having the infrastructure in place to facilitate it is critical. The right infrastructure can help with the selling of agricultural products throughout the year. Any road infrastructure improvements that improve access to local and international markets are likely to boost the competitiveness of products in regional and international markets (74).

Table 5: List of SDG targets for which transport resilience has the strongest impact

Resilience	Sustainable Development Goal indicator
Socio-economic resilience	1.5: Build resilience to climatic events and environmental shocks
	8.9: Promote sustainable tourism
	9.1: Develop resilient infrastructure for human well-being
	9.a: Facilitate resilient infrastructure in developing countries
Resilience to global shocks	3.3: End epidemics and combat communicable diseases
	3.d: Strengthen capacity for early warning and management
	11.5: Decrease economic losses cause by disasters
	11.b: Develop holistic disaster risk management strategies
	13.1: Strengthen resilience and adaptive capacity to climate-related hazards
	13.2: Integrate climate change measures into national policies, strategies and planning
	13.3: Improve education and capacity on climate change adaptation and early warning

Source: Adapted from SLOCAT (75)

2.6 Mechanisms to support climate change adaptation

There are many mechanisms available for stakeholders at all levels to inform and support their activities relating to climate change adaptation. They can range from high-level policy documentation, which may vary from country to country, to tools that focus on specific climate impacts and areas of transport infrastructure, such as a tool that maps flooding against highway infrastructure.

2.6.1 Policy and strategy

In the context of climate change adaptation, both policies and strategies provide guidance to relevant stakeholders to enable them to pursue and achieve adaptation and resilience targets. A policy lays out fixed principles and rules, whereas a strategy sets out planned actions with more flexibility. In the scope of this report, policies and strategies are considered together, as both are key documents communicating national government positions and goals.

2.6.1.1 International policy and strategy

It is in the interest of all nations to work together to combat climate change. The document that contains the greatest international commitment regarding climate change is the Paris Agreement. This is a legally binding international treaty on climate change, currently ratified by 191 of 197 Parties (which are primarily countries). Its core goal is to limit warming to no more than 2°C above pre-industrial levels. NDCs, which include national climate plans, are at the heart of the Paris Agreement and Parties are invited to communicate their plans and progress on climate actions every 5 years.

The Paris Agreement has a dedicated section on climate change adaptation. Article 7 outlines the goal for adaptation as “enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development”; this does not compromise any GHG mitigation efforts (4). Article 7 advises Parties to submit their progress on adaptation periodically to the United Nation’s Framework Convention on Climate Change (UNFCCC), which could be done in the form of a NAP.

Article 7 of the Paris Agreement also mentions how adaptation action should take a transparent approach and involve a wide range of local stakeholders, which supports knowledge sharing, particularly at a local level, and recognises the importance of international co-operation.

Additionally, the Paris Agreement refers to the Cancun Adaptation Framework. This framework provides Parties with a range of adaptation-related work streams, work programmes and specialised groups and committees (76). It provides support for less developed countries, including developing NAPAs to help LICs identify priority adaptation activities.

The Sendai Framework for Disaster Risk Reduction includes climate change as one of the drivers of disaster risk. The expected outcome of using the framework is a “substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries” (77). The Sendai Framework document supports nations to develop disaster risk reduction plans.

2.6.1.2 National policy and strategy

NDCs and NAPs can facilitate adaptation commitments for transport on a national scale by providing a country-led direction towards their adaptation goals. They give insight into the knowledge pertaining to climate change in African and South Asian LICs, their adaptation implementation plans and monitoring and evaluation processes, and the institutional and financial capacity available or required to meet their goals.

LICs would benefit greatly from NAPs that include infrastructure, particularly transport. This is because these plans raise awareness and encourage adaptation to be incorporated into existing institutional processes as opposed to independent projects. In Europe almost every country has a NAP or national adaptation strategy (78). In contrast, many LICs are still developing their NAPs, although the number with NAPs is expected to increase steadily (79).

However, many NDCs and NAPs do not mention transport adaptation. According to the Tracker of Climate Strategies for Transport (80), where transport adaptation measures are included, they can be categorised as:

- Structure and technical;
- Informational and educational;
- Institutional and regulatory;
- Other adaptation measures.

NDCs, particularly first submissions, did not include much information regarding transport adaptation across all countries. However, more recent submissions focus on transport adaptation. The new (second generation) NDCs include 65 adaptation measures for transport from 15 countries, most of which (46%) refer to structural and technical adaptation. Twenty measures focus on infrastructure resilience improvements, eight on design standards and seven on disaster information systems (81). The Tracker did not record any long-term transport adaptation strategies in NDCs submitted by LICs.

The effectiveness of leadership is a factor in raising the profile of and commitment to climate change adaptation in LICs. As shown in Case Study 1, the engagement of top political leadership heavily influences the development of national adaptation planning, which cascades down to sectoral plans including transport and other LIC interests.

Case study 1. Leadership-driven national policy design in Ethiopia

Ethiopia is the second most populous nation in Africa and the fastest-growing economy in the region. It has an ambitious aim to reach middle-income status by 2025 while developing a green economy (40,82) through its Climate-Resilient Green Economy (CRGE) strategy, published in 2011. Among LICs, this is an uncommon example of policy development in the area of climate mitigation and adaptation, particularly given that its formation took place prior to the Paris Agreement. Ethiopia's approach of using green growth as a driver and resilience as an outcome was considered unusual by the international community (83).

Ethiopia's top political leadership was considered a key force behind this national prioritisation of climate change (84). In 2009, the Prime Minister of Ethiopia, Meles Zenawi, was appointed as Chair of the African Heads of State and Government on Climate Change and subsequently played an important role in developing the African Union's position on climate change. As a result, Ethiopia's profile gained a significant boost; it quickly became a key player in the UNFCCC process and the size of its national delegation increased significantly at the 15th Conference of the Parties (COP15) in Copenhagen (compared with COP14).

Zenawi took it upon himself to take a deep dive into material on climate change. Ethiopia's centralised, technocratic leadership fostered greater institutional capacity so "the political will at the top [led] to institutional setup" for Ethiopia (83).

Zenawi approached the Ethiopian Development Research Institute (EDRI) to investigate the country's needs regarding mitigation and adaptation. The EDRI, in turn, approached the Global Green Growth Institute (GGGI), a South Korean organisation that collaborates with governments on low carbon growth strategies and capacity building. The GGGI reported significant potential for Ethiopia and the outcomes were well received by the Ethiopian Government. As a result, consideration of climate change grew across the country's ministries, leading to the creation of a Ministerial Steering Committee as a cross-sectoral policymaking body with the remit to develop a national response to climate change (84). The outcome was Ethiopia's CRGE strategy.

Consultants drafted the CRGE strategy in collaboration with GGGI and local experts from government, civil society and academia. CRGE implementation included extensive consultation with governmental and public stakeholders and selected experts from academia (82). However, local civil society groups criticised the Ministerial Steering Committee responsible for coordinating and delivering the national response to climate change for excluding their input in the policymaking process (84).

In the CRGE strategy, transport is one of the four pillars identified to foster development and sustainability. This mainly comes from a stance of mitigation, as the focus of this pillar is on a reduction of GHG emissions. However, the rationale is that, from a socio-economic stance, improved energy efficiencies in cooking facilities and transport would lead to savings in household income, resulting in improved domestic investment capacity (82). Leading on from this strategy came the Climate Resilience Transport Sector Strategy (63), which is aligned to the CRGE vision.

Following the death of Meles Zenawi in 2012, Ethiopia continued to prioritise climate action. It was the first LIC to submit its intended NDC (85). As a result, other LICs in Africa have approached Ethiopia to help them replicate the CRGE strategy for their own countries because of a desire for a strategic model that pursues sustainable development while remaining resilient to climate change.

2.6.1.3 Subnational policy and strategy

For transport, subnational policies and strategies may focus on a specific sector, transport mode or location, such as an urban centre. This scale of strategy would be best derived from a national strategy, such as in Case Study 1. However, subnational strategies and policies are not common in LICs, and climate change adaptation may only form part of the plans.

Recent rapid urbanisation, particularly in Africa, has focused on the largest cities (86): therefore these may be the only areas where LICs could prioritise subnational strategies due to capacity challenges. Conversely, the benefit of subnational plans is that best practice from them can be exchanged, because cities in a similar region may have similar infrastructure challenges, resources and governance structures (87).

2.6.2 Standards

The International Organization for Standardization (ISO) provides guidance on standards across a multitude of organisational processes and is widely recognised globally. Many ISO standards support practices related to climate change adaptation and resilience, such as:

- ISO 9000 family – Quality assurance;
- ISO 14000 family – Environmental management;
- ISO 22316 – Security and resilience;
- ISO 26000 – Social responsibility;
- ISO 31000 family – Risk management.

ISO 14090, published in 2019, is part of the ISO 14000 family on environmental management and is entitled "Adaption to climate change – Principles, requirements and guidelines" (10). **ISO 14090 is the first international standard on climate change adaptation** and uses terms and key concepts largely adapted from the IPCC. ISO 14090 provides guidance for organisations of any size and type, regardless of the scope of adaptation. It does not provide specific requirements but instead is focused on how to mainstream and embed climate change adaptation into an organisation's processes, rather than it being a standalone activity.

British Standard BS 8631 "Adaptation to climate change – Using adaptation pathways for decision making" (88) is linked to ISO 14090, which mentions adaptation pathways as an effective approach to planning for climate change uncertainty. Adaptation pathways can be used within adaptation planning to develop more flexible, long-term responses, incorporating long-term visions and helping to facilitate planning for multiple possible future scenarios.

Another climate change-related ISO standard relevant to LICs in Africa and South Asia is under development. This is the proposed ISO 14093 "Mechanism for financing local adaptation to climate change: Performance-based climate resilience grants" (89). This standard would support governments, such as those in less developed countries, to channel climate change financing from national to local level (90).

For built infrastructure, such as roads, rail and bridges, some LICs in Africa refer to design standards used by HICs (91). However, depending on their age, these standards may be less relevant now than when they were created, particularly as LICs' understanding or awareness of the impacts of climate change on transport may only be recent.

LICs may also face financial barriers in meeting certain standards, for example if the standards require updating to increase resilience to climate change. It is important to consider the predicted frequency and intensity of the most extreme weather events to support overarching design standards (92), but the implied changes could be a significant barrier for LICs in terms of resources and finances to deliver updated, climate-resilient transport infrastructure design standards.

2.6.3 Adaptation tools and frameworks

There are many tools and frameworks readily available online related to transport adaptation to climate change.

In the context of climate change adaptation for transport resilience, a tool is an instrument that is utilised by transport stakeholders to gather information, data or results relevant to the adaptation planning process to support decision-making. A framework is a conceptual process to guide adaptation planning, but it does not provide results. Both serve the purpose of supporting the development of effective planning processes and selection of appropriate measures and strategies for adaptation.

2.6.3.1 Tool and framework characteristics

Tools and frameworks are classifiable by many characteristics, such as: purpose; scope target group; the functions they perform; and suitability at different steps in adaptation planning (93,94). Table 6 summarises the diversity of available tools and frameworks.

Many tools and frameworks cover multiple climate change impacts, sectors and adaptation processes, thus provide a holistic level of support to stakeholders. Therefore, their strength lies in their applicability,

scalability and transferability. However, to be fit for purpose, the scope of a tool or framework should be specified and reflected in its design. Stakeholder engagement and benchmarking exercises can help improve the efficacy of frameworks and ensure that they successfully address the challenges for which they are designed.

Table 6: Classification of adaptation tools and frameworks for transport

Categorisation	Examples
Purpose	Informative guidelines, methodologies and assessments, software
Target group	Designers and engineers, operators and managers, planners and policy-makers
Geographic scope	Single state, multiple states, global
Vulnerable sector	Urban, transport, agriculture, energy, resources
Climate impacts	Flooding, heat, cold, storms, drought
Adaptation planning steps	Information engagement and scoping, vulnerability assessment, scenario building, adaptation planning, implementation and monitoring
Functionality	Visualisation, modelling, decision support

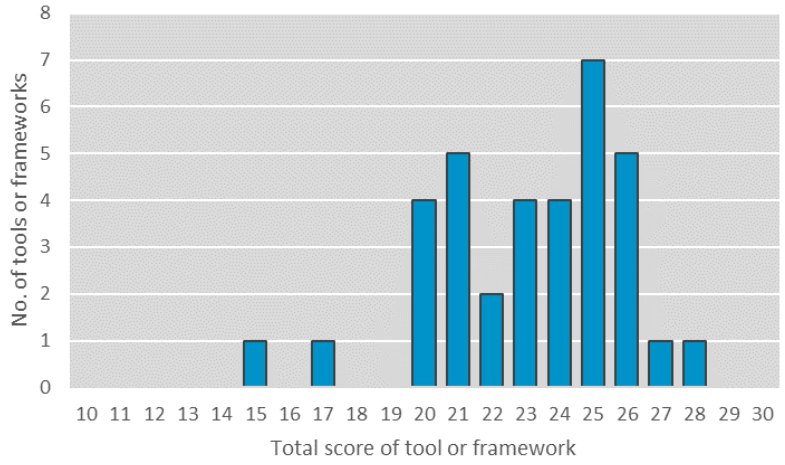
Source: Adapted from Lykou et al. (93)

2.6.3.2 Assessment of tools and frameworks

Thirty-five tools were assessed as part of this project. These ranged from global climate data visualisation tools such as the IPCC Interactive Atlas (95), which supports spatial and temporal analyses of climate change variables for many applications, to those that offer adaptation decision-making support to an individual infrastructure operator, for example the World Association for Waterborne Transport Infrastructure (PIANC) Climate Change Adaptation Planning for Ports and Inland Waterways (96). Section 1.4.2.3 provides the methodology for tool and framework assessment and Appendix E lists the tools and frameworks reviewed. “Score” in this context refers to the MCA rating according to the principles designed by Cash et al. (11). The total score refers to the sum of each tool or framework MCA, with a possible maximum score of 30.

Figure 5 shows how many tools and frameworks scored a particular amount. The lowest score was 15 out of 30, the highest score was 28 and the most common score was 25. Two scored between 15 and 19, 19 scored between 20 and 24, and 14 scored between 25 and 30. Most of the highest scoring tools were focused only on one step within the adaptation planning process (nine of the 14 that scored between 25 and 30).

Figure 5: Total score of tools and frameworks according to the six criteria designed by Cash et al. (11)



The tools and frameworks were divided into three main purposes. Twelve were informative guidelines, 13 were methodologies and assessments, and 10 were software. Figure 6 shows the mean scores of each measurement criteria according to these three purposes. The highest scores were for credibility (making clear

reference to the range of scientific sources used). The tools and frameworks also scored highly for translation, suggesting that the language used was often clearly defined and relevant to transport stakeholders. Tools and frameworks that focused on methodologies and assessments scored the highest for translation.

Scores were lowest overall for legitimacy and communication. Notably, scores for software tools and frameworks showed an inverse trend in these criteria compared with those of other tools and frameworks; the former scored higher for communication relative to legitimacy, whereas other tools and frameworks scored lower in communication relative to legitimacy. The higher scores for communication could be because providers of some software-driven tools and frameworks (of which the highest scoring are at a local scale) consulted with transport stakeholders in the design process and/or are available for support while their tool is being used. Conversely, the lower scores for legitimacy could be because software can require training or technical input from the user, and LICs may lack the capacity in time or resources to train users.

Figure 6: Mean scores of criteria by purpose of tools and frameworks

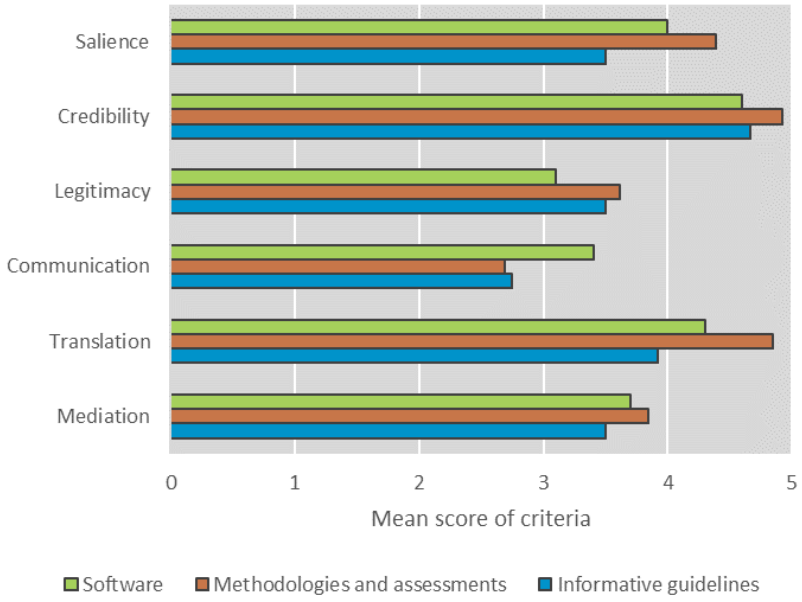


Figure 7 shows the difference in mean scores of tools and frameworks by target group and functionality. Those best suited to operators, managers, planners and policymakers were rated similarly.

Salience scores were highest for tools and frameworks best suited to operators and managers, which is likely to be because they are mode-specific, making them directly relevant to transport stakeholders. On the other hand, legitimacy, translation and mediation scores were highest for tools and frameworks best suited to planners and policymakers – those whose guidance is broader in scope, which benefits multiple transport stakeholders, with clear language suitable for planners and policymakers and explicit consideration for LIC capacities, challenges and culture. The types of tools and frameworks that scored highest in legitimacy, translation and mediation for planners and policymakers vary in content, but primarily provide decision support at different stages of the adaptation planning process. Only one of these tools scored 5 across all three criteria; this one supports the process of writing proposals to access the Green Climate Fund.

There is a divergence in the scores for translation for tools and frameworks primarily aimed at designers and engineers as opposed to other target groups. These are all software focused and include a local geographic scope, and are therefore likely to be quite technical, which would have an impact on translation. Additionally, only three tools/frameworks were classed as appropriate for designers and engineers, which could affect the overall mean scores.

The mean scores differ when grouped by functionality. In Figure 7, decision support tools and frameworks scored higher than modelling and visualisation ones. Salience scores, in particular, were higher for the former, as these types of tools and frameworks include those explicitly focused on certain modes of transport, which drives up the score in terms of relevance for transport stakeholders.

Translation scores were highest in decision support tools and frameworks. Those that had a high overall score, including a 5 in translation, are all primarily aimed at planners and policymakers, but none are transport-specific.

Figure 7: Mean scores of criteria by target group (left) and functionality (right) of each tool or framework

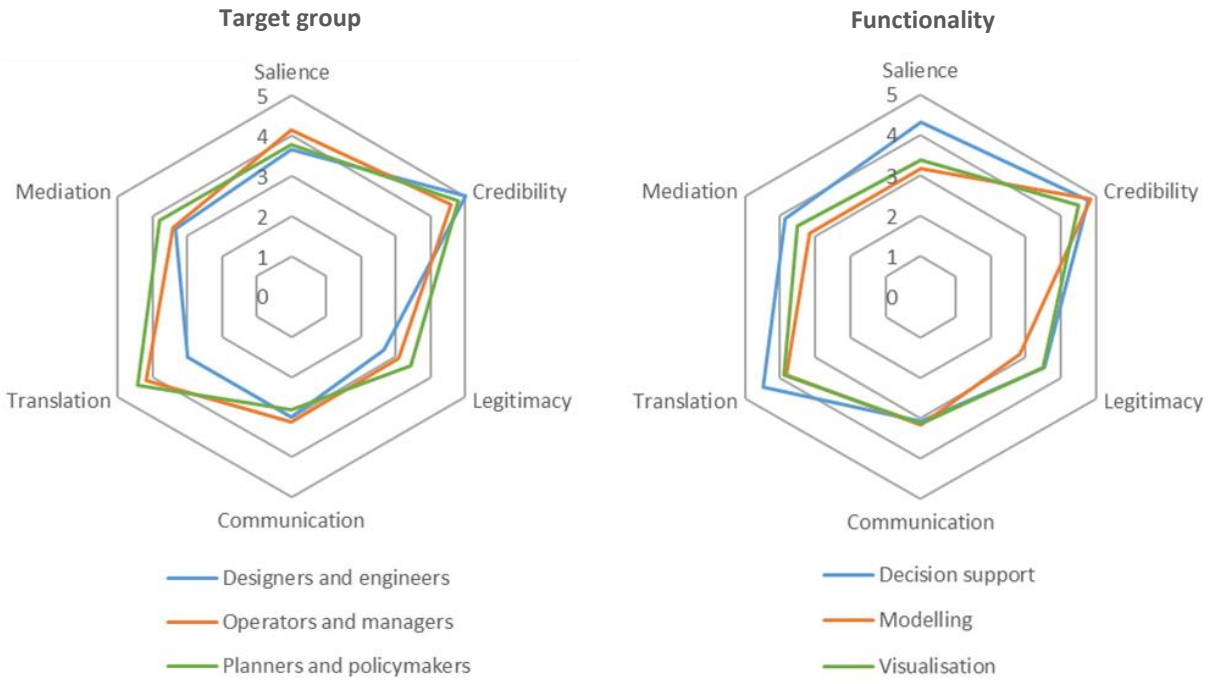


Figure 8 shows how the tools and frameworks compared according to the stage of the adaptation planning process they are aimed at. It shows that those aimed at scenario building scored lowest for almost all the criteria. They scored lowest for communication and mediation, which suggests that they are not designed in a way that benefits multiple transport stakeholders, or that the providers did not engage transport stakeholders to assess their needs. Many of these tools refer to the RCP scenarios, which contributes to a high credibility score, but may have resulted in lower scores for other criteria because they are technical in content. Tools and frameworks are less suitable for transport stakeholders in LICs if their content is not explained in the appropriate context.

Figure 8: Mean scores of criteria by tool or framework's adaptation planning steps

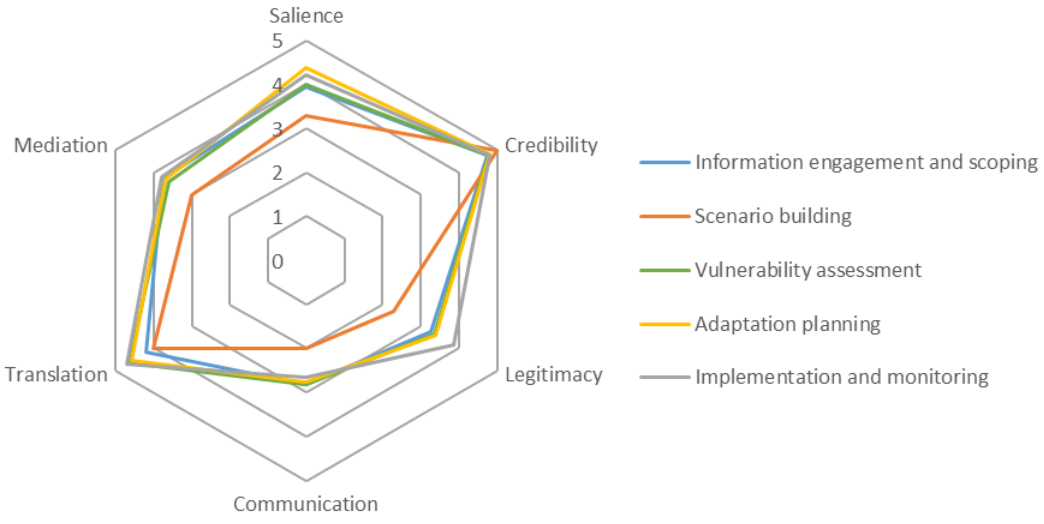


Figure 8 also emphasises how low all the tools and frameworks scored for communication relative to the scores for other criteria, regardless of which adaptation planning step they focus on. It infers that LIC

transport stakeholders may not have been involved in the development of tools or frameworks that would be explicitly fit for their purpose, or that there is little opportunity for them to get support from the provider of a tool or framework to enable them to use it to the best of their ability.

The transport mode-specific tools and frameworks scored similarly across the criteria and the scores were all the same and relatively high (25 out of 30). This is possibly because their intentions are similar in terms of process, with the same purpose (methodologies and assessments), target group (operators and managers) and functionality (decision support). Therefore, the processes they apply are similar, iterative, set out in stages and, in some cases, supported with case studies or document templates to guide the users. Case Study 2 demonstrates how using a framework supports an iterative process to standardise devolved plans and build improvements into it.

This assessment highlights the vast diversity in tools and frameworks, and therefore demonstrates the difficulties that LICs may face when considering which tool or framework to use to support processes in adaptation planning. Because each tool has different purposes, scales and target audiences, no single tool is effective at supporting all stages of adaptation planning. Providers of tools and frameworks will have had to trade off characteristics such as scale of detail (by reducing or generalising content or data) in order to maximise performance in order to increase the user base. Alternatively, providers may charge an additional fee to tailor a tool or framework to its user. Both trade-offs are disadvantageous to LICs in Africa and South Asia because they may not be able to access the tools and frameworks best suited to their needs due to lack of funds or capacity. In the interests of improving transport resilience, it is imperative that guidance in choosing suitable tools and frameworks for LICs is provided by groups, bodies or organisations working with transport stakeholders in LICs, and that tool/framework providers offer sufficient support to use them.

Case study 2. Iterative climate change adaptation processes in the transport sector: Network Rail's Weather Resilience and Climate Change Adaptation Plans

In the UK, under the Climate Change Act 2008 (97), the Government has the power to ask certain organisations to produce reports on their progress to adapt to climate change. This applies to organisations responsible for essential services and infrastructure, which includes transport. Currently, the UK Government is in the process of its third round of reporting.

Network Rail, Great Britain's national railway infrastructure owner and manager, has developed a Weather Resilience and Climate Change Adaptation (WRCCA) policy (98) and strategy (99). It uses the WRCCA strategy to publish its adaptation reporting to the UK government.

The WRCCA strategy provides Network Rail's framework for adaptation and resilience activities within the organisation and engagement with external stakeholders, such as third-party landowners and academia. The stages within the framework broadly align with other mode-specific adaptation frameworks; however, Network Rail has also demonstrated how an overarching WRCCA policy can be applied to specific areas of its business.

WRCCA Route Plans that are set out in accordance with geographic areas of Network Rail's business, or Routes, are supported by the overarching strategy document. There are eight Route Plans, all structured in the same way, which detail the five-year adaptation plans. The most recent publications are the second round of WRCCA documents, covering 2019 to 2024, which aligns with the budgetary and management cycle of the business.

A review of the second WRCCA Route Plan documents (100) highlights that climate-resilient planning within the organisation is relatively high in maturity compared with other rail sectors internationally, but requires implementation and alignment into asset management, as well as more clarity regarding monitoring processes, such as reviewing the use and type of metrics and indicators. The outcomes of this review emphasise the benefits of using a framework to identify the opportunities for improvements in the iterative process for the next round of adaptation planning.

2.7 Conclusion

LICs in Africa and South Asia are likely to experience severe consequences of climate change relative to other parts of the world. This is in part due to the sensitivity of their geographic location (for example their

topography or climate zone) and their dependency on natural resources as a core function of income and livelihood. The evidence, notably from the last decade, shows that climate change is already occurring in these regions with severe consequences, particularly damage caused by flooding and drought. Climate projections for these regions point to a major risk caused by variability in precipitation, its intensity and shifts in seasonality, emphasising the extent to which LICs in Africa and South Asia are vulnerable.

The resilience of infrastructure is difficult to measure quantitatively. However, building resilience is an iterative process and as climate changes, so will the extent of resilience and the capacity to adapt. As just one of the infrastructure sectors, transport cannot be made more resilient independently because there are interdependencies with other sectors such as ICT and energy. For rapidly urbanising areas in LICs in Africa and South Asia, this is a particular vulnerability and a key reason to prioritise transport resilience. For rural areas, transport resilience is important due to the limited transport options available and potential lack of investment in maintenance in the past.

The range of possible hazards that climate change can cause for transport infrastructure are broad and the impacts can be far-reaching, with major socio-economic consequences. As a result, maintenance schedules and design standards need to be reviewed to reduce the likelihood and extent of damage to infrastructure – damage that may increase the potential for disruptions and incur increased costs over time the longer adaptation actions to improve resilience are delayed. The challenge is that LICs have financial constraints, so it is critical that money available to them is allocated appropriately to maximise transport resilience through climate change adaptation. PIARC, for example, are taking such issues into account as they are currently assessing uniform and holistic methodological approaches to climate change and other hazards in its Technical Committee 1.4 Climate Change and Resilience of Road Networks, with the inclusion of risk management approaches and socio-economic impacts of hazard on roads.

Many mechanisms exist to support LICs in Africa and South Asia. Policies, standards, tools and frameworks are available to decision-makers to structure the processes towards the best options for transport adaptation to climate change. These mechanisms have similar concepts and goals, and it may be difficult for LICs to select the most appropriate methods due to lack of capacity. The extent of leadership involvement and engagement on the issue of climate change is important, as this can have a significant impact on exposure, publicity and, ultimately, actions.

3. Ambitions to achieve transport resilience in LICs in Africa and South Asia

3.1 Overview

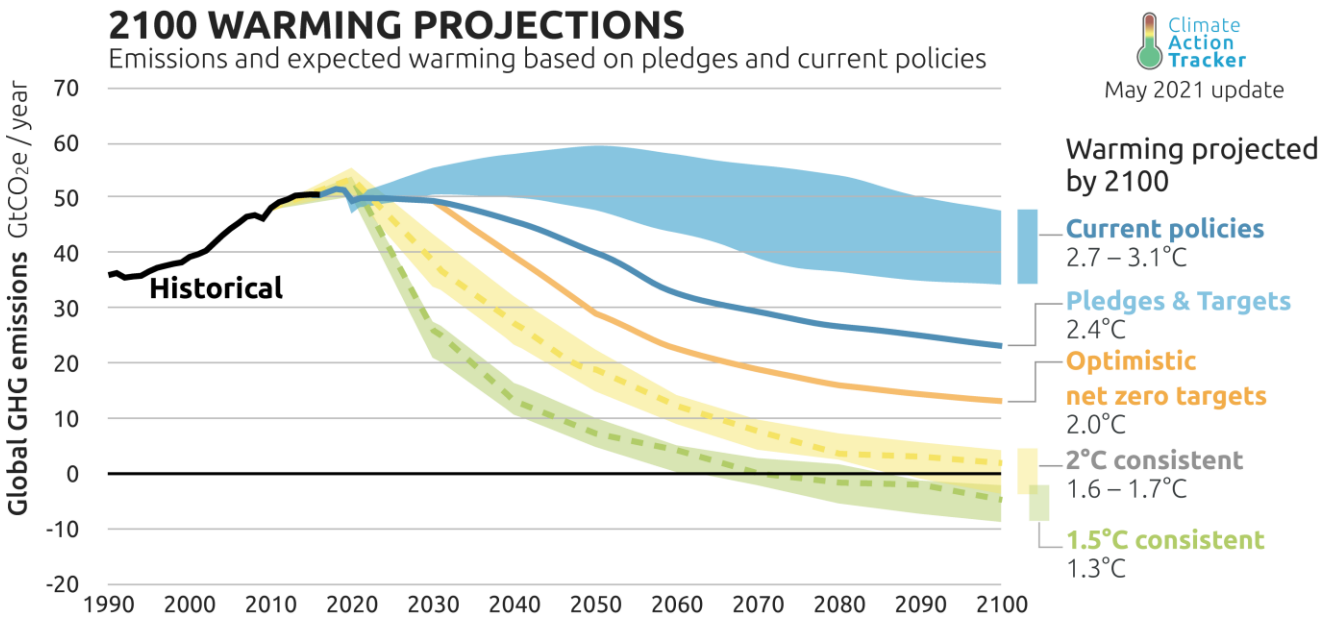
This section investigates the extent of current and planned activity on transport resilience and climate change adaptation in LICs in Africa and South Asia. It includes the outcomes of reviewing literature, government publications and interviews with stakeholders.

3.2 The magnitude of required ambition and actions

The extent to which climate adaptation is required depends strongly on the level of GHG emissions. The Paris Agreement set a goal of 1.5°C warming (shown in green in Figure 9) and no more than 2°C (shown in yellow). However, existing global pledges and targets (blue line) exceed both of these. Current policies around the world (blue shaded area) would not even meet these pledges and targets.

The evidence to date indicates that climate change is having measurable effects and that there is a risk of irreversibility in the climate system if the global mean surface temperature rises further (12). As such, the ambition to adapt to climate change may grow significantly.

Figure 9: Warming projections up to 2100 based on pledges and current policies (101)



3.3 Commitments on climate change adaptation

As per the Paris Agreement, pledges to enhance adaptive capacity are part of the NDCs that Parties to the Agreement are invited to share once every five years with the UNFCCC. NDCs have been submitted by 192 Parties (79 first NDCs and 113 new or updated NDCs). Of these, 151 Parties included climate adaptation in their most recent NDC submission, but only 21 included adaptation measures relating to transport.

Parties in sub-Saharan Africa and South Asia all mention adaptation in their most recent NDCs. Notably, most of the 21 NDCs that include transport come from Parties in the Africa and South Asia regions (102).

3.3.1 Transport adaptation NDC commitments in LICs in Africa and South Asia

Table 7 shows details from the NDCs of LICs that include specific transport adaptation measures in Africa (note: none are from South Asia). These measures are conditional, or partly conditional, on other factors, the primary one being access to adaptation finance. Some of these NDCs identify financing through sources that include the private sector and bilateral and multilateral funds.

The extent of detail set out for transport adaptation measures in each NDC varies. Liberia and Malawi's updated first NDCs provide the most detail, incorporating disaster risk management and monitoring, cross-cutting strategies, SDG alignment, quantitative targets, estimated costs and ministerial/departmental responsibilities (103,104).

Table 7: NDCs by LICs in Africa that mention adaptation measures in the transport sector (102)

Country	NDC submission	Submission date	Conditional actions
Liberia	Updated first NDC	3rd August 2021	• Implement and reinforce design standards and planning codes for roads and other infrastructure to cope with flooding, sea level rise and windstorm; • Install signs high above the ground that can alert pedestrians and motorists of unsafe zones, such as low-lying areas; • Maintain and upgrade roads with appropriate drainage systems to cope with flooding; • Improve and enhance public transport services.
Malawi	Updated first NDC	29th July 2021	• Construct infrastructure for flood control, transport, etc.
Madagascar	First NDC	21st September 2016	• Updating transport codes and regulations and implementing measures to ensure compliance with them; • Updating of risk assessment guidelines.
Togo	First NDC	28th June 2017	• Development and improvement of roads in main urban centres.
Uganda	First NDC	21st September 2016	• Updating transport codes and regulations and implementing measures to ensure compliance with them; • Updating of risk assessment guidelines.

3.4 Current adaptation policy and strategy

As discussed in Section 3.3, many countries across Africa and South Asia submitted NDCs that included adaptation commitments, with some in Africa including a focus on transport adaptation. The extent of this engagement from LICs may be due to the support they historically received through the Least Developed Countries Expert Group (LEG), established in 2001 under the UNFCCC.

The LEG provides technical support for the least developed countries to formulate and implement NAPs. The development of NAPs predates NDC submissions, but there are links between the two, which are mutually reinforcing; in particular, they overlap at the stage of identifying adaptation priority needs and sectoral analysis (79).

3.4.1 Assessment of national adaptation plans, strategies and plans of action

LICs in Africa and South Asia are at different stages of development in their adaptation plans. By 31st March 2021, 22 Parties supported by the LEG had submitted NAPs. Five of these NAPs are from LICs or LMICs in Africa or South Asia; these are published in English. Many other LICs in these regions have submitted NAPAs and are now developing NAPs.

For this project, 18 national documents pertaining to climate change adaptation (seven NAPs and 11 NAPAs, including the five NAPs mentioned above) were assessed. (See Section 1.4.2.2 on the methodology for policy assessment and Appendix C for the list of documents reviewed.) "Score" in this context refers to the MCA rating for a NAP or NAPA section, according to the ISO 14090 guidelines. The total score refers to the sum of each NAP or NAPA MCA, with a possible maximum score of 25.

Figure 10 shows the total scores for each document, including a breakdown of each criteria score. Burkina Faso's NAP scored the highest (23 out of 25; see Case Study 3), whereas Tanzania, South Sudan and Maldives' NAPAs scored lowest (11 out of 25). Six NAPs and NAPAs scored between 10 and 14, nine scored between 15 and 19 and three scored between 20 and 25.

Figure 10: Score of each NAP and NAPA assessed according to the five ISO 14090 criteria

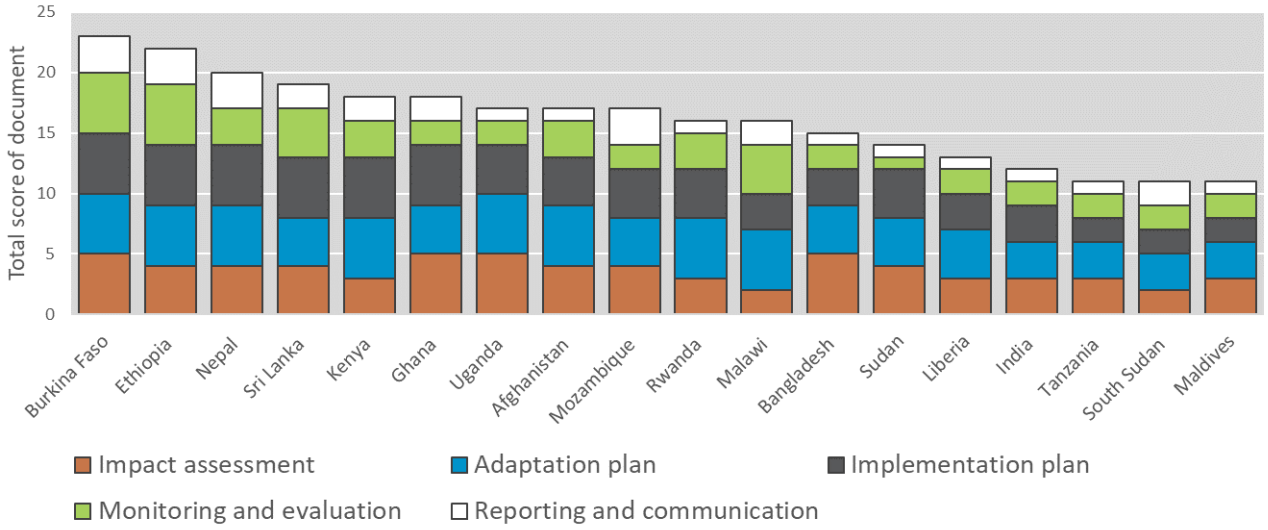


Figure 11 shows how each NAP and NAPA scores against the ISO 14090 guidelines, plotted by year of publication. The trend over time, as shown by the dotted line, indicates that NAPs and NAPAs in Africa and South Asia have improved in terms of alignment to ISO 14090 guidelines. However, the correlation is quite weak, as shown by the coefficient of determination (R^2). Improvements in NAP and NAPA scores are not dependent on time itself but are more likely to be linked to improvements in knowledge or capacities, as shown by an improved alignment to the ISO 14090 guidelines. The greatest positive and negative deviation from the trend line are in 2015 (Burkina Faso) and 2016 (South Sudan) respectively.

Differences in each country's development from a social, economic or political stance could be a contributing factor for the deviations. For example, South Sudan is the newest country in Africa, having gained independence in 2011; it remains underdeveloped, so is at an earlier stage in the adaptation process and likely to have fewer resources or lower institutional and financial capacity to begin with.

Figure 11: Score of each NAP and NAPA assessed according to the ISO 14090 criteria, by year of publication

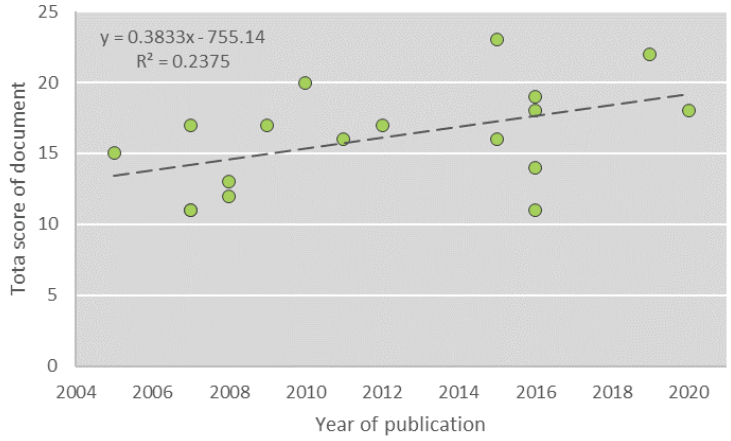
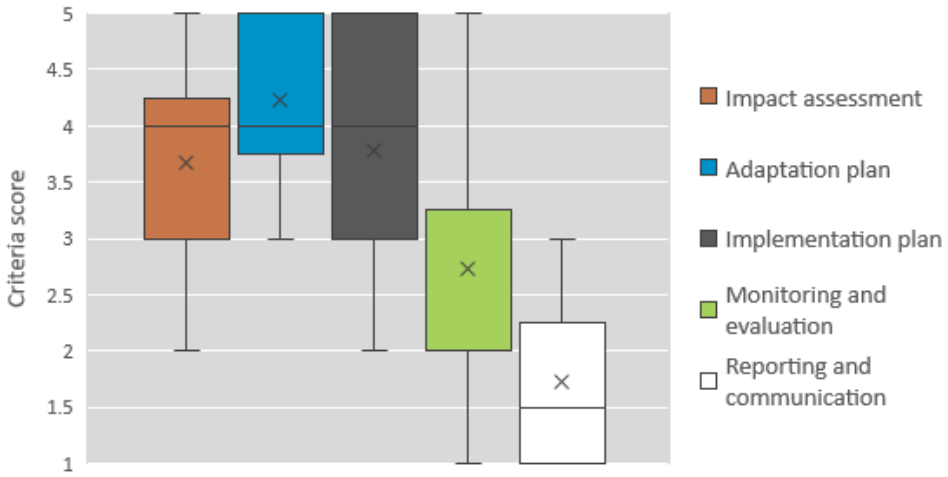


Figure 12 shows the range of scores for the NAPs and NAPAs for each of the criteria. The "x" marks the mean score of each of the criteria and the boxes represent their interquartile range. The subject area structure of most NAPs and NAPAs follows the order of the criteria shown from left to right, starting with an impact assessment of weather and climate and ending with monitoring and evaluation or reporting and communication of the adaptation plans put forward. The following subsections of this report evaluate each of the criteria in more detail.

Figure 12: Range of scores of each NAP and NAPA assessed according to five of the ISO 14090 criteria



3.4.1.1 Impact assessment

According to ISO 14090, the impact assessment in a NAP or NAPA should evaluate how an organisation's activities, products and services might be affected by climate change (10). The mean score for this criteria was 3.7, with scores ranging from 2 to 5. The countries whose NAPs/NAPAs scored highest (Burkina Faso, Ghana, Uganda and Bangladesh) considered aspects such as observed and projected climate, a range of weather and climate variables, spatio-temporal considerations, cross-cutting issues, sectoral breakdowns and vulnerability assessments. They used a combination of literature reviews, stakeholder engagement and supporting analyses from academia.

3.4.1.2 Adaptation plan

A NAP/NAPA's adaptation plan describes the range of potential actions that address the country's adaptation needs and priorities (10). For the combined reports, this criteria scored highest, with a range from 3 to 5 and a mean score of 4.2; eight of the NAPs and NAPAs scored a 5.

The methodologies each country has taken to create their adaptation plans vary. Examples include:

- Setting out programmes or projects by sector, each with a range of options to achieve them;
- Breaking down options by short-, medium- and long-term scales;
- Consultative processes with a range of stakeholders;
- Differentiating "big win" (may have the biggest overall impact) and "quick win" (may be easiest to action first, with impact) options;
- Shortlisting from multiple options using an MCA.

3.4.1.3 Implementation plan

The implementation plan refers to the way that adaptation plans are transformed into activities (10). The scores had the largest interquartile range of all the criteria and a mean of 3.8. The drop in the implementation plan mean score compared to that of the adaptation plan indicates there is a small gap in the countries' capacities to transition from planning into implementation.

Thirteen NAPs or NAPAs scored the same or lower for their implementation plan as they did for their adaptation plan. Compared with NAPs, a higher proportion of NAPAs scored lower for their implementation plans than for their adaptation plans.

The implementation plans covered a wide range of areas and institutional setups varied. Accountability for delivering plans was often allocated to one ministry or lead sector, with support from related ministries. Eleven of these NAPs and NAPAs explicitly linked to other national strategies, plans and/or policies to help streamline processes and implementation – these include climate change, development, poverty reduction

and other sectors. Mentions of funding also differed in extent, including identification of funding sources, estimated costs of activities and the body responsible for securing funding.

Not all NAPs/NAPAs mentioned stakeholder collaboration or engagement to support implementation. The role of leadership was also not always clear; only three countries (Ethiopia, Kenya, India) referred to their prime minister or president's accountability in adaptation, where they are chairs of councils on climate change.

3.4.1.4 Monitoring and evaluation

Monitoring and evaluation refers to assessing, informing and reviewing the adaptation plan so that satisfactory progress is made, and where unsatisfactory work is highlighted, corrective action can be taken (10). The mean score for this criteria is 2.7, with scores across the full range from 1 to 5, making it the most varied in its extent across the NAPs and NAPAs. Only two scored a 5, and 14 of the 18 NAPs and NAPAs scored lower for this criteria than for their combined mean score for the previous three criteria. This therefore appears to be an area where these countries lack capacity in delivery.

One recurring aspect of monitoring and evaluation across these documents was the lack of baseline setting or indicators to monitor progress. There is even explicit indication in some cases (such as Sudan) that there is a lack of system in place for monitoring and evaluation. Nevertheless, there are often references to high-level review of these documents, both internally and externally, over set periods of time (some NAPs mention five-year cycles).

Case study 3. Why does Burkina Faso's NAP score so highly?

Burkina Faso's NAP (105), published in 2015, scored highest of all the documents reviewed during the project, with a total score of 23 out of 25. It features some plans, activities and approaches that stand out due to the best practice principles they adopt:

Vision statement: "Burkina Faso intends to manage its economic and social development more efficiently by implementing planning mechanisms and measures taking account of resilience and adaptation to climate change between now and 2050." This statement emphasises the link between achieving adaptation and building socio-economic development as a reason to adapt.

Evenly distributed objectives by sector: No sector was overlooked when prioritising adaptation objectives. There was consideration of a wide range of options for each sector and prioritisation was based on development needs, climate change vulnerability and risk as opposed to cost.

Advanced data and tools: The University of Ouagadougou formulated mathematical climate modelling and risk analyses for the NAP. It considered three weather stations' data as representative of the three climate zones in Burkina Faso, providing an improved spatial scale for the impact assessment. Several senior Burkinabe civil servants from multiple ministries were trained on a multi-sectoral dynamic model, designed to help with long-term planning (79,105).

Continued stakeholder engagement: The term "stakeholder" or "stakeholders" occurs 85 times in the NAP. It also refers to a very wide range of stakeholders, including the state, technical and financial partners, private sector, civil society organisations and the international community. There is transparency regarding which stakeholders were consulted or contributed to the NAP.

Gender inclusivity: A women's association representative was consulted at the NAP's draft stage and the NAP sets out adaptation actions appropriate to vulnerabilities specific to women.

Clarity of monitoring and evaluation processes: The NAP sets qualitative indicators for every adaptation objective. In addition, the implementation strategy specifies performance indicators, data sources and risks for each strategic priority. The NAP performance plan sets out data collection methods and collection frequency for every strategic priority. The monitoring and evaluation methodology contains a template used for monitoring activities under the NAP.

Communication strategy: The NAP sets out the primary targets of communication and the channels it will utilise to cascade national adaptation information, including an emphasis on using national languages to disseminate information with a "mass and grass-roots basis" in mind, as well as international outreach.

3.4.1.5 Reporting and communication

Reporting and communication relates to the way in which climate change adaptation is communicated to external parties (10). The scores for this were the lowest of all the criteria in the NAPs and NAPAs, with a mean score of 1.7 and a range from 1 to 3. The lower scores are primarily due to these documents not explicitly mentioning a process regarding communication activity or scheduling, or regarding their format and maintaining integrity. Four NAPs and NAPAs scored a 3 and these featured:

- A specific communication plan or strategy that considers channels to disseminate information;
- Utilisation of an information dissemination platform;
- A multi-stakeholder climate change initiatives coordination committee, responsible for establishing, maintaining and improving communications among institutions.

3.4.2 Transport sector incorporation

Transport as a sector has not been a priority focus area for adaptation across all of Africa and South Asia, as demonstrated by a detailed review of NAPs and NAPAs in LICs and LMICs (see Section 1.4.2.2). Table 8 shows that while most of the reviewed NAPs and NAPAs incorporate transport in some way, they may not have a dedicated section or recurring mention throughout. NAPAs are more likely to mention transport, whereas NAPs are more likely to discuss it in more detail. By comparison, NAPs in HICs may have a greater focus on the transport sector. Some NAPs in HICs include a range of transport-specific action plans, such as in the UK (106) and Japan (107), which also separate measures by each mode of transport. In another example, Sweden's NAP (108) includes a dedicated sector adaptation plan for transport.

Table 8: Extent of engagement in NAPs and NAPAs regarding transport sector adaptation

Country	Does not mention transport	Mentions transport	Discusses transport
Afghanistan			x
Bangladesh		x	
Burkina Faso			x
Ethiopia			x
Ghana			x
India	x		
Kenya			x
Liberia		x	
Malawi		x	
Maldives		x	
Mozambique		x	
Nepal	x		
Rwanda			x
South Sudan		x	
Sri Lanka			x
Sudan		x	
Tanzania		x	
Uganda		x	

Where transport is mentioned, rather than discussed, it is often in relation to the impact assessment, and particularly concerns the vulnerability of roads due to their quality or condition and their role as a link to another vulnerable sector, such as agriculture or health. On the other hand, those NAPs or NAPAs that discuss transport are likely to refer to it as a sector, though in some cases it is integrated as part of a wider sectoral discussion, for example alongside energy or general infrastructure. These NAPs and NAPAs are more likely to include transport sector-specific adaptation plan options. For example:

- **Burkina Faso:** Construct public facilities and infrastructures (inclusive of roads) that are fit for purpose and resilient thanks to high quality design, implementation and proper maintenance (105);

- **Ethiopia:** Building a sustainable transport system, which includes reconstruction of climate-vulnerable transportation infrastructure (40);
- **Ghana:** Plant and manage vegetation along roads to decrease direct exposure to heat (109);
- **Rwanda:** Implement a multi-mode approach to urban transport to prevent dependency on a single mode (110);
- **Sri Lanka:** Establish an early warning and hazard communication system for commuters and managers of energy, transport and industrial facilities (111).

3.5 Current understanding of transport adaptation and activities

The project team carried out stakeholder interviews to identify the extent of knowledge, understanding and activities in LICs relating to climate change adaptation of transport infrastructure. Among the areas discussed were knowledge and experience regarding weather and climate change and their impacts, managing those impacts and financing future resilience plans.

3.5.1 Weather patterns as a result of climate change

The two key areas discussed in interviews around weather patterns and climate change related to the types of weather experienced in respondents' countries, and what data they access.

3.5.1.1 Observed changes in weather and climate

All the stakeholders interviewed had observed changes in weather and climate in recent decades, including:

- Many more cyclones per year (Bangladesh);
- Shifts in seasons (Pakistan);
- Increased weather unpredictability (Nepal, Kenya);
- Increased frequency of hazardous weather events, such as bigger floods leading to greater levels of damage (Nepal);
- Worse or more intense levels of rainfall (Nepal, Madagascar, Pakistan);
- More extreme extents of rainfall and drought (Uganda).

3.5.1.2 Data availability

Many of the stakeholders have access to weather and climate data that they may use for planning and asset design, monitoring of the impact of weather on infrastructure and/or project-based analyses. The most commonly available data relate to precipitation and temperature. This data helps them with planning and setting design standards, as well as preparing environmental impact assessments (EIAs). Rail infrastructure practitioners explicitly referred to using these for important tasks specific to operation, such as monitoring tracks for defects every 30km to prevent derailment risk (infrastructure practitioner, Ethiopia).

Some respondents obtain data from their national meteorological departments. These data are not always free; three respondents indicated that they pay for weather and climate data, but one mentioned that it is not expensive (infrastructure practitioner, Kenya). One respondent (infrastructure practitioner, Bangladesh) identified that there can be challenges or barriers in using the data because datasets can be fragmented, or inconsistent and weather stations may be spread out. Only one infrastructure practitioner (Ethiopia) reported having their own weather stations, which are fitted with a rainfall gauge and thermometer to collect temperature and precipitation measurements; however, the data collected is not used formally.

One stakeholder, who does not currently use meteorological data (infrastructure practitioner, Zimbabwe), mentioned that the impacts of a recent cyclone led them to realise the need to address climate change, as there was large-scale damage to roads. The respondent did not disclose which cyclone they were referring to, but one possibility is cyclone Idai in March 2019, which was one of the worst cyclones ever experienced in the continent of Africa. The cyclone destroyed a significant amount of infrastructure in Zimbabwe, including roads, bridges, power lines and communication infrastructure (112).

RCP scenarios are a form of climate information that infrastructure operators use to assess and prepare their assets for future impacts caused by climate change (see Section 2.2.2 for details of RCPs). For example, Network Rail's eight WRCCA 2019-2024 Route plans in the UK (113) use the RCP 6.0 90th percentile as a baseline scenario for evaluation and decisions, and RCP 8.5 as a sensitivity test on assets with a lifespan beyond 2050. Only one respondent (infrastructure practitioner, Bangladesh) referred to climate projections in the scope of approving designs, which in this case is in accordance with the RCP 4.5 scenario. This scenario is normally used due to financial reasons. In extreme cases, RCP 8.5 is considered.

The weather and climate data used by stakeholders are not always appropriate for their needs. Two respondents (infrastructure practitioners, Kenya and Bangladesh) mentioned this and referred to the need to collect further data, for example for forestry and climate simulations. The infrastructure practitioner in Bangladesh also mentioned using a loss modelling platform called Oasis (114) and accessing data through research projects and pilots conducted by local universities. The Department of Environment respondent in Bangladesh noted that it is the responsibility of "proponents" to collect climate data. This means that they expect other government departments to evaluate climate impacts to the infrastructure for which they are responsible and undertake EIAs for their projects, which the Department of Environment then reviews.

Not all stakeholders share or exchange data with other authorities. Those who do (infrastructure practitioners, Pakistan, Tanzania, Uganda, Zimbabwe; urban planning/transport authority, Nepal) exchange with authorities such as the ministries of water, transport, infrastructure, climate change, disaster risk management and home affairs. One infrastructure practitioner (Zimbabwe) also exchanges information internationally but not within its national government.

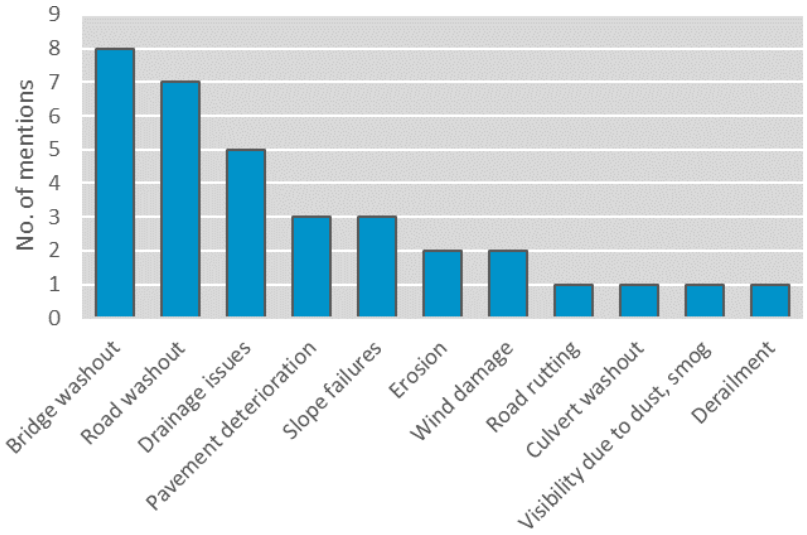
Not all stakeholders felt it was beneficial to exchange this data, but those who did reported that doing so provides a greater regional perspective and awareness on climate change issues for transport. One infrastructure practitioner (Uganda) described an event that suggests there was no collaboration to manage the impacts of flooding: "In 2019, lake levels rose by 1 to 2 metres, requiring intervention at dams, releasing water. [The river] Nile expanded and has affected infrastructure. Some roads were submerged for a year".

3.5.2 Impacts of climate change on transport, society and the economy

All the interviewees had observed increased damage to their country's transport infrastructure from weather events. Figure 13 shows how many of the stakeholders mentioned specific impacts in the interviews. Most of the impacts mentioned were related to flooding or precipitation and many affected roads. Every road infrastructure practitioner mentioned bridge washouts as a particular issue (i.e. removal or scouring of part of a structure, which may lead to its complete collapse following a flood). In Bangladesh, washout risk is also associated with sea-level rise in coastal areas.

Heat risks were mentioned less frequently but noted as a growing concern by some respondents. Interviewees from some countries referred to rutting of roads and material loss due to high temperatures. One respondent (infrastructure practitioner, Uganda) mentioned that there are many factors involved in the deterioration of asphalt pavements, so it is difficult to identify the extent to which climate change is having an impact. Two rail infrastructure practitioners (Tanzania, India) mentioned heat as the main type of weather that causes, or may cause, problems for their infrastructure.

Figure 13: Mentions of types of infrastructure damage in interviews



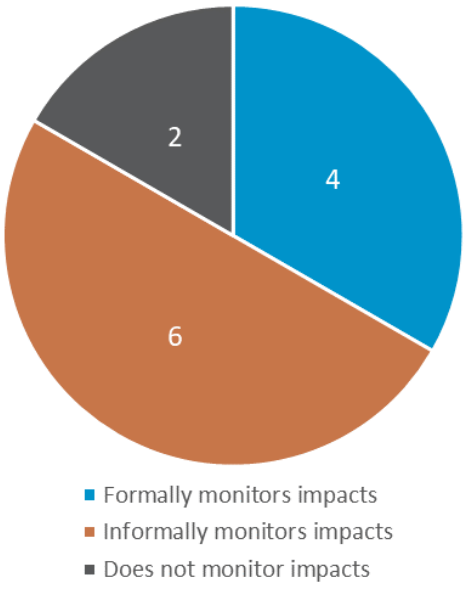
3.5.3 Transport resilience and infrastructure adaptation

Respondents discussed a range of ways that transport infrastructure is managed or that act as barriers in achieving better resilience to weather and climate change: monitoring the impacts; meeting design specifications; and operational management.

3.5.3.1 Monitoring impacts

The extent to which respondents monitor the impacts of weather and climate on their infrastructure varies. Twelve of the 13 respondents were asked whether they monitored the impacts on their transport infrastructure: of these, six do so informally, four formally and two do not monitor impacts at all (see Figure 14). The proportion of informal monitoring suggests there is a desire or even a need to formally monitor impacts, but there may be barriers or underlying reasons that have prevented this.

Figure 14: Extent of weather and climate impact monitoring by proportion of respondents



The infrastructure practitioner in Zimbabwe said they do not monitor impacts, but that there is appetite to consider it (see Section 3.4.1.1). In Madagascar, the infrastructure practitioner does not undertake monitoring of areas within their remit (rural roads), but it is done for national roads. The case is similar in Pakistan, where the impacts on key roads, such as the main highway from Pakistan to China via the mountains, are monitored.

The remainder of those interviewed who formally monitor impacts take different approaches. The infrastructure practitioner in Uganda monitors the hydrological cycle in-house and has 100 years of records, whereas the infrastructure practitioner in Bangladesh monitors through a mix of sources, including a climate change database, regional and local reporting, social media and citizen reporting. In Bangladesh, the Local Government Engineering Department is reviewing its business processes to mandate climate risk assessments. Its prime purpose is to plan, develop and maintain local level rural and urban infrastructure, encompassing roads, buildings and small-scale water resources management infrastructure throughout the country. In India, the impacts of extreme events on rail infrastructure is recorded, but it is not necessarily aligned to, or associated with climate change, because it is not a perceived need at present. The respondent from India (rail infrastructure practitioner) explained their limitations in terms of capacity to undertake further monitoring or studies on climate change due to loss of revenue from the COVID-19 pandemic.

3.5.3.2 Design specifications

There were mixed answers from respondents regarding the use of design specifications. An overview of the how much they were mentioned is shown in Table 9. The extent of their mention throughout the interviews, including multiple times by some stakeholders suggests that design standards are an important foundation for achieving resilience in transport infrastructure. However, in most instances, weather and climate are not integrated into design standards, but stakeholders see this as an aspiration to work towards. In some cases, this is already underway to some extent.

The design specifications used by the respondents are a mix of local, regional and national scale. These are sometimes outdated and in need of updating. For example, one respondent (infrastructure operator, Zimbabwe) referred to Southern African Development Community (SADC) manuals for high volume roads, which do not have provision for the effects of climate change. Local design standards are, in some cases, up to 30 or 40 years old and only available in hard copy. Two rail infrastructure practitioners (Tanzania and Ethiopia) reported their infrastructure was built to Chinese standards (in Tanzania this was between 1970 and 1975) but did not include any weather-related specifications. However, the rail infrastructure practitioner in India mentioned that while there is a Research and Design Standards Organisation that their rail infrastructure must adhere to (including tests and trials with a 2 to 3 year duration), designs are based on recent and/or historic weather data. Therefore the typical rail design standards do not reflect the likely reality of climate in the future.

The climate impact problem can be exacerbated by inflexibility in design because of these aged standards, as identified by the urban planning/transit authority in Nepal. Nepal's design standards are primarily from 1990 and there are no specific urban design plans. Consequently, the Department of Roads recently refused a wider road design proposal for an urban area. However, road widening, such as extending a road's shoulders, is important from resilience perspective as it can help manage precipitation damage (115). This shows a misalignment between the scope of existing standards and the actual needs of this urban area, which presents a significant barrier to implementing adaptation activities.

Many interviewees reported that their transport infrastructure design standards are under review. The Ugandan Ministry of Works is currently planning a revision of standards and to refine manuals to account for climate resilience. There is also interest in researching the impact of climate change on roads, which could build on previous work carried out under the Research for Community Access Partnership (ReCAP). The ReCAP project focused on transport improvements to improve accessibility for the rural poor in Africa and Asia, with outputs including a climate adaptation handbook (116).

The infrastructure practitioner in Nepal mentioned that there were some changes to national standards in 2019. However, these revisions did not contain the level of detail the respondent felt might be required based on their experience. For example, the revisions included a change to standard drainage design to withstand a 100-year flood instead of a 50-year flood but do not cover bitumen mixes to cope with higher temperatures. The respondent also referred to some perceived trade-offs in transport infrastructure design that require consideration. For example, widening roads may result in higher cut slopes, increasing the road's vulnerability. Wider roads may also require wider drains but widening drains to the required amount may be unfeasible due to road safety risks.

One respondent (infrastructure practitioner, Bangladesh) provided a long list of infrastructure specifications showing the broad range of guidelines they work with. Many of these guidelines, manuals and specifications are relatively recent (from at least 2016), and some of the older standards (Road Design Standards 2004, Road Design Standards Rural Road 2005) are currently being updated. Their building codes were updated in 2021. They reported that departures from standards can be approved and are often used for additional slope protection, inferring that there is still a gap between the infrastructure resilience needs and the design standards issued.

Table 9: Extent of design specifications mentioned in interviews by country and transport mode

Country	Mode	Design specifications mentioned
Bangladesh	Road	National building code, building code requirements for reinforced concrete, engineering guidelines per infrastructure type such as bridge design, climate-resilient rural road/concrete manuals, technical specifications for buildings, quality test protocols for road embankments.
Ethiopia	Rail	Chinese Class II standards.
Ghana	Road	Specifications mentioned, but not climate specific.
India	Rail	Research and Design Standards Organisation in India. Designs based on recent weather data, including flood levels.
Kenya	Road	Specifications mentioned, currently under revision.
Madagascar	Road	National specifications mentioned. Manual for maintenance of roads, but not climate specific.
Nepal	Road	National specifications mentioned, but not climate specific.
Pakistan	Road	National specifications mentioned, including flood levels.
Tanzania	Rail	No specifications mentioned that are climate specific.
Uganda	Road	Specifications mentioned, currently under revision.
Zimbabwe	Road	Local design standards mentioned but outdated. Reference to Southern African Development Community manuals.

3.5.3.3 Operational management

Table 10 shows the types of operational management of stakeholders' transport infrastructure in response to the impacts of weather and climate change. Most respondents reported they have annual maintenance schedules, but that these vary in content and extent. For instance, the respondent in Zimbabwe does not have computerised schedules and has not undertaken a condition survey since 2016, while Kenya has road maintenance schedules set at a local level and aspires to centralise them through its newly established disaster management agency.

Some respondents noted that their maintenance schedules do not account for the effects of climate and require updating, and that there are challenges pertaining to this due to lack of data.

Based on the interviews, it appears that responses to weather events are reactive, including infrastructure repair and rehabilitation activities. There is also little-to-no formal process to prioritise emergency maintenance or repair. The only respondent who referred to a prioritisation method for repairs was the infrastructure practitioner in Bangladesh, who explained the use of traditional systems, including site visits to undertake a detailed survey and estimate costs based on pre-determined factors such as schedules of rates and design standards.

Respondents did not indicate that any infrastructure was ever closed, or services reduced as a precautionary action, and therefore a road may only ever become impassable due to damage, for example. It was unclear who was responsible for closing infrastructure or services. For example, some respondents (Kenya, Nepal) said that the road authority or department of roads in their country was in charge of closing roads, whereas in another country (Zimbabwe) this was not the case. One respondent (infrastructure practitioner, Zambia) has not undertaken any major maintenance activities on its rail infrastructure for 45 years. Early warning systems

are also not widespread – they are either informally created (infrastructure practitioner, Ethiopia), accessed through another agency (infrastructure practitioners, Pakistan, Bangladesh) or only in certain locations with a high tendency to experience extreme weather events, such as flooding (urban planning/transport authority, Nepal). One stakeholder (infrastructure practitioner, Pakistan) mentioned that its early warning system is not reliable.

Most respondents did not have, or were not aware of, any strategy related to a business recovery plan for infrastructure. Bangladesh was the only country to provide any detail on this. They referred to a National Resilience Programme, which includes a project to implement asset management policies. Nineteen engineers involved in a national infrastructure project hold Institute of Asset Management certification from the UK and are involved in a "train-the-trainer" programme to propagate their knowledge. Similarly, the infrastructure practitioner of the railway in Ethiopia is in the process of an infrastructure monitoring skills transfer from the builders of the railway in China to an on-site management team in Ethiopia, which is due to be completed by 2023.

Respondents often mentioned funding and budget challenges related to maintenance and repair. Some reported that annual maintenance and repair budgets needed to be increased, but not all could attribute increased costs to climate change. Some key statistics mentioned by respondents included:

- Ninety percent of the current year's maintenance budget was spent on damage that could be attributed to climate change (infrastructure practitioner, Zimbabwe);
- Annual maintenance budget is increasing around 15% per year due to higher infrastructure demands, as well as a result of climate change (infrastructure practitioner, Bangladesh).

Seven respondents mentioned that infrastructure has been, or is to be modified, such as:

- Increasing culvert size (infrastructure practitioner, Ghana);
- Higher embankments and retaining walls and use of more gabions (infrastructure practitioner, Zimbabwe);
- Installation of rain gardens (urban planning/transport authority, Nepal);
- Larger drainage and longer bridges (infrastructure practitioner, Nepal).

Table 10: Extent of operational plans mentioned in interviews by country and transport mode

Country	Mode	Operational plans mentioned
Bangladesh	Road	Annual maintenance schedule, formal early warning system.
Ethiopia	Rail	Annual maintenance schedule, informal early warning system.
Ghana	Road	Annual maintenance schedule, reactive emergency maintenance.
India	Rail	Annual maintenance schedule, reactive emergency maintenance.
Kenya	Road	Annual maintenance schedule.
Madagascar	Road	Annual maintenance schedule, reactive emergency maintenance.
Nepal	Road	Annual maintenance schedule, reactive emergency maintenance.
Pakistan	Road	Annual maintenance schedule, reactive emergency maintenance, formal early warning system.
Tanzania	Rail	Annual maintenance schedule.
Uganda	Road	Annual maintenance schedule, reactive emergency maintenance.
Zimbabwe	Road	Annual maintenance schedule, reactive emergency maintenance.

3.5.4 Capacity building and financing

Few of the respondents collaborate with other organisations with the intention of improving their transport infrastructure's resilience to the impacts of weather and climate change, but those who do said they work with transport operators, academia and research institutes. In addition, most respondents have not been directly involved in accessing funds in this area, mentioning that this sort of funding is either available in a different sector (such as agriculture) or handled at a higher level than theirs (such as ministerial), or they do not know the mechanisms available to approach funders. However, one respondent (urban planning/transport authority, Nepal) had accessed joint funding from the World Bank and Asian Development Bank for large projects in the last 6 years, with other funding for their authority coming from the city budget.

The interviewees reported a desire to incorporate new technologies into their organisations' work including:

- Bioengineering techniques and geotextiles for stabilising slopes;
- More tree planting to stabilise areas;
- Soil and road binders with greater resistance to high temperature and heavy precipitation;
- Early warning systems (including solar-powered communications);
- Quick-assembly steel bridges;
- Flood mapping;
- Artificial intelligence, drones and "unmanned monitoring vehicles".

If money was not an object in terms of transport infrastructure resilience to climate change, two key areas were mentioned by respondents: more or improved hard infrastructure and building knowledge. Table 11 shows their suggestions.

Table 11: Respondent suggestions: What would make the biggest difference to climate resilience?

Capacity building area	Respondent suggestions
More/improved hard infrastructure	• Increased blue and green infrastructure, such as corridors and public spaces; • Increase culvert size or add extra culverts; • Improve and refurbish drainage systems; • Increased focus on structures such as bridges, river structures and retaining walls; • Pave as many roads as possible; • Use local materials for roads; • Explore soil stabilisation rather than importing materials; • Focus on local roads as well as national roads.
Building knowledge	• More studies on different transport modes; • Build systems to deal with climate change knowledge; • Integrate climate change into maintenance schedules; • Provide training to engineers to understand and incorporate climate change into standards and specification changes; • Provide training to contractors; • More international technical support; • Bring climate resilience and adaptation into mainstream awareness and into political debate; • Look at the socio-economic situation of countries, assess financial and technical means and fund a local solution.

A common theme within their suggestions was the need to raise the profile of climate change in their organisation. In some instances, this was at a higher, political level, whereas in others it was about more local, organisational awareness. This, in turn, links to funding provision and the current quality of design standards.

3.6 Conclusion

Global pledges to reduce or limit GHG emissions will have a direct impact on the extent of adaptation activities required in different regions to cope with projected climate change. It is clear from NDC submissions to the UNFCCC from LICs in Africa and South Asia that they are extremely vulnerable and should be prioritising adaptation as it underpins their capacity to develop in the future.

The NDCs link to national adaptation planning processes. The LEG supports LICs in developing their adaptation plans and LICs are aware of overlaps between NDC and NAP activities. More LICs are currently developing their NAPs and are expected to submit them in the near future.

Through the lens of ISO 14090, NAP and NAPA quality in Africa and South Asia has improved over time. However, this standard does not take a country's social, economic, political or development status into account. Nevertheless, as more NAPs are submitted, this offers more resources for other LICs to refer to, such as in the outcomes in Case Study 1 and specific examples of NAP features in Case Study 3. This therefore offers an opportunity for future NAP submissions to be improved.

NAPs and NAPAs from Africa and South Asia demonstrate competency in assessing the impacts of climate to a high degree at a country, and, in some cases, at a sectoral or regional level, through vulnerability assessments. Adaptation plans are also strong, as they focus on stakeholder engagement, options analysis and robust methodologies to prioritise the options. On the other hand, NAPs and NAPAs vary in their ability to translate these plans into implementation plans or processes to undertake monitoring and evaluation activities. This suggests there is a gap in the capabilities needed to set out these processes to the same calibre as the impact assessments and adaptation plans.

Similarly, there is a mixed level of focus on the transport sector in NAPs and NAPAs. It is not clear why this is the case. However, NAPAs focus on activities of a national priority before a country then develops its NAP, and transport is often less accounted for in NAPAs than NAPs. Therefore, the inconsistency may be because other sectors, such as agriculture and health, take precedence over transport in terms of adaptation needs.

Transport stakeholders across LMICs and LICs in Africa and South Asia are acutely aware of climate change affecting their infrastructure. They report that the levels of damage or frequency of damage to assets such as roads, bridges and culverts has increased over time. However, this has not necessarily led to a greater level of activity on the ground to manage the increasing impacts. Formal monitoring of impacts is not standardised, and annual maintenance and repair costs have increased. Design specifications are of high importance to transport stakeholders, but there is evidence that they will not be fit for purpose in the future if they are designed according to historic climate data. Reviewing design standards may hold the key to increasing countries' ability to adapt.

If money was no issue for transport stakeholders in Africa and South Asia, they would have two primary aspirations. One would be to raise the profile of climate change risks in the transport sector through improved technical and scientific knowledge and training activities. The other is to increase or improve the infrastructure through hard engineering methods that protect assets from the effects of extreme weather events, such as paving more roads and expanding culverts. This particularly highlights the capacity gaps in these LICs pertaining to knowledge and funding. These two areas are the ones where respondents felt they would most benefit from improvements to help them achieve transport resilience to climate change adaptation.

4. Challenges and barriers in achieving transport resilience

4.1 Overview

This section identifies the challenges LICs in Africa and South Asia face in order to achieve transport resilience, according to the project's research activities.

4.2 Broad challenges identified through the literature review

Many governments in LICs may lack understanding and knowledge of the possible scale of the climate change problem in terms of potential impacts on their infrastructure. Even if there is a basic understanding, there is often a failure to act because the policies and strategies in place are inadequate, and do not address the risks associated with extreme climate events. Stakeholders may not have achieved transport resilience for climate change adaptation due to (117):

- **Lack of knowledge:** Not familiar with or unable to understand the form or scale of the problem;
- **Lack of options:** Inadequate/insufficient information on appropriate adaptation measures;
- **Failure to act:** Unable to put appropriate measures in place or to address the problem;
- **Insufficient funds:** Not appreciating the scale of the problem or unable to secure funding.

Multiple barriers underpin these causes. From the literature, common themes include: access to and interpretation of data of the appropriate scale; the institutional arrangements in LICs' governance, transboundary partnerships and crossovers; confusion between climate change adaptation and disaster risk reduction; and acquisition of funding.

4.2.1 Weather and climate data

Reliable in-situ meteorological observations are necessary in order to monitor and project climate variables; this then informs a nation's understanding of its climate and thus the actions it designs and undertakes. This is particularly important for LICs where inadequate meteorological infrastructure can result in limited, patchy or incomplete observations, which can then hinder their ability to deduce risk and respond appropriately to natural disasters.

Some of these data challenges are due to a lack of capacity to create and maintain the meteorological infrastructure and collect the data. Another issue may be a lack of skills, knowledge and institutional arrangements to enable the data to be comprehensively interpreted.

4.2.1.1 Observational data

Employing instruments such as weather stations to collect temperature and precipitation data as a minimum provides a good foundation to collect observational data in LICs. There have been improvements, but there is still a lack of comprehensive data on regional climate in LICs, which is in part due to disproportionate research focus on HICs and MICs (23). Overall, there are fewer data available from LICs compared with more developed countries.

The historical observational data used in the NAPs and NAPAs of LICs tends to be at a national scale. However, in some instances NAPs and NAPAs do contain more detailed climate variables, including:

- Changes in annual minimum and maximum temperature;
- Changes in the annual number of hot days and nights;
- Spatial distribution in precipitation levels by climate zone or regions;
- Number of consecutive dry days;
- Rate of sea level rise (where applicable).

While these variables may have some value in broadly describing how climate has changed in LICs, their value in a localised context may be limited. Some LICs have a wide range of climate variability due to their geographical position. In such cases, getting observations at a suitably localised level is crucial due to the

spatial and/or temporal differences across each country as a whole. Having the correct scale of observations has a knock-on effect on the ability of policymakers to interpret the data and make effective decisions for climate change adaptation. From the perspective of preparing for the future by incorporating expected shifts in weather events and extremes due to climate change, having localised data becomes even more important.

4.2.1.2 Climate change projections

Climate projections are available on global and regional scales (118), but again there is a lack of local and downscaled data (119), just as there is with observational data. This can be particularly challenging for countries affected by the ITCZ. These countries lie astride multiple climatic regions, which have contrasting controls and drivers of climate, making them particularly troublesome to simulate in climate models (110). Liberia's NAP, for example, mentions that its projection downscaling scenarios rely on World Meteorological Organisation (WMO) station data from neighbouring countries or weather stations elsewhere that are representative of their climate (120).

Furthermore, current climate projection toolkits were not developed with sectors like transport in mind. The transport sector is vulnerable to short-term, extreme events and these are not typically captured in weather generator tools (49). This is a global concern but is worse for LICs.

4.2.1.3 Data interpretation

Data interpretation across LICs can vary as it is dependent on human and technological capacity. Typically, seasonal and sectoral interpretation of data provided by regional or national climate centres (such as the Inter-Governmental Authority on Development Prediction and Climate Applications Centre in Nairobi, Kenya) is often the responsibility of individual countries (110), but there is a need for these centres to provide higher spatial resolution forecasts that are more relevant at a local level (121). Therefore, LICs are likely to be dependent on data made available to them from projects and research institutes.

Sometimes stakeholders in different sectors solicit data from these types of centres (e.g. transport and logistics organisations) on an ad-hoc basis and will then interpret that data internally (41). However, the effectiveness of data analysis depends on its timeliness. If there is a delay in data provision, that data are unusable for real-time analysis (15).

The extent of climate data dissemination in terms of its usefulness for LICs is also dependent on the skills and ability of those interpreting it. Weather bulletins provided by government ministries may eliminate probability when published, for example, due to a lack of capacity to articulate and interpret it (41). Interpreting this data may be even more challenging for decentralised governments where the data provided is too vague to apply practically at a local scale.

4.2.2 Institutional arrangements

LICs require greater institutional capacity in order to achieve transport resilience. Some NAPs from LICs include a gap analysis that outlines their needs in order to achieve resilience to climate change, with the analysis going beyond that of the transport infrastructure alone. According to some of these NAPs, the changes needed include:

- Building and maintaining data on climate impacts;
- Availability of climate observation and projection models at national and more localised scales;
- Increased institutional, financial, technical, material and human capacities for adaptation programme implementation;
- Involvement of under-represented demographic groups.

There are opportunities to address these gaps at multiple levels of governance. This includes empowering local communities, with support from the national and ministerial level. Adaptation planning requires locally inclusive, bottom-up approaches that complement the top-down mobilisation of resources (122). Additional opportunities may come from mobilising the private sector to support government aims to achieve climate resilient transport infrastructure through provision of funds, resources and specialist knowledge.

Some LICs report capacity issues pertaining to the retention of public sector staff and their performance. There can be high vacancy rates for government roles (53), which may in part be related to poor job

satisfaction caused by issues such as low pay, dissatisfaction and lack of motivation (123). The retention of key, specialised staff is a challenge, which in turn makes regulation, monitoring and policy setting difficult, hindering the ability of the public sector as a whole to carry out its role effectively for its citizens (53).

Issues with low pay can also impact productivity if any government employees are tempted to obtain more money in the form of bribery through corruption. An increase in widespread absenteeism, moonlighting and corruption leads to further demoralisation, resulting in a vicious cycle of poor productivity at the expense of national output (123).

4.2.2.1 National government

National governments can direct the priorities of their ministries and access and allocate funds for local provision of resources for climate change adaptation projects, but this is only successful if national governments have the skills to do so. Laws, regulations and policies in governments may not have developed in a coordinated way, nor be integrated or consider sustainable development strategies. Therefore, these laws and regulations may lack clarity regarding their interactions with each other in order to reconcile both economic progress and environmental sustainability (124).

LICs' access to funding is not always steady. In part, this is likely to be due to poor institutional organisation. Somalia, for example, is unable to access international financing for large-scale infrastructure projects or deliver a systems-based approach for long-term planning in its infrastructure sector because of the lack of centralised coordination (125). Furthermore, if a national government receives international funding, it cannot be spent effectively without knowing how best to use it. This is a particular challenge for LICs, as they may not have prior experience in allocating funds appropriately. This is why it is crucial to facilitate the appropriate levels of training as part of spending, to support formulation of appropriate plans. Given the scale of the need, this can be incremental so that it does not overwhelm key stakeholders.

In the past in Afghanistan, for example, even with well-structured planning and decision-making processes, scattered sector responsibilities made it difficult to implement coherent plans. Donor concerns also tended to prevail in the planning process – this is possibly what led to 48% of public investments bypassing the government's budget process and being implemented "off budget" (that is, not passing through the government's public financial management system). "Off-budget" investment has implications for the coherence of planning (58), with investments that followed the budget process being easier to allocate resources to according to strategic priorities.

4.2.2.2 Ministerial departments

Ministerial departments are responsible for governing specific sectors. Adaptation is usually the remit of ministries of environment, as they are normally most motivated to promote it (126) and are often responsible for a large proportion of NAP and NAPA actions.

In order to deliver transport adaptation, ministries responsible for transport require a good understanding of areas that they may not be familiar with, such as change management, policy, climate change science, embedment and capacity development. Part of the problem faced by LICs is that for transport, the institutional landscape may be fragmented, with several ministries involved in the operation and regulation of the sector. The ideal solution would be to have an apex institution for transport planning and policy (58) in order to build institutional capacity specifically for transport adaptation. Where this is not the case, it is necessary to have structures in place to engage other ministries, facilitated by the lead ministry or national government.

4.2.2.3 Local government and communities

Adaptation and resilience building at a local level is extremely important for LICs. It is imperative that local government is involved in adaptation planning, as it is in closest contact with the communities directly affected by the impacts of climate change. However, there are a number of obstacles that prevent local government from contributing effectively to adaptation, including (127):

- Climate finance is often only available and accessible through application to national programmes with specific, earmarked arrangements;
- Lack of appropriate budgetary allocations from national level;

- Local governments' inability to absorb incremental costs of climate change;
- Weak or lack of institutional capacity in local government to deal with climate change issues.

Building capacity at local level for climate change adaptation is one way to break the unsustainable chain of humanitarian intervention, as it can help mobilise authorities to take preventative action as opposed to reactive. At present, a range of agencies provide much of the support and resilience building at local level in LICs and LMICs, but this approach is not necessarily incorporated in national level policy and transformational adaptation (128). Similarly, the implementation of any national policy on humanitarian intervention that does exist can end up fragmented due to lack of coordination (129).

Strategic decisions or processes at regional or national level may cause some of the challenges and barriers experienced at local level. For example, a national focus solely on technological or managerial solutions to vulnerabilities fails to take account of their possible socio-political causes, such as inequality, discrimination and lack of access to resources (129). Overlooking the needs of marginalised communities may result in decision-makers missing critical information that would be beneficial at a local scale. For instance, a study in South Asia highlighted that women usually have indigenous knowledge of managing the environment (65) that would be particularly helpful in adapting to extreme events.

4.2.3 Financing

LICs face complex financial challenges when it comes to increasing the resilience of their transport infrastructure to climate change. LICs perceive inadequate funding to be one of their biggest barriers in implementing adaptation (130). Some other challenges in financing climate-resilient infrastructure include:

- Reluctance to implement, despite long-term benefits, because it requires greater upfront costs;
- National governments are unaware of available funding sources, and how to access them;
- Distribution of funds to local level and ensuring those on the ground are appropriately trained to use the funds effectively;
- Prioritising climate change mitigation.

Funding for climate change adaptation in LICs comes from a variety of sources, such as donors to international climate funds, and bilateral and multilateral development assistance. There may also be domestic public finance or opportunities for public–private partnerships, but such partnerships may be challenging to initiate, particularly if there are security challenges in the country (103).

4.2.3.1 International and multilateral funding

According to Climate Funds Update (131), US$4.72 billion in multilateral funds was pledged for adaptation projects in less developed nations in 2003–2020. This was 11% of all multilateral funds pledged (US$41.8 billion) for mitigation, adaptation and multiple focus projects. However, as projects with more than one focus may include adaptation, the total funds for adaptation were likely to be greater than 11%.

Adaptation funding was approved for 724 projects across developing nations. More than half of the approved adaptation funding (54%) was allocated to sub-Saharan Africa (41%) and South Asia (13%).

Multilateral funding was not equally distributed across LICs. Figure 15 shows the total funds approved for climate change adaptation projects across LICs in Africa and South Asia during 2003–2020, and Figure 16 shows how those funds compare with each country's GDP. Approximately US$1.2 billion was allocated to these countries. However, almost half of the funds were allocated to five LICs (Niger, Mozambique, Ethiopia, Mali and Uganda), with the greatest share allocated to Niger (15%). Relative to GDP, the funding distribution is not equitable. The Gambia and Guinea-Bissau received a large proportion of funding relative to their GDP, whereas Uganda and Ethiopia stand out as receiving disproportionate funds relative to GDP compared with others.

Multilateral funding often focuses on specific sectors. Of the adaptation projects funded in 2003–2020, most had objectives related to agriculture or general environmental protection or were multisector. There was only one explicitly transport-related project among the countries in Figure 15 and 16, which was in Mozambique (see Case Study 4).

Figure 15: Multilateral climate adaptation funds approved by LICs in Africa and South Asia, 2003–2020

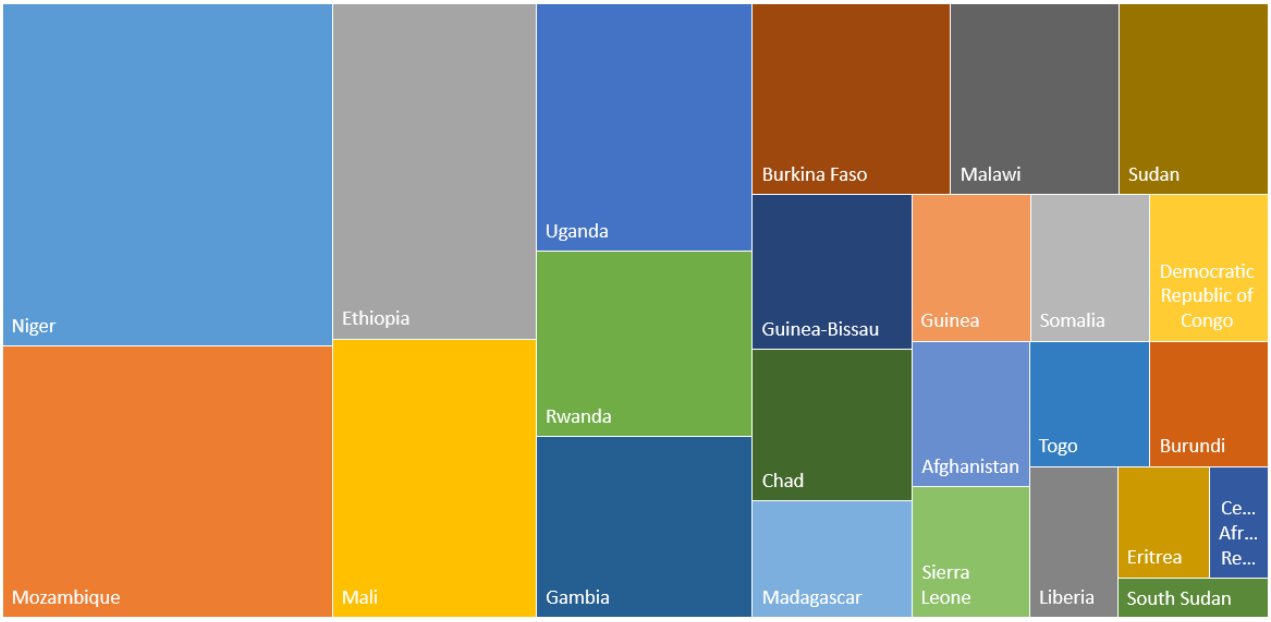
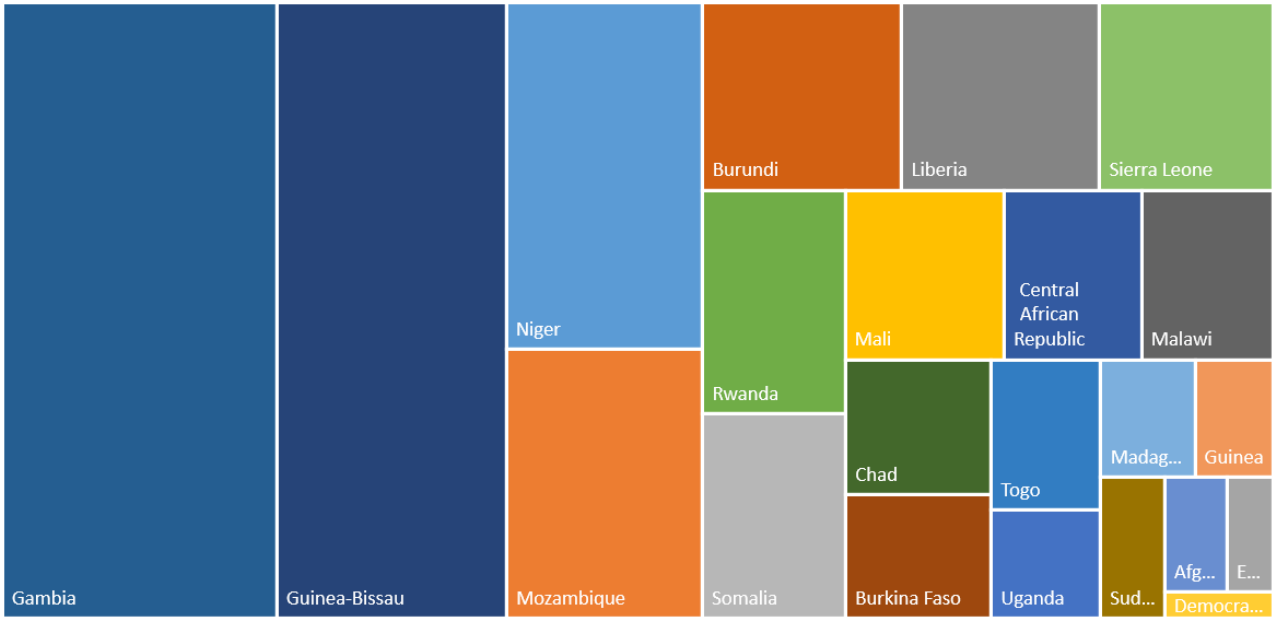


Figure 16: Multilateral climate adaptation funds relative to total GDP in 2020[5]



Source: adapted from Climate Funds Update (131) and The World Bank (132)

[5] Eritrea and South Sudan data are removed due to lack of GDP figures for 2020.

Some LICs in Africa and South Asia manage a large portfolio of funding sources, such as Rwanda, which identified 30 sources across all sectors in its Green Growth and Climate Resilience Strategy (110). Disaster risk reduction as a sector has comparatively less access to funds than transport. Only four funding sources are aligned to both sectors: the Adaptation Fund; Global Climate Change Alliance; Global Facility for Disaster Risk Reduction and Recovery; and International Climate Initiative (Germany) (110). Similarly, Guinea-Bissau also reported a number of eligible sources of climate finance (17) but the financial, technical and capacity-building support packages it received were not allocated to any transport adaptation projects. On the other hand, SIDS – which have small economies and are often highly indebted – are classified as MICs and therefore have limited access to development assistance such as concessionary loans and resources (133). Consequently, they have significant barriers to accessing the funds they need to undertake adaptation activities.

There was little evidence that LICs have an awareness of insurance-linked loan package financial services and no evidence of awareness in the context of transport resilience. This is surprising given that the InsuResilience Global Partnership for Climate and Disaster Risk Finance and Insurance Solutions was officially launched at the UN Climate Conference COP23 in November 2017. Its aim is to create a global initiative between the Group of Twenty (G20) nations and Vulnerable Twenty (V20) nations with a needs-based approach to increase resilience among the poorest and most vulnerable people (134). Moreover, partners include Ethiopia, The Gambia, Madagascar and Rwanda. Three of these countries' NAPs or NAPAs were reviewed through the capability assessment (Ethiopia, The Gambia, Rwanda; see Section 3.4.1) and the focus of insurance-linked funding or products is exclusively for crops.

The InsuResilience Solutions Fund (ISF) is administered by the German Development Bank and funded by the Federal Ministry of Economic Cooperation and Development (135). Importantly, the ISF became fully operational in 2019 and provided financial support for the development of climate risk insurance products. Most NAPs and NAPAs were published prior to the ISF becoming fully operational, and with the ISF in its infancy, there has been limited impact to date in LICs. As NAPs and NAPAs mature, mobilising the ISF for LICs would mean more sectors than agriculture could consider this funding as an option. More is needed to promote and market this financial service and the benefits that it can bring.

4.2.3.2 Domestic and private sector funding

The private sector is playing an increasingly important role in helping LICs bridge the financing gap for infrastructure development. As such, incentives are required to increase private sector engagement and thereby maximise funding opportunities. Relevant private sector players include infrastructure managers, investors, operators, consultants and contractors (53).

LIC adaptation plans, such as NAPAs, address the need for private sector engagement, but historically the role the private sector was expected to play in the NAPA process was unclear (130). There are three possible explanations for this lack of clarity (130):

- An intentional approach to avoid distraction from the need to scale up public funding;
- A lack of awareness of the potential of private sector engagement in adaptation;
- National adaptation planning (in this case NAPA) guidelines focus on public financing when considering the public sector, which may increase their dependency on public financing.

The private sector can enhance access to multilateral funding such as the Green Climate Fund (136). However, to date LIC governments have not engaged with the private sector very much, due to the structural constraints of governance and policy design (137). Another issue is that the private sector is not transparent. This can contradict the requirements of multilateral funding provision such as the Green Climate Fund. As a result, public–private partnerships may require a level of transparency that discourages private sector involvement (138).

Case study 4. Multilateral funding for transport adaptation: Mozambique's Roads and Bridges Management and Maintenance Program

The Pilot Program for Climate Resilience (PPCR) is a programme within the Strategic Climate Fund. The PPCR "aims to demonstrate ways in which climate risk and resilience may be integrated into core development planning and implementation by providing incentives for scaled-up action and initiation transformational change in participating pilot countries" (139).

In 2013, the PPCR provided US$14.64 million for a roads and bridges project in Mozambique: $6.26 million as a concessional loan and $8.38 million as a grant to the Ministry of Economy and Finance of the Republic of Mozambique. The project was implemented by two government agencies: The Road Fund and the National Road Administration (131).

The aim of the project was to stimulate growth and contribute to poverty reduction through improved road infrastructure, better sector policies and enhanced road sector management (140). The objectives were to: improve coverage and conditions of roads and bridges in the territory; strengthen the institutional capacity to manage and administer the road sector; establish financing mechanisms for road maintenance; promote the use of local resources in road construction and management; and improve road transport safety.

Core indicators were set for the project (141):

- Percentage of classified roads in good and fair condition: **increase from 64% to 73%;**
- Percentage of rural population within 2km of an all-season road: **increase from 11% to 42.5%;**
- Project beneficiaries (rural only): **6.1 million.**

The outcomes of this project were considered satisfactory in accordance with the indicator targets. At 72%, the percentage of roads classified as in good or fair condition was slightly lower than expected due to the impacts of some unexpected floods during the project. The percentage of the rural population living within 2km of an all-season road was revised during the project due to an error in the assessment methodology; the final outcome was 29.3%, which equated to about 40% using the old methodology. However, the beneficiaries fell short of the project's target, with 4.66 million reported in the latest survey in 2015. On completion of the project, the World Bank identified five lessons and recommendations (141):

- Substantial long-term sector engagement stimulates progress in institutional reforms;
- Commitment of partners to procedures and guidelines for management of joint arrangements should be secured prior to project approval;
- Introduction of new methodologies and approaches should be accompanied by the required resourcing to enable effective learning and capacity building;
- Project design should be flexible, considering the specific situational context;
- Project designs should ensure that local regulations are accounted for during project preparation and negotiated prior to project approval.

4.2.4 Crossovers in climate change adaptation and disaster risk reduction

Both climate change adaptation and disaster risk reduction are concepts that have gained interest and momentum in recent decades. They both incorporate preparedness to reduce damage that affects society and thus have common policy goals. However, they have different theoretical and cultural origins.

Climate change adaptation focuses on climate-related hazards and is rooted in scientific theory. On the other hand, disaster risk reduction covers a much wider field of environmental hazards and originated from the humanitarian field and emergency response to disaster events (142). Furthermore, climate change adaptation may have a longer temporal and larger spatial outlook for planning, whereas disaster risk reduction planning is about near-term response at a more localised scale.

In LICS, climate change adaptation and disaster risk reduction are not necessarily integrated. Some governments and ministries may consider both of these, or possibly look at one but not the other. In Madagascar, for example, disaster risk management, disaster risk reduction and climate change adaptation

functions are distributed at the level of national government (41). The resulting silo effect causes confusion between roles and responsibilities and leads to competition across agencies for international climate finance.

Policies normally focus on disaster risk management, resulting in reactive actions often taking precedence over preparedness. However, disaster risk reduction interventions can contribute to climate change adaptation by reducing vulnerabilities to climate change. Such interventions build adaptive capacity potential at a local level in the scope of improving infrastructure resilience, but do not contribute to improved levels of knowledge and information (143). Integrating these functions may offer financial benefits, as well as releasing resources that overlap.

There are a number of challenges to address in order to integrate climate change adaptation and disaster risk reduction, such as: aligning their scope of work; administrative differences in values and principles; poor communication of risk and planning tools; incoherent policy approach; different funding sources; and issues related to community involvement (144). As these are major challenges that would require significant institutional change, integration would need to be a gradual process. Ministries or government sectors with responsibilities for climate change adaptation and disaster risk reduction would themselves ultimately require integration, but in the near-term could benefit from linkages to enable knowledge exchange. Integration should also consider both horizontal (across boundaries and functions) and vertical (national to/from local) functions of government (119).

4.2.5 Transboundary partnerships

The geographic location of a LIC can create barriers as well as opportunities. Establishing regional connectivity with neighbouring countries can strengthen social links and support efforts towards peace and reconciliation, particularly where physical links have been destroyed by war (125). However, landlocked LICs face specific operational and resource issues due to their dependency on neighbouring countries for sea access or necessary natural resources. This has implications for costs of imports, especially where the country has limited transport infrastructure options (110). High transport charges for imports can therefore constrain the availability of funds for transport resilience. Strategies to counter this include promoting alternative modes of transport, but these also need to be climate resilient to appeal to users.

4.2.6 Impacts of COVID-19

COVID-19, the disease caused by a novel coronavirus, was discovered in late 2019 and rapidly spread around the world. The pandemic led to governments attempting to suppress its impact and reduce the risk of infection, hospitalisation and death of citizens through travel restrictions. The resulting significant drop in transport services severely affected the sector, particularly public transport and aviation.

These restrictions had (and may continue to have) negative indirect consequences for LICs. Mobility restrictions undoubtedly affected economic growth, as GDP fell. This suggests a growth in poverty, with poor workers being hit hardest because they had fewer savings and were more likely to rely on casual work to afford the basic needs required for survival (145). In Africa, in particular, the consequences included a decline in Chinese demand for goods in emerging markets and key exports (such as livestock and tea), drops in global oil demand (which in turn affected national currencies in supply countries such as Nigeria) and loss of income from tourism (146). As a result, one of the financial consequences of the pandemic may be that transport adaptation is seen as a lower priority, both because capacities have reduced and because LICs have shifted their focus to emergency economic recovery.

When considering resilience, there are also parallels between the impacts of the COVID-19 pandemic and the impacts of climate change on transport systems. The parallels are primarily regarding the necessity of effective and timely responses in the event of a crisis that impairs mobility – in the case of COVID-19 this has been as a result of “lockdowns” and “stay at home” orders, while in the case of climate change this might be as the result of an extreme weather event that disrupts transport operations. Response in the face of a disaster requires collaborative efforts by multiple stakeholders, including transport service providers, emergency services and communication channels in order for essential goods and services to reach those whose mobility is impacted – particularly vulnerable and remote/secluded people.

Moving forwards beyond this pandemic, PIARC has identified a three-phase framework of “reopening-recovery-reimagining” in order to return to a society that is prosperous, sustainable, resilient and happier

(147). The framework's principles could also apply to responses to the impacts of climate change, given its emphasis on evaluating and applying data to rapidly learn lessons and shape decision-making.

4.3 Specific challenges identified through stakeholder interviews

4.3.1 Financial and economic challenges

Insufficient funding for routine maintenance was mentioned by five of the stakeholders interviewed for this project. Respondents from Pakistan and Nepal noted that emergency maintenance related to weather damage was reducing the resources available for routine maintenance. Timely maintenance can prevent further damage (infrastructure practitioner, Kenya) whereas poor maintenance can exacerbate weather impacts, reducing transport resilience.

No interviewees reported a business recovery plan for weather damage, with the respondent from Ethiopia explicitly noting that capital injection would be needed to develop such as plan or strategy. Funding could also provide early warning systems (infrastructure practitioner, Ethiopia).

Resource limitations and the lack of skilled workers can also prevent sufficient assessment of infrastructure (infrastructure practitioner, Bangladesh). For transport networks that generate their own income (infrastructure practitioner, India), the COVID-19 pandemic has exacerbated resource issues due to loss of funds; as a result, monitoring and maintenance activities are not prioritised.

Only three interviewees have accessed development partners and associated funding for climate resilience (Ministry of Environment, Bangladesh, urban planning/transport authority, Nepal, infrastructure practitioner, Uganda), although others (infrastructure practitioners, Pakistan, Zimbabwe) have received funding for non-climate resilience projects. The infrastructure practitioner from Madagascar reported that there was minimal disaster funding available for infrastructure, with most resources directed towards humanitarian relief.

4.3.2 Social and political challenges

The interviewees did not explicitly mention any social or political challenges related to transport resilience to weather and climate. Seven mentioned a general low awareness of climate adaptation and transport resilience within ministries and agencies. Indeed, several of the respondents mentioned smog, air pollution or other environmental issues such as decarbonisation when asked about transport resilience to weather and climate, suggesting there is some confusion or uncertainty surrounding the topic.

The interviewee from Uganda provided a perspective of the social and political challenges of climate change: "We need an initiative to bring climate resilience/adaptation into the mainstream awareness of the public and into political debate. There needs to be discussion around key issues. Quality of life is also relevant and how climate issues affect poorer people and where their priorities lie. Can they afford to be climate aware? For those who struggle to feed themselves, climate is a minor issue. Climate needs to be in the collective conscience of the public. It needs awareness and commitment at all levels, including regional and global."

4.3.3 Technical challenges

The technical challenges raised by the interviewees coalesced around two areas: data and knowledge/ expertise.

The majority of interviewees (all except two) use meteorological and/or climate data within their organisations. Some noted the need for additional datasets on climate projections (infrastructure practitioner, Bangladesh) and the role of trees and vegetation (infrastructure practitioner, Kenya). Within Bangladesh, the EIA mandated by planning policy requires climatological datasets to be considered, although this is not done for every challenge. One interviewee described a focus on hydrology rather than climate change (infrastructure practitioner, Uganda). Another noted that better meteorological data was required to support the revision of their design codes and specifications (infrastructure practitioner, Ghana).

Six interviewees highlighted insufficient knowledge/expertise as a technical barrier. Examples they gave included that engineers either need to be trained to understand climate change and how this can be incorporated into infrastructure standards and specifications (infrastructure practitioner, Ghana) or to understand what new technological solutions are available and whether they are suitable (infrastructure

practitioners, Zimbabwe, Tanzania). The infrastructure practitioner from Bangladesh commented: “Investing money is not enough, we need international technical support.”

4.3.4 Institutional and regulatory challenges

The interviews highlighted three institutional and regulatory challenge areas. These included: awareness of climate change; design standards and guidance; and monitoring and reporting of weather impacts and transport vulnerability. These are core aspects of many climate adaptation frameworks, such as Rail Adapt (59) and an important part of building transport resilience to weather and climate.

For many organisations, awareness of weather impacts and climate adaptation are at early stages (for example in Ministry of Environment, Bangladesh, infrastructure practitioners, Zimbabwe, Tanzania, Ghana). The transport professionals and politicians interviewed described an institutional awareness of the main issues, but also a need to develop systems and regulations to respond to the challenge. Only four interviewees had accessed guidance documents or materials on transport resilience to weather and climate, for example from PIARC, the International Union of Railways (UIC), Transport Research Laboratory (TRL), Resilience Shift and the World Bank to support their organisation in becoming resilient to climate change. The reasons for not accessing the current available guidance were not provided. Two interviewees mentioned the PIARC adaptation framework, although one noted this required localisation for their country as it was more relevant for HICs (infrastructure practitioner, Uganda). Three stakeholders also mentioned the ReCAP project although one (infrastructure practitioner, Zimbabwe) highlighted that the guidance is not used yet as they feel additional training required.

Design specifications and standards provide an opportunity to embed weather and climate resilience within operations management by ensuring that infrastructure is appropriately designed for future conditions. Currently, only two respondents confirmed that weather and climate are considered within their design standards (infrastructure practitioners, Bangladesh, Ethiopia). Some countries are updating their design standards (infrastructure practitioners, Kenya, Uganda) with view to including climate resilience, whereas some countries have no design standards relevant to transport resilience. A lack of enforced regulations to protect infrastructure also gives transport stakeholders less incentive to act; no stakeholders were able to provide any non-compliance consequences.

The interviews showed that there is both formal (four responses) and informal (seven) monitoring of the impacts of weather and climate change, but when it comes to review of transport vulnerability to climate, monitoring is only informal (four) or lacking altogether (six). Understanding the impact of weather and climate change and transport vulnerability are important inputs for a climate change risk assessment, which should be undertaken as part of climate adaptation.

4.4 Specific challenges identified through evaluating policy

Evaluating the NAPs and NAPAs across LICs in Africa and South Asia through the lens of ISO 14090 identified that countries are at various stages of progress in their adaptation planning. Despite the differences in climate risks that LICs face now and are likely to face in future, they are generally competent at scoping the climate change issue at a national scale and undertaking impact assessments. This indicates that the ministries responsible for writing NAPs and NAPAs across LICs are aware of the scale of the climate change challenge and have accessed sufficient resources to help them.

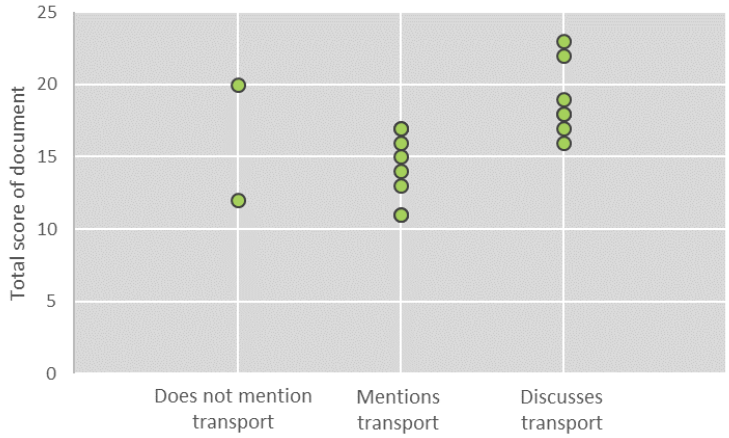
In most cases, the NAPs and NAPAs include comprehensive options for adaptation planning, with many countries engaging a wide range of stakeholders for support. However, it is clear LICS face challenges at the implementation, monitoring and evaluation stages, suggesting there are gaps in their knowledge and technical capacities at the delivery stages of their strategies.

Nevertheless, national adaptation planning across LICs in Africa and South Asia shows a significant underrepresentation of transport as a sector. The NAPs and NAPAs that did discuss transport tended to score higher in the capability assessment, as shown in Figure 17. The exception is Nepal, whose NAPA does score relatively highly despite not mentioning transport: however, it is one of the older documents assessed (published in 2010).

Many of the highest scoring documents are NAPs, not NAPAs, and were published more recently (see Section 3.4), which suggests that the incorporation of transport is a later consideration in the adaptation planning process for LICs.

The absence of focused transport adaptation is also apparent in the lack of multilateral funding for transport-specific projects in LICs (see Section 4.2.3.1). This may underpin some of the acute financial challenges LICs face and is likely to be connected to the difficulties LICs have in implementing, monitoring and evaluating adaptation plans.

Figure 17: Score of each NAP and NAPA against ISO 14090 criteria, by extent of engagement regarding transport



4.5 Specific challenges identified through evaluating tools

There is a wide range of tools available for transport stakeholders to support them with transport adaptation to climate change in a multitude of ways. However, evaluating a range of these tools indicated that no single tool is effective in supporting the full process of planning and implementing adaptation activities.

Many of the tools are credible, being well designed from a technical perspective and based on extensive, robust scientific research and evidence. However, they may be unsuitable when considering the limitations of transport stakeholders in LICs, with insufficient supporting material for their level of skills, knowledge or capacity. This could be because of a lack of LIC representation when the tool was being designed. Similarly, if a tool's purpose is to serve a general audience, it cannot account for the capacity issues identified by LICs, rendering the tool less effective.

Some of the highest ranked tools were designed for use at a local geographic level. In some ways, this contradicts the needs of LICs, which is a national scale of adaptation planning. However, if local transport stakeholders can use such tools effectively, they may unlock an increased adaptive capacity across multiple areas, and therefore do so collectively at a national level. This emphasises the importance of building technical and financial capacity at local level.

4.6 Conclusion

LICs face various barriers in the pursuit of transport resilience to climate change adaptation. These include capacity gaps in knowledge, technical infrastructure and finance.

The literature reviewed indicates that LICs might lack weather data and climate projections at an appropriate scale and with sufficient historic observations for the purposes of impact analysis and vulnerability assessment. LICs also have capacity issues in terms of their ability to interpret this data. If regional institutions or meteorological centres do not have data at the right scale, it is of no practical use for making decisions at a local level.

Institutions at all levels of governance in LICs have a role to play in delivering transport adaptation, with each level of governance experiencing different challenges. In national government, the lack of central coordination has an impact on financial access. At the ministerial level of government, the ministry responsible for the country's NAP may face implementation and monitoring challenges if not well acquainted

with key transport stakeholders, especially other supporting ministries. Those at the local government and community levels face a lack of integration in decision-making by ministries and national governments, which could be problematic for longer-term planning as they may miss out on the value of local community knowledge for adaptation.

The complexities around finance are particularly problematic for LICs. There is a severe lack of funding across LICs to deliver adaptation plans, so they are heavily dependent on multilateral funding. However, the various sources of funding can form a complex landscape to manage. The disproportionate allocation of adaptation funds across LICs suggests that their capacity to secure it varies. Also, there are opportunities to mobilise private sector funds, but there are barriers due to conflicts in terms of transparency and lack of clarity in the private sector's role in transport adaptation planning.

Crossovers in disaster risk reduction and climate change adaptation have implications for transport stakeholders. As they have different origins, there are often separate institutions that manage disaster risk reduction and climate change adaptation. The crossovers in the way they operate can cause confusion over who can access funding, and this may lead to avoidable competition for resources.

Transport stakeholder interviews across LICs and LMICs in Africa and South Asia highlighted a range of challenges they face when maintaining transport infrastructure in a changing climate. Financially, there is a lack of funding for effective maintenance. Those responsible for managing funds and infrastructure operations struggle to keep up with the required levels of maintenance and its timeliness because funds are often diverted to emergency repair, humanitarian relief and projects that are not related to climate resilience. Social and political issues in the context of climate change adaptation are not well understood, with reports of low awareness among ministries and agencies. There are gaps in terms of access to and formal use of meteorological data, as well as general understanding of climate in the context of transport, which has a knock-on effect on design specifications. Climate change awareness, design standards/guidance and monitoring of impacts on transport are also institutional challenges, as in many cases the level of understanding needs to grow in order for transport resilience needs to be met.

The capability assessments identified that transport is underrepresented in national adaptation planning across Africa and South Asia. Furthermore, there is a capacity gap in policy around implementation, monitoring and evaluation, which may link to the funding challenges that LICs face. As for tools, despite being credible, LICs may struggle to use them if they were not accounted for as a key user group for the tool or framework, not involved in its design stage by the provider, or cannot access adequate support from the provider to meet their needs. There are highly rated tools, but they primarily focus on local scale needs; this would require increased capacity at that level, whereas LICs require support from tools at a national level.

5. Addressing knowledge gaps and needs to facilitate transport resilience

5.1 Overview

This section identifies the needs of LICs in Africa and South Asia that need addressing in order for them to work towards implementing transport resilience for climate change adaptation. It discusses the potential opportunities available for LICs to achieve this based on the holistic findings from this project and options to facilitate ways to improve their transport resilience.

5.2 Identified knowledge gaps and needs

The research activities in this project highlighted that LICs across Africa and South Asia are aware of the impacts of climate change in their countries and the need to adapt. However, **adapting transport to climate change is often less considered than other sectors** – the impacts of climate change on transport are not prioritised in early stages of scoping, or not yet understood. LICs need increased capacity to raise the profile of transport as an important element of climate change adaptation and implement more resilient transport services.

The core barriers faced by LICs in achieving transport resilience (as summarised in Section 4.2, (117)) require specific actions to overcome them. Table 12 shows some of the ways that these barriers could be addressed. Meeting these needs will require a range of actions, as outlined in this section. They fall under three general themes: improved government coordination, capacity building and stakeholder engagement.

Table 12: LIC needs in order to overcome key barriers in achieving transport resilience to climate change

Barrier	Needs of LICs in Africa and South Asia
Lack of knowledge	• Capacity building: sufficient number of trained staff in national, ministerial and local government who understand the impacts of climate change on transport; • Capacity building: support to select and access appropriate knowledge tools and resources; • Stakeholder engagement: collaboration with groups or institutions with relevant knowledge.
Lack of options	• Capacity building: support to select and access appropriate tools or frameworks; • Stakeholder engagement: collaboration with groups or institutions to share best practice.
Failure to act	• Improved government coordination: frameworks and policies in place with a clear process for decision-making; • Improved government coordination: updated design standards incorporating weather and climate change; • Stakeholder engagement: collaboration with private sector for innovation.
Insufficient funds	• Improved government coordination: ensuring the transport sector has equal opportunity to access funds alongside other sectors; • Capacity building: mechanisms and support to apply for and mobilise multi- and bi-lateral funds; • Stakeholder engagement: collaboration with private sector for additional funding.

5.2.1 Government coordination

Coherent policy requires strong political leadership, backed up by legal frameworks (142). Weak coordination between organisations at national and local levels constrains the abilities of LICs to plan for, respond to and adapt to climate change. This can be a particular problem for governments that have decentralised or are in the process of doing so (41).

Effective adaptation policy development requires cross-sectoral cohesion and practice across national and local government. Policy inadequacies will require ongoing attention in light of climate change in order for LICs to build appropriate levels of adaptive capacity (148). This is crucial, as the impacts of climate change cut across sectors and geographic boundaries, regardless of the division of authority and governance (149).

National governments or ministries with responsibilities for transport and climate change adaptation would need to lead engagement across other stakeholders. This could be achieved through facilitating cross-sector dialogues, such as establishing sector working groups, to discuss policy and priorities.

An example can be found in Malawi (53), whose sector working groups are a mechanism for dialogue between itself, development partners, the private sector and civil society organisations within the relevant sector. The group meets at least once a year at a joint sector review to assess the sector's performance and this feeds into the Malawi Growth Development Strategy progress reporting system. The joint sector review is the basis for a dialogue on policy revisions, strategy and programming.

This type of dialogue at national level also provides the opportunity to initiate design standard revisions, which may be a way to significantly enhance the resilience of new transport sector investments in particular (117).

5.2.2 Capacity building

The overall level of adaptive capacity across LICs in Africa and South Asia is low, in that they do not currently have the social or economic means to withstand the impacts of climate change (23).

This low adaptive capacity is connected to low levels of competency in governments, as they struggle to manage complex socio-ecological change and translate it into ad-hoc project level support (23). Improving competency requires increases in institutional capacity and improvements in knowledge. The latter can be transferred into actions that help LIC governments manage the impacts of changes in climate, society and environment and build compelling applications for funding. Improving the capacity of transport stakeholders could therefore lead to transformational change.

5.2.2.1 Climate and technical knowledge

The stakeholder interviews within this project emphasised that improved knowledge is necessary to help transport stakeholders articulate the scope of the climate change problem for transport infrastructure, now and in future. Good climate knowledge comes from good data. Limited or lack of access to good quality data, such as meteorological data and data from monitoring transport infrastructure and assets, is a major barrier in delivering improved climate knowledge.

Instead of developing new systems exclusively for transport stakeholders, they could benefit from joint databases and repositories for data sharing with other organisations, such as infrastructure practitioners, ministries and meteorological agencies. This would provide common ground for understanding risks that in turn could inform policymaking. Including the use of very local data would also strengthen local institutions (142). Adaptation platforms are an effective, centralised way to hold such information, but only if stakeholders are aware of them.

National government would need to oversee and take accountability for processes that standardise the provision and management of data. However, there need to be avenues for data users to provide feedback to data providers on how data is used; this kind of feedback loop could help decision-makers better link meteorological and climate events, their longer-term impacts and the actions to take in specific sectors. For example, this process could help define drought conditions across regions in order to help develop and implement a drought early warning system that transport stakeholders could access (41).

Mobilising the private sector in LICs can also support technical capacity building. Private sector involvement in projects can lessen burdens on human, technical and financial resources. This may be key to unlocking development opportunities that support transport and infrastructure resilience. Involving the private sector in projects may also allow decision-makers to tap into their tacit knowledge on infrastructure design, implementation and monitoring and evaluation of adaptation actions.

Information provision in capacity building can be incremental – the primary objective is to embed climate change information into planning and management systems (117).

5.2.2.2 Accessing and allocating financial resources

The adaptation financing gap in less developed nations around the world is still wide (149), even though climate change is acknowledged as a financial risk (54). Only a small fraction of global financing reaches countries such as LICs in Africa and South Asia, and even less of this reaches local level, which is where climate

action is required (150). Additionally, only a small fraction of all climate finance comes from dedicated climate funds that are transparent enough for analysis (150).

Building resilience takes time and LICs' financial resources are not consistent. There is therefore a need to secure funds over longer time periods to maintain sustainable income in order to build the relevant support and political buy-in (150). To secure large levels of funding for long-term projects, such as through the Green Climate Fund, those within national governments who apply for these funds require upskilling. This loops back to capacity building needs in climate and technical knowledge (see Section 5.2.2.1).

In addition, local governments should have greater involvement in adaptation planning processes and require greater access to funds from national government. Therefore, to have a positive impact on transport resilience for local communities, it is critical that there is an improved level of communication between all levels of government in LICs in Africa and South Asia.

Initiatives through public–private partnerships are an opportunity to further increase funds and/or reduce financial risk to the public sector as the private sector absorbs the additional costs. The Green Climate Fund incentivises the private sector to engage in proposals and hence may have the additional benefit of increasing the likelihood of additional funding for LICs. This incentive has not been utilised in past proposals by LICs in Africa (136), demonstrating a need for LICs to increase private sector engagement or build capacity to understand the most appropriate way to mobilise them in order to strengthen applications.

5.2.2.3 Integrating climate change adaptation and disaster risk reduction

A strong governance system can help achieve long-term resilience by facilitating the integration of climate change adaptation and disaster risk reduction in an effective way. This would enable more efficient use of human and financial resources. This would require collaboration between experts in climate change adaptation and disaster risk reduction and policymakers at national level in a range of activities including (142):

- Mapping institutional mechanisms and legal frameworks already in place for climate change adaptation and disaster risk reduction to identify synergies, crossovers and gaps;
- Collaborating with cross-sectoral and local, regional and national stakeholders (see examples in Figure 18) through peer-learning exchanges to review information and identify opportunities to harmonise these institutional mechanisms and legal frameworks and address the gaps;
- Promoting integrated legal frameworks that address both climate change adaptation and disaster risk reduction with respect to the needs of vulnerable groups;
- Integrating administrative setups of existing mechanisms, such as disaster risk platforms or climate change committees, to produce joint platforms or committees;
- Increasing awareness and understanding through training and peer-learning exchanges;
- Systematic integration of policymakers and experts in climate change adaptation and disaster risk reduction through national and local platforms and committees;
- Utilising processes such as NAPs to involve lead implementing agencies on climate change adaptation and disaster risk reduction to facilitate structural integration;
- Utilising national statistics offices to produce and centralise relevant data and information;
- Utilising monitoring and reporting processes such as the Sendai Framework.

When climate change adaptation and disaster risk reduction are not integrated, the input into EIAs can lack cohesion. There are significant benefits to identifying national and international climate change obligations early in the EIA process of a project. Failing to do increases the risk of overlooking necessary adaptation measures, thereby resulting in greater future costs (151). Such integration requires both human and technological capacity building, underpinned by greater monitoring and evaluation processes.

An integrated function covering both climate change adaptation and disaster risk reduction may require its own policy in order to address both loss and damage from extreme events and slow onset processes (152).

5.2.3 Stakeholder engagement

Communicating with transport stakeholders should take place from the start of adaptation planning and continue throughout the process. Decision-making can be made more effective by engaging those stakeholders directly affected in some way by the impacts of climate change on transport (and thereby affected by adaptation planning decisions) (117). This also makes adaptation planning processes more transparent. Through an integrated approach, stakeholders can anticipate and mitigate negative impacts more effectively (117).

The project's literature review, stakeholder interviews and capability assessments revealed that some transport stakeholders are underrepresented in LIC planning for transport resilience to climate change. It is not clear whether there is a specific reason this happens. Figure 18 shows the types of transport stakeholders LICs would benefit from engaging with during their adaptation planning process. It is not an exhaustive list but does illustrate the breadth of stakeholders involved.

Local communities in LICs across Africa and South Asia require increased inclusion in climate change adaptation decision-making processes, and arguably should be at the heart of adaptation planning. Local engagement is important because understanding what local communities would value most in terms of current and future improvements in quality of life and standards of living can inform which actions should be prioritised for long-term resilience building (149). This emphasises the benefits of including local communities at multiple stages of the adaptation planning process, particularly at the early "scoping" stage.

Another important reason to include local communities is because it enables women in particular to contribute to the planning processes, whereas they often lack access to or involvement in political decision-making (65). Even in a situation where there is an inadequate or absent budget for transport adaptation, engaging local community stakeholders would help to identify possible remedial actions for when weather-related disruption to transport occurs. Local stakeholders would include businesses, clinics, hospitals, farmers, charitable organisations, non-governmental organisations (NGOs) and development partners.

Engaging with the private sector in LICs may also support local engagement, as they may have the capacity to support local activities that national or local government has difficulties participating in. In Malawi (53), for example, the Ministry of Transport is planning to train its staff on the development, management and monitoring of public–private partnership projects, as recommended in academic studies (55). If LICs rethink the purpose of private sector involvement from being a funding body to an innovation resource (137), it may help build the technical capacity they need to push forward transport adaptation to provide resilience to climate change. LICs should utilise the private sector as a means to an end, not an end in itself (137).

5.3 Channels and options to facilitate LICs' needs

There are resources and support available to LICs in Africa and South Asia to meet their needs in achieving transport resilience for climate change adaptation. However, LICs may not be aware of them or do not have the ability to select what is appropriate for them. Therefore, the support and resources available need greater signposting.

Some of the options are provided in the following section, based on the findings of this project.

Figure 18: Example stakeholder groups and institutions for transport adaptation consultation

Source: Adapted from Burton et al. (153)

5.3.1 Progressing national adaptation planning and mainstreaming into policy

NAPs in LICs across Africa and South Asia are in their infancy and many countries are in the process of developing their first NAPs (some may already have published a NAPA), which support the mainstreaming of adaptation into policy. Developing and reviewing NAPs over time ca provide a formal snapshot in time of resilience building in progress, as it reflects a LIC's improved government coordination, institutional capacity and stakeholder engagement.

The transport sector requires greater visibility in national adaptation planning. This project's review of NAPs indicates that this is beginning to happen.

5.3.1.1 Adaptation pathways

Developing adaptation pathways would benefit LICs as they enable a long-term perspective, particularly where there are greater magnitudes and rates of climate change projected (12). The assessment of NAPs and NAPAs across Africa and South Asia suggests that the adaptation plan aspects are relatively good, which in turn suggests that LICs could strive for excellence by steering their adaptation plans into adaptation pathways.

Adaptation pathways are a technique that, while still relatively new in concept, has been tested in a number of cases across the world, particularly in the infrastructure sector. A well-known example of applying an adaptation pathway technique is the Thames Estuary (the plan is known as TE2100) – part of the River Thames in the UK – where defences are required to manage tidal flood risk and protect the millions of

residents in London from the effects of sea level rise. Implementation lead times for adaptation options were estimated, as well as points in time where decisions would be required and approved before actions. The adaptation pathway included a cost–benefit analysis according to climate scenarios.

Some key industry bodies advocate for the adaptation pathway approach. PIARC's International Climate Change Adaptation Framework for Road Infrastructure (154), which is currently being updated, refers to them as forming an element of the third part in its four-stage framework and TE2100 is provided as an adaptation pathway case study in supporting documentation (155). The concept of adaptation pathways is incorporated directly into the guidelines in the PIANC adaptation framework in the fourth part of its four-stage approach for ports and inland waterways (96), as well as in the rail sector through the Rail Adapt framework (59), which would enable adaptation to be embedded into its "business as usual" processes (156). The impending updates to the PIARC International Climate Change Adaptations will also pay particular attention to defining the starting point or baseline for adaptation, in order to capture all the various needs of road authorities, including LICs and LMICs.

The adaptation pathway approach is also emerging in developing countries. Proposals to utilise them include adapting Tunisia's most vulnerable coastal areas (157), as well as on coastlines across central Africa (158). The government of Malawi has also mentioned the use of adaptation pathways as part of its upcoming NAP. Malawi proposed working group meetings to support the design of adaptation pathways alongside experts drawn from various sectors relevant to climate change adaptation in order to build capacity (159). On the basis that adaptation pathway strategies such as TE2100 are reviewed every five to 10 years, this could align with NAP monitoring and review processes for LICs, helping integrate them into pre-existing structures that support capacity building.

5.3.1.2 Sustainable implementation

Sustainability, as defined by the IPCC (12), is the "dynamic process that guarantees the persistence of natural and human systems in an equitable manner". Similarly, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Therefore, when implementing adaptation plans, LICs need to consider how they apply sustainable practices and promote sustainable development in order to provide a balance between infrastructure and nature, as well as to provide equitable prosperity for current and future generations. Sustainable transport infrastructure and services would also complement efforts to mitigate climate change as well as adapt to it.

Sustainability-led approaches in the context of implementing adaptation plans can comprise a range of actions. From an institutional perspective, this may include growing adaptive capacity through improving analytical skills and technical information for iterative planning. It may also include shared decision-making across government that includes stakeholder engagement on the "what" and "how" of adaptation projects (126).

Practically speaking, sustainable implementation in terms of resource management includes utilisation of nature-based solutions or locally sourced materials, including consultation with local stakeholders to incorporate their skills and knowledge, and encourage their buy-in and ownership. As per ISO 14090 (10), top management (in this case, heads of national government or relevant ministries) should demonstrate their support for implementation by taking accountability for it. They should ensure there are clearly defined terms of reference for the adaptation plan, which transparently describe objectives, outcomes, activities and stakeholders involved (153).

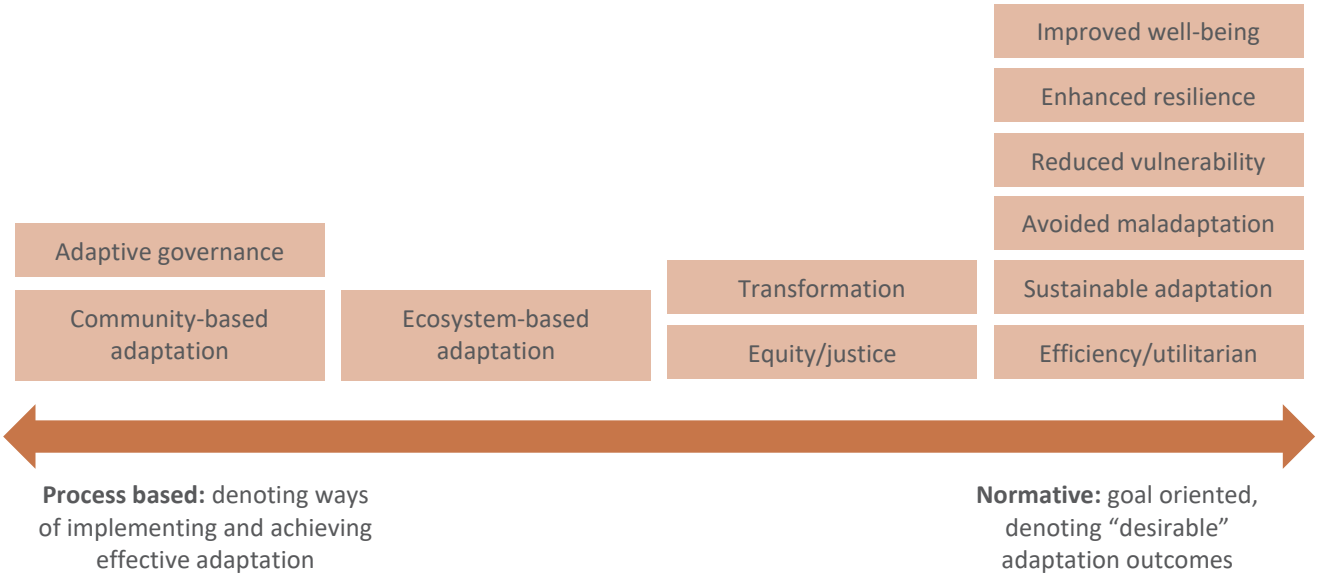
5.3.1.3 Monitoring and evaluation

The competency of monitoring and evaluation processes across LICs in Africa and South Asia varies, based on the project's evaluation of NAPs and NAPAs.

Effective monitoring and evaluation is important for LICs as it can help monitor implementation as well as measure results (160). It can support capacity building, such as enhancing the processes in data collection and dissemination of lessons learned, which leads to improved knowledge management (157). However, monitoring and evaluation approaches are likely to depend on the adaptation plan or project approach, such as whether it is based on hazards, vulnerability, policy or adaptive capacity (153). Similarly, the way an adaptation plan is framed will influence whether the monitoring and evaluation process would measure outcomes as effective. Figure 19 shows 11 ways that effective adaptation can be conceptualised and informed

by different underlying assumptions or biases, which therefore affects implementation and outcomes (161). The reviewed NAPs and NAPAs lean more to normatively framed plans.

Figure 19: Framing of adaptation from process based to normative



Source: Adapted from Singh et al. (161)

Monitoring and evaluation will therefore vary, as there is no "one size fits all" approach. Some countries only frame adaptation in limited ways, which could explain the range of competence in monitoring and evaluation processes in NAPs and NAPAs.

Bodies responsible for NAPs and NAPAs, such as national government leaders and ministries of environment or transport, should focus attention on developing or improving monitoring and evaluation in national adaptation planning. This may require use of a tool such as the Adaptation Monitoring Evaluation Navigator decision support tool (160), or expansion of adaptation plans to consider different perspectives of the challenge, as shown in Figure 19.

5.3.1.4 Reporting and communication

Explicit reporting and communication plans were absent from some of the NAPs and NAPAs reviewed in this project. This could be linked to the extent of detail or quality of monitoring and evaluation processes, as reporting and communication activities would take place as an outcome of monitoring and evaluation. Communicating adaptation, particularly as part of NAPs, is important for transport stakeholders, as it helps give the sector an effective voice and aids the perception of adaptation being integrated into "normal business", which can have a lasting impact (59) – this may be in terms of increasing infrastructure resilience to weather and climate and reducing the cost of weather-related damage over the lifetime of the asset

The challenge for LICs in Africa and South Asia is that they may lack knowledge regarding the optimal channel through which to reach intended target audiences. The average age of the population in LICs is typically younger than in MICs and HICs, and this has an implication for which media platforms are preferred (i.e. social media). Ministries or bodies responsible for adaptation therefore need to research the channels available for communication, which could include engaging with private media as well as seeking opportunities within government departments (see Case Study 3).

5.3.2 Resource utilisation

There is a large volume of resources available to support adaptation planning for transport; however, LICs in Africa and South Asia have not utilised them, or at least not fully. LICs may not be aware of the resources available or do not yet have the capacity to implement them, or do not believe they are fit for purpose (specifically for LIC needs). Transport stakeholders in LICs may also be overwhelmed by the volume of resources available and lack the capacity to identify what is most appropriate for their needs. Therefore, it is important that signposting is provided to help LICs rationalise resource options and choose suitable ones.

5.3.2.1 Tools and frameworks

This project identified that effective adaptation planning may require the use of multiple tools and frameworks to help build knowledge and skills. Those best suited for specific steps in the adaptation planning process for LICs require signposting, as some of the most effective tools and frameworks do not cater to multiple steps in the adaptation planning process.

Furthermore, tools and frameworks should be used at national, regional and local levels to achieve vertical integration of adaptation plans, ensure common goals and empower local level and marginalised community groups during adaptation planning. Stakeholder engagement is essential. Tools and frameworks should not be used in isolation.

Adaptation platforms provide a way to host many tools and frameworks centrally and can be seen as the key to enabling action (162). Reviewing an existing national platform, if available, and comparing it with other national platforms would support peer knowledge sharing and help identify best practice.

5.3.2.2 Data and technological innovation

Access to good quality weather data, or any weather data at all, is a challenge for LICs in Africa and South Asia. However, access to such data is important as the evidence shows that the climate across these regions is changing and some of the extreme weather they have already experienced has been severe. They would therefore benefit from support in finding and accessing appropriate sources of weather data for analysis.

The IPCC has identified that lack of access to historical weather records creates a major knowledge gap, which could be addressed by integrating access to data from other sources such as satellites (23). LICs are beginning to access satellite data to supplement data shortcomings in weather observations and are using integrated models for impact analyses (41,79), but this is not widespread nor is it used in their transport sectors.

The rollout of 5G mobile cellular networks could have a positive impact on the application of smart sensing, metering and monitoring for the transport sector, as well as for disaster management and response (163). However, awareness and uptake in LICs is currently low. Both knowledge and financial capacity need building in order to incorporate such technologies into projects to increase the resilience of transport networks.

5.3.2.3 Transport infrastructure design innovation

Infrastructure practitioners interviewed for this project were particularly interested in increasing transport resilience for climate change adaptation by enhancing infrastructure in locally sustainable ways (i.e. reducing their dependency on imported material or supplies). LICs could therefore benefit from signposting towards ways do this.

Including the private sector in adaptation activities in a structured way can present business opportunities. Firstly, it helps open up a market for new and innovative products. Secondly, involving specialised businesses (such as those who understand and allow for climate risks during design and implementation) to support publicly-funded activities can result in greater innovative capacities, thereby enlarging existing markets (130).

5.3.2.4 Collaboration

The outcomes of stakeholder engagement should be utilised as they provide a valuable resource for transport adaptation. LICs in Africa and South Asia would benefit from knowledge exchange through a facilitative, collaborative approach, because countries that have areas of similar climate or socio-economic status may have different or novel ways of tackling the same problem. This is shown in Case Study 5, where southern African cities successfully undertook knowledge exchange workshops supported by academics to improve urban climate resilience in the partner cities.

Case study 5. City-to-city knowledge transfer through FRACTAL: Future Resilience for African Cities and Lands

The FRACTAL project (164) was devised to advance scientific knowledge about regional climate responses to human activities. Led by a trans-disciplinary group of researchers from partner organisations around the world, it was originally a four-year project (2015 to 2019) but received a funded extension to mid-2021. The funding was through the former UK Department for International Development (now the FCDO) and the Natural Environment Research Council.

The project operated in nine cities in southern Africa. University officials collaborated with city practitioners to develop research questions around resilience, co-exploring on solutions and trans-disciplinary dissemination of findings. During city exchange visits, researchers, decision-makers and practitioners from two or more cities learnt from each other about key climate change adaptation processes. These exchanges fostered co-learning through shared experiences, lessons, best practices and failures among cities (86).

The FRACTAL project enabled city officials to build capacity in their climate knowledge by transforming complex climate information into a format they were able to engage with, in the form of a "climate risk narrative" (CRN). The CRNs were developed at city level, building stories in an engaging way on relevant climate risks, the potential impacts and suggested societal responses. In turn, the narratives helped climate scientists understand the city context and encouraged city officials, community representatives and social scientists to engage. The CRN process was rearranged for some activities in the participating cities, starting with a socio-economic narrative. Applying a climate lens to the outcomes was an engaging activity as it started by dealing with issues important to the city participants (165).

The cities benefitted from sharing information on urban challenges, such as waste and water management, informal settlements, energy issues and city planning, in order to find innovative solutions to common problems. Community engagement to find solutions "with" as opposed to "for" the people on the ground was successful and, in some cities, could lead to green job creation (87).

To date, the FRACTAL researchers have published 30 journal articles on the project's outputs (164).

5.4 Conclusion

This project has identified that LICs have a variety of knowledge gaps and needs that must be addressed in order to achieve transport resilience. Primary barriers are a lack of knowledge, lack of options, failures to act and insufficient funds. LICs require greater attention and support around government coordination, capacity building and inclusion of relevant stakeholders to deliver transport that is more resilient.

Delivering resilient transport that adapts to climate change requires engagement between national and local government; where LIC governments are decentralised, special attention is required to help drive a coordinated approach. A similar consideration applies across government sectors and ministries as transport disruption can propagate through an area and affect multiple sectors. Different sectors therefore need to communicate with each other to ensure all are kept informed and activities are initiated to move adaptation activities forward.

Capacity building is necessary to enable and mobilise transport stakeholders in LICs across Africa and South Asia to take action. This can happen in a range of ways: increasing climate and technical capacity could include introducing collaborative data sharing practices or private sector mobilisation; improving financial capacity could include increased upstream and downstream engagement with those at a local level to strengthen applications for multilateral funding; and streamlining climate change adaptation and disaster risk reduction practices can free up overlapping resources.

Full engagement of transport stakeholders should take place through scoping, planning, implementing and monitoring at all stages of adaptation. This is essential to meet the needs of local and marginalised communities directly affected by the impacts of climate change. Their tacit knowledge could be valuable when it comes to determining appropriate remedial actions for transport resilience, even where budgets are limited.

LICs in Africa and South Asia need to increase consideration of transport needs in their NAPs. Future NAP revisions (and first NAPs based on existing NAPAs) could be enhanced by: developing pathways for adaptation options; sustainable implementation of these options; improving monitoring and evaluation programmes; and

defining reporting and communication plans. These NAPs could consider process-based framing to review not only the progress of an existing adaptation option's implementation, but the ways in which implementation is undertaken for future improvements.

There are numerous resources available to LICs in Africa and South Asia, but they could benefit from signposting to those that are most useful for their circumstances. Tools and frameworks, innovation in data and design, and collaboration opportunities are all valuable resources when it comes to building transport resilience. Some LICs, though not many, are beginning to tap into these resources, but they require support to identify how best to utilise them and to elicit help from the most appropriate stakeholders.

6. Report summary and future directions

The scope of this project was to identify the challenges, barriers, interest and gaps in knowledge and/or capacity building related to climate change adaptation for transport resilience. This included: a review of how the climate has and is projected to change across LICs in Africa and South Asia; the physical, social and economic impacts of weather and climate upon transport infrastructure; the extent of national adaptation ambitions; the extent of action taken and planned by transport stakeholders; the challenges and barriers in achieving transport resilience; and the knowledge gaps and needs that have to be addressed in order to facilitate increased transport resilience for climate change adaptation.

The project team collected and analysed primary data through stakeholder interviews and reviewed secondary data such as academic and non-academic literature, reports (including capability assessments of policy [NAPs and NAPAs]), tools and frameworks. Interviews with transport stakeholders from across Africa and South Asia provided specific transport-focussed results that were particularly related to physical infrastructure and operational activity, whereas the secondary data provided broader insights into adaptation themes and concepts, such as governance, institutional arrangements and national perspectives on climate change adaptation.

The research questions this project aimed to answer fitted broadly into four categories:

- Future weather patterns as a result of climate change;
- The impacts of climate change on transport, society and the economy;
- Transport resilience and infrastructure adaptation;
- Capacity building and financing projects.

Appendix A shows where the evidence answering each research question can be found within the report.

This project identified several key findings, which are discussed in this report:

- The climate is noticeably changing across Africa and South Asia – particularly in the last 10 years. Continued climate change will include changes in precipitation that will have specific consequences for countries in these regions related to increased intensity and unpredictability, seasonal shifts and their greater exposure to monsoon and cyclone events;
- While tools and frameworks relevant for adapting transport to climate change are created using credible scientific sources, their design may not be suitable for the technical capacities of LICs, limiting their use and/or effectiveness;
- Some of the most appropriate tools and frameworks relevant for adapting transport to climate change only focus on one step in the adaptation planning process;
- Insufficient data hinders the ability of LICs to analyse the impacts of weather on transport infrastructure and is probably partly responsible for LICs' technical and knowledge capacity gaps;
- Monitoring of weather by transport stakeholders is mostly informal, as they do not have the capacity to formalise the process, primarily because of lack of data, knowledge or awareness of the issue;
- Transport maintenance budgets take precedence over enhanced resilience, much of which is due to weather-related impacts in some countries. The cycle of chasing ever more funds for increasing annual maintenance costs is unsustainable because this does not increase resilience to the worsening impacts of climate change;
- If money was no object, transport stakeholders feel transport resilience could be built through improvements to hard infrastructure (linked to design standards) and increasing the profile of climate awareness in the sector;
- Transport stakeholders do not explicitly link impacts of weather on transport infrastructure to wider socio-economic issues;
- Transport is underrepresented in NAPs and NAPAs across Africa and South Asia; however, where these have matured over time, the inclusion of transport does increase;

- The adaptation planning stages in NAPs and NAPAs are comprehensive and could be enhanced by designing adaptation pathways;
- Monitoring and evaluation processes in NAPs and NAPAs require improvement, and could be influenced by reframing the way adaptation options are implemented;
- Multilateral funding for transport-led projects is almost entirely lacking across LICs in Africa and South Asia. Governments and institutions need greater knowledge in this area in order to access this funding and disperse it to local governments; however, this is particularly challenging for decentralised governments as their capacity building needs are more widespread and the competition for funds may be greater;
- The private sector presents a significant opportunity to access funding. This can be either directly through mobilising their investment in adaptation projects or through their inclusion in multilateral funding applications (such as the Green Climate Fund); both approaches may increase a LIC's chance of securing such funding;
- Stakeholder engagement at all stages of transport resilience for climate change adaptation is crucial. Local community engagement should take priority in order to build knowledge and technical capacity; it also helps empower marginalised groups to meet their development needs and fosters sustainable implementation.

In terms of future directions, this report highlights key barriers to increasing transport resilience in LICs. These can be addressed by the following actions:

- **Improved government coordination:** Improving the relationships between national and local government and among ministries and sectors, to share knowledge, facilitate data sharing and downscale NAP implementation to local level;
- **Capacity building:** Upskilling by increasing technical knowledge to improve awareness of climate change, the impact of weather on infrastructure and the tools and resources available; improving financial knowledge and access to data; mobilising under-utilised sectors of society and the private sector; and streamlining processes where climate change adaptation and disaster risk reduction cross over;
- **Stakeholder engagement:** Increasing the participation of all groups affected by the impacts of climate change on transport, enabling them to contribute to adaptation options and decisions, leading to sustainable implementation and effective monitoring and evaluation.

LICs in Africa and South Asia require support and guidance to take steps towards transport resilience for climate change adaptation. This highlights the importance of local, national and international collaboration, the sharing of knowledge and ideas, and iterative processes that drive change that is gradual and incremental, but ultimately transformational.

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APPENDIX A: PROJECT RESEARCH QUESTION REFERENCE TABLE

Research question	Research question category	Research findings	Section reference
To what extent are changing weather patterns monitored and analysed in Africa and South Asia, and how can LICs access the outcomes?	Future weather patterns as a result of climate change	The level of monitoring and analysis varies across LICs in Africa and South Asia. Some rely on national meteorological data (which can be fragmented) or through regional meteorological agencies. This is historic and may include near-term forecasts. From a transport perspective, most stakeholders have access to historic data, often at low or no cost from meteorological agencies.	2.2.1 3.5.1 4.2.1 4.3.3
To what extent are LICs in Africa and South Asia monitoring and analysing changing weather patterns and are the outcomes available in an appropriate form for transport professionals?	Future weather patterns as a result of climate change	NAPs and NAPAs demonstrate a high-level understanding of climate impacts across LICs, but analysis is often at a national scale, which is less likely to be relevant to transport stakeholders. Transport stakeholders mainly access historic temperature and precipitation data, but most stakeholders only analyse the data informally or do not have the capacity to analyse it in the context of their infrastructure. Furthermore, some transport stakeholders are not fully aware of the link between climate change and impacts on transport infrastructure, so some are not monitoring or analysing due to a lack of awareness.	3.4.1.1 3.5.1 3.5.3 4.3.3 5.2.2.1
What tools are available to LICs to identify vulnerable sections of infrastructure and related services, and their locations?	The impacts of climate change on transport, society and the economy	There are numerous tools and frameworks available to transport stakeholders that support adaptation decision-making. Most of the online resources are free and web based. They often focus on one aspect of the adaptation planning process, but there are also mode-specific frameworks that cover multiple aspects. However, the way tools and frameworks are designed may not be suitable for the technical capacities of LICs or are presumed by LIC stakeholders to be more useful to HICs, therefore limiting their use and/or effectiveness for LICs.	2.6.3 4.5 5.3.2.1

Research question	Research question category	Research findings	Section reference
What advances in technology can facilitate monitoring of infrastructure performance to climate change, for instance rail track performance in higher temperatures?	The impacts of climate change on transport, society and the economy	Transport stakeholders mentioned that artificial intelligence, drones and "unmanned monitoring vehicles" would be useful for monitoring purposes. However, monitoring is not undertaken in all LICs, so establishing formal monitoring practices would be required first. This would require improved data to start with, such as satellite data, or consideration of the implementation of 5G.	3.5.4 5.3.2.2 5.3.2.3
To what extent are infrastructure design methods and specifications changing to take account of climate change events?	The impacts of climate change on transport, society and the economy	Design specifications of transport infrastructure are in place in LICs, but not in all of them. Many are outdated or in the process of updating, as they are based on historical thresholds. Climate projections are not referred to where revisions are underway.	2.6.2 3.5.3.2 4.3.4
To what extent do coastal LICs and SIDS have disaster preparedness plans and recovery strategies that protect their critical transport infrastructure and services?	The impacts of climate change on transport, society and the economy	Most transport stakeholders did not have, or were not aware of, any strategy related to a business recovery plan for infrastructure. Bangladesh was the only country to provide any detail on this, referring to a National Resilience Programme that includes a project to implement asset management policies.	3.5.3.3 4.3.1
What is the extent and scale of the cost (direct and indirect) of these disruptions on the economy, businesses and people in LICs in Africa and South Asia?	The impacts of climate change on transport, society and the economy	GDP loss is likely to increase, and the rate of loss may vary depending on whether an area is likely to experience a drier or wetter future climate.	2.4.3.1
What is the extent and scale of the cost of these disruptions on transport infrastructure and the viability of transport services?	The impacts of climate change on transport, society and the economy	Costs to transport infrastructure caused by climate change can be widespread and related to maintenance, infrastructure and operations. Maintenance costs, for example, are increasing year-on-year for some LIC transport infrastructure. In LICs in Africa, the level of maintenance of road infrastructure relative to economy size is comparatively high, while still considered low when compared with other developing countries. For transport networks that generate their own income, the COVID-19 pandemic has exacerbated resource issues due to loss of funds and therefore monitoring and maintenance activities are not prioritised. There is a risk of a perpetuating a feedback loop of poor quality infrastructure, greater transport disruption and less maintenance undertaken.	3.5.3 4.3.1

Research question	Research question category	Research findings	Section reference
What is the extent of cooperation between transboundary river basin management authorities and regional and national transport agencies on sharing rainfall data, flood management strategies, and identifying vulnerable road, rail and urban infrastructure?	Transport resilience and infrastructure adaptation	Cooperation varies. Some transport stakeholders liaise with other ministries, whereas others do not. The main purpose of cooperation relates to data sharing, which helps provide a more regional perspective or raise awareness of climate issues. However, there is evidence of a lack of collaboration between river management and transport agencies, which in one case led to the inundation of some road infrastructure for a year following actions to manage lake levels by releasing water.	3.5.1.2
What is the extent of cooperation between municipal agencies within urban conglomerations to mitigate flooding caused by poorly controlled development and to protect transport infrastructure and services?	Transport resilience and infrastructure adaptation	Municipal agencies and local governments require greater involvement in national adaptation planning to address these sorts of challenges; there are particularly challenging capacity issues at local levels of governance in LICs where governance has been recently decentralised. A recent project, with the support of academia in Southern African cities, has tested a knowledge sharing approach to adaptation, with positive results. Therefore, while collaboration at present may not be extensive, there is growing evidence that this may be achievable in future to address this particular issue.	5.2.1 5.3.2.4 Case Study 5
To what extent are regional and national transport and planning agencies in LICs equipped with tools to identify vulnerable road and rail infrastructure, and if so, to what extent has vulnerability been identified?	Transport resilience and infrastructure adaptation	Some NAPs and NAPAs document that ministries accessed tools for impact analyses, but this is limited to few countries and is not transport-specific. LICs are aware that transport systems may be impacted by climate change, but the level of understanding and focus varies. Transport stakeholders are beginning to identify that their infrastructure is vulnerable to climate change, but this knowledge is not widespread nor is it mainstreamed in activities. It has been identified to the extent that current transport design standards are recognised as insufficient and budgets for maintenance are increasing.	Case Study 3 3.4.2 3.5.1 3.5.3 4.3.3

Research question	Research question category	Research findings	Section reference
To what extent are LIC transport agencies aware of guidance published on road, rail and urban transport resilience by PIARC, UIC, TRL, Resilience Shift and the World Bank?	Transport resilience and infrastructure adaptation	Only four interviewees had accessed guidance documents or materials on transport resilience to weather and climate from these organisations. Reasons for not accessing the current available guidance were not provided. Two interviewees mentioned the PIARC adaptation framework, although one noted this required localisation for their country as it was more relevant for HICs. The ReCAP project was also mentioned but is not used yet as stakeholders feel additional training is required in order to implement it.	4.3.4
To what extent have LICs identified options to reduce the vulnerability of infrastructure, for instance road and rail relocation, raising road and rail levels, increasing drainage capacity, sea and river wall protection, etc.?	Transport resilience and infrastructure adaptation	Options LICs have addressed include increasing culvert size, making embankments and retaining walls higher, using more gabions, installation of rain gardens, larger drainage and longer bridges. Hard infrastructure improvement is a primary option and if money was no object, many stakeholders identified these types of options would be important for them to implement. However, the barriers to implementing this include a lack of awareness of the issues and a lack of funding to implement.	3.5.3.3 3.5.4 5.2
To what extent are transport agencies in LICs carrying out recommended road, rail and urban transport maintenance in a timely manner? Or where recommended, carrying out enhanced maintenance?	Transport resilience and infrastructure adaptation	Maintenance schedules in some LICs do not account for the effects of climate and require updating, therefore LICs are unlikely to be undertaking activities in a timely manner. Responses to weather events are reactive, including infrastructure repair and rehabilitation activities. There is also little-to-no formal process to prioritise emergency maintenance or repair. Enhanced maintenance is therefore unlikely to take place.	3.5.3.1 3.5.3.3 5.2.2.1
To what extent is the knowledge on climate change leading to revised road design, for instance using alternative road binders?	Transport resilience and infrastructure adaptation	In most instances, weather and climate are not integrated into design standards in LICs, but stakeholders see this as an aspiration to work towards. One transport stakeholder referred to the revision of standards and manuals to account for climate resilience, but detail was not described. Many stakeholders expressed concern that there is a lack of knowledge of climate change regarding transport infrastructure and therefore it is only integrated into revised design standards to a limited extent.	3.5.3.2 4.3.4

Research question	Research question category	Research findings	Section reference
To what extent are regional and national transport agencies enforcing regulations that protect road and rail infrastructure, for example vehicle loading and axle load limits?	Transport resilience and infrastructure adaptation	Transport-specific adaptation plans in NAPs and NAPAs do not include enforcing regulations that protect transport infrastructure. Most stakeholders also do not have or enforce regulations. This gives transport stakeholders less incentive to act – no stakeholders were able to provide any non-compliance consequences.	3.4.1.3 4.3.4
To what extent are LIC transport agencies equipped and capable of warning users and authorities of climate-related transport disruptions?	Transport resilience and infrastructure adaptation	Early warning systems are not utilised across all LICs and those who do have found there are limitations. Infrastructure is not closed nor are services reduced as a precautionary action. It is unclear who is responsible for closing infrastructure or services – it varies by LIC.	3.4.2 3.5.3.3 3.5.4 4.3.1
To what extent are LIC governments quantifying the broader impact of climate change related disruptions? And where road, rail and urban transport disruption could severely affect the economy, business and people, is the case being made to make road, rail and urban transport networks more resilient?	Transport resilience and infrastructure adaptation	More mature national adaptation documents such as NAPs (as opposed to NAPAs) are increasingly incorporating transport into their adaptation plans and therefore their impact assessments are more likely to incorporate them. Specific concerns raised in NAPs include the vulnerability of roads due to their quality or condition and their role as a link to other vulnerable sectors, such as agriculture or health. Transport stakeholders, on the other hand, have a more challenging time quantifying these impacts themselves.	3.4.2 3.5.2 3.5.3 4.2.1
What examples exist of a coordinated approach and how could these be adapted for LICs?	Capacity building and financing projects	Some of the more mature NAPs demonstrate a greater extent of stakeholder engagement, with the leadership being accountable for implementation and chairing councils on climate change. Knowledge sharing among cities and regions was a successful example for LICs, by LICs. With support from academia, this process could be expanded elsewhere. Sector working groups could steer design standard revisions.	Case Study 1 3.4.1.3 Case Study 3 5.2.3 5.3.2.4 Case Study 5
What innovative strategies using new technology could improve the patchy data collection and analysis in many LICs on changing weather patterns, road and rail infrastructure conditions, vulnerability that requires rigorous programming and monitoring?	Capacity building and financing projects	Integrating satellite data into patchy data across LICs will improve data – some LICs are already starting to access this sort of data for their NAPs. The rollout of 5G mobile cellular networks could have a positive impact on the application of smart sensing, metering and monitoring for the transport sector, as well as for disaster management and response.	5.3.2.2

Research question	Research question category	Research findings	Section reference
What are the potential opportunities for tailoring some of these initiatives on capacity building on climate change promoted by PPMC, TUMI, etc. to LICs' institutional situations?	Capacity building and financing projects	Newly decentralised governments in LICs would require support and they, in particular, would require further capacity building in both climate knowledge and finance mobilisation. This could be in the form of accessing the appropriate funding themselves, or how to improve engagement with national government to gain access to larger, national funding sources.	4.2.1.3 5.2.1
To what extent are LICs able to tap into the financial market and secure finance through insurance-linked loan packages (InsuResilience Global Partnership), resilience impact bond, etc.?	Capacity building and financing projects	ISF is in its infancy and is not yet reflected in NAPs and NAPAs. However, insurance-linked funding and products are mentioned in NAPs and NAPAs but are currently focused on the agriculture sector for weather-indexed crop insurance. There needs to be greater efforts made to promote these types of funds for LICs, so that they are captured in future NAPs.	4.2.3.1 4.2.2.1
To what extent are LICs eligible to draw upon climate change and disaster relief initiatives, for instance the Global Facility for Disaster Reduction and Recovery or the ACP-EU Natural Disaster Risk Reduction Program?	Capacity building and financing projects	Some NAPs and NAPAs identify funding sources that include climate change and disaster relief initiatives. However, not all LICs provide the same level of detail; as such, the amount that has been allocated to date to these LICs is unequally distributed. Virtually no adaptation funding was previously allocated to transport-specific projects.	4.2.3.1 4.2.2.1
To what extent can LICs leverage funding from traditional development partners for additional funding in early project preparation processes to integrate climate change design measures?	Capacity building and financing projects	Most transport stakeholders have not been directly involved in accessing these types of funds, stating that they are available in a different sector (such as agriculture) or handled at a higher level than theirs (such as ministerial), or they do not know the mechanisms available to approach funders.	3.5.4
How should resilience works be prioritised and how could access to finance influence prioritisation?	Capacity building and financing projects	Resilience works could be prioritised based on the competency of LICs in meeting the current needs highlighted in this report – through improved government coordination, capacity building and stakeholder engagement – as doing so can lead to transformational change, which is required to improve transport resilience for climate change adaptation.	5.2 6

APPENDIX B: STAKEHOLDER INTERVIEW QUESTIONS

Research question category	Pre-interview questions			Interview questions
Future weather patterns as a result of climate change	Do you use weather and climate data?	If yes:	What does the data show (temperature/precipitation)? What is the source of the data? Do you have to pay for it? What frequency is it (daily/hourly)? Do you make it available to other agencies?	How do you use the data? Is it appropriate for your needs? How could it be improved?
		If no:	What are the barriers/challenges to using such data?	What data would be most useful for you to access? How would you use this data?
The impacts of climate change on transport, society and the economy	Do you monitor the impacts of weather events or climate change on the infrastructure?	If yes:	How do you do this? What type of weather causes the most problems? What parts of your infrastructure are most vulnerable to extreme weather?	What type of damage are you seeing to infrastructure that is a result of climate change (i.e. not seeing 20-30 years ago)? Have the impacts changed over time? If so, how? Do you use an early warning system? If so, can you describe it? Do you use any tools/technology to help monitor the impacts? Are there any other /technology you could benefit from for monitoring? Do you collect data on the number / duration of road closure or service disruptions as a result of climate-related events (e.g. flooding, landslides)?

Research question category	Pre-interview questions			Interview questions
		If no:	Why not? What technology could you benefit from for monitoring purposes?	N/A
The impacts of climate change on transport, society and the economy	Is the infrastructure built to any weather/climate design specifications, or similar?	If yes:	What are the specifications? Are they national/ international/industry-specific? Please provide a link if possible Do these specifications consider new or alternative climate-resistant materials (e.g. bio-engineering/bio-diversity or low-carbon technologies)? If so, what?	Are there any updates to these specifications or reviews underway? When did/will these come into place? Has climate change been a factor in the updates? Do your existing practices allow 'departures' from design standards and, if so, how easy is it to get departures evaluated and approved? Were there any barriers/challenges to meet these specifications?
		If no:	Why not (e.g. no specs exist, any barriers or challenges to meet them)? Are you aware of any specifications that you would consider? What are they?	N/A
The impacts of climate change on transport, society and the economy	How do you manage weather impacts to the infrastructure when they happen?	If yes:	Do you reduce or close services? Are there any other actions you take?	Discuss how services would be reduced/closed Discuss how repair work is prioritised Do you calculate the loss/impacts of these actions to your organisation? Can you give any examples?
		If no:	N/A	N/A
		If yes:	Please share if possible.	Discuss

Research question category	Pre-interview questions			Interview questions
The impacts of climate change on transport, society and the economy	Do you have or refer to a strategy or business recovery plan for the infrastructure?	If no:	Why not (any challenges/barriers)?	Discuss
The impacts of climate change on transport, society and the economy	Do you monitor or quantify weather impacts of the infrastructure beyond your organisation?	If yes:	On other businesses/the wider economy/the population and commuters?	Discuss Can you give any examples?
		If no:	Why not (any challenges/barriers)?	Discuss
Transport resilience and infrastructure adaptation	Do you share/exchange/receive information with other organisations regarding weather and transport impacts (e.g. flood plans, weather data, monitoring strategies)?	If yes:	Which organisations? What data?	What benefits do you get from doing this? Are there any organisations/types of organisations you do not share with which you would like to?
		If no:	Why not (any challenges/barriers)?	N/A
Transport resilience and infrastructure adaptation	Does the infrastructure operate through urbanised areas?	If yes:	Do you know if these urbanised areas controlled developments? Can you describe the characteristics of these urban areas?	Does your organisation communicate with these areas' municipal/local authorities? Do these areas affect your infrastructure operations in certain weather conditions (e.g. more flooding)?
		If no:	Does your organisation communicate with the municipal/local authorities the infrastructure operates in? What are the primary reasons?	N/A

Research question category	Pre-interview questions			Interview questions
Transport resilience and infrastructure adaptation	Do you review transport vulnerability to weather?	If yes:	Do you report / publish findings? To who? Can you share any?	What data do you collect and how do you review/analyse it? What methodologies, tools or resources do you have to undertake this (e.g. do you do conduct any risk and vulnerability assessment for your infrastructure)?
		If no:	Why not? (challenges/barriers?) If you could, what would you prioritise for review/analysis?	N/A
Transport resilience and infrastructure adaptation	Have you accessed guidance documents or material on transport resilience to weather / climate before (e.g. PIARC, UIC, TRL, Resilience Shift, World Bank)?	If yes:	What material have you accessed?	What did you use it for? How beneficial was it to your organisation?
		If no:	Were you aware of the availability of this guidance?	Why were they not used (e.g. not relevant, not sufficient for your needs?) Do you think additional guidance material would be useful?
Transport resilience and infrastructure adaptation	Has any part of your infrastructure or surroundings required modification because of recent changes in weather?	If yes:	How have weather patterns changed (e.g. any specific aspects which have become more frequent or severe)? How did it affect the infrastructure? What corrective action has been taken or needs to be taken?	Will the corrective action (if applicable) be effective? Will it need replacing again / relocation / improvement soon? Is there any concept of "build back better" applied? If so, how, what is done, and in what way is it enhanced?
		If no:	Do you anticipate any future modifications?	How would these be prioritised?
Transport resilience and	Does the infrastructure have an annual maintenance schedule?	If yes:	Are there activities to prepare for certain weather events? What and when are they?	Are these activities recorded? If so, how (e.g. are they in a computerised system)?

Research question category	Pre-interview questions			Interview questions
infrastructure adaptation		If no:	Why not (any challenges/barriers)?	How is maintenance carried out and recorded?
Transport resilience and infrastructure adaptation	Do you notify customers and relevant authorities if the infrastructure is experiencing any delays?	If yes:	How do you notify them? What information is communicated (Through what channels)? What is the Service Level Agreement or timescale in which to communicate disruptions?	Discuss
		If no:	Why not (any challenges/barriers)?	Discuss
Transport resilience and infrastructure adaptation	Does your organisation communicate/liaise with the national government, or does the government provide any weather and climate guidance for infrastructure?	If yes:	Have you ever shared information with the national government regarding weather and climate impacts to transport infrastructure? What? Has the national government published any viewpoint of weather and climate impacts to transport infrastructure? Is there any policy enforced to ensure infrastructure is resilient to weather and climate? What is it? How is it enforced? What are the non-compliance impacts? Are there any requirements for transport agencies to reduce carbon in construction or operations phases? Is there any guidance/coordination with local disaster management agencies with regards to preparation/response/recovery/mitigation?	Discuss
		If no:	Why not (any challenges/barriers)? Is there any guidance/coordination with local disaster management agencies with regards to preparation/response/recovery/mitigation?	Discuss

Research question category	Pre-interview questions			Interview questions
Transport resilience and infrastructure adaptation	Do you think the profile is being raised of the impacts of weather and climate to transport infrastructure in your country?	If yes:	What steps have been or are being taken to raise the profile? How would you rate the level of awareness (High, Medium, Low)? Does the profile need to be raised further?	What is the rationale (e.g. socioeconomic reasons)?
		If no:	What are the challenges/barriers? Does the profile need to be raised?	How would you raise the profile? What steps should be taken?
Capacity building and financing projects	Do you work with any other organisations (e.g. research bodies, NGOs, government, other transport infrastructure operators) to improve infrastructure to the impacts of weather and climate?	If yes:	Which organisations?	How do you collaborate? What are the benefits of collaboration for your organisation and your infrastructure?
		If no:	Why not (any challenges/barriers)? Any specific organisations you would like to work with?	N/A
Capacity building and financing projects	Are you aware of any new or upcoming technology that might improve data/analysis/monitoring of infrastructure to the impacts of weather and climate?	If yes:	What technologies are you aware of?	How will this benefit you in the future?
		If no:	What would be the most useful development for the infrastructure?	N/A
Capacity building and financing projects	How would any new technology need to take into account and prioritise the needs of your country?	If yes:	N/A	Cultural/social considerations? Economic/financial considerations? Environmental considerations?
		If no:	N/A	
		If yes:	Who was it with (insurance company)	What was it for?

Research question category	Pre-interview questions			Interview questions
Capacity building and financing projects	Has your organisation ever used an insurance-linked loan on the infrastructure for its improvement?	If no:	Why not (any challenges/barriers; not needed)?	N/A
Capacity building and financing projects	Has your organisation ever accessed development partners (e.g. UN, World Bank, ADB, AfDB, EU) for additional funding in early project preparation?	If yes:	Who was it with?	What was it for?
		If no:	Why not (any challenges/barriers; not needed)?	N/A
Capacity building and financing projects	Has your organisation ever accessed disaster relief support?	If yes:	Who was it with (agency, NGO)?	What was it for? What was the process to secure it?
		If no:	Why not (any challenges/barriers; not needed)?	N/A
Capacity building and financing projects	How should funding be prioritised from support organisations like those described to improve infrastructure resilience to weather and climate?	If yes:	N/A	How should funding be prioritised from support organisations like those described to improve infrastructure resilience to weather and climate?
		If no:	N/A	
Capacity building and financing projects	What one thing would make the biggest difference to climate resilience (if money was no object)?	If yes:	N/A	N/A
		If no:	N/A	

APPENDIX C: LIST OF NATIONAL ADAPTATION DOCUMENTS ASSESSED

Country	Region	Document	Year
Burkina Faso	Africa	Burkina Faso National Climate Change Adaptation Plan (105)	2015
Ethiopia	Africa	Ethiopia's Climate Resilient Green Economy: National Adaptation Plan (40)	2019
Ghana	Africa	Adaptation Strategy and Action Plan for the Infrastructure Sector (109)	2020
Kenya	Africa	Kenya National Adaptation Plan 2015-2030 (166)	2016
Liberia	Africa	Liberia National Adaptation Programme of Action (167)	2008
Malawi	Africa	Malawi National Adaptation Programmes of Action: Second Edition (168)	2015
Mozambique	Africa	National Climate Change Adaptation and Mitigation Strategy (169)	2012
Rwanda	Africa	Green Growth and Climate Resilience: National Strategy for Climate Change and Low Carbon Development (110)	2011
South Sudan	Africa	Republic of South Sudan's National Adaptation Programme of Actions (NAPA) to climate change (170)	2016
Sudan	Africa	National Adaptation Plan (171)	2016
Tanzania	Africa	National Adaptation Programme of Action (172)	2007
Uganda	Africa	National Adaptation Programmes of Action (173)	2007
Afghanistan	South Asia	National Capacity needs Self-Assessment for Global Environmental Management and National Adaptation Programme of Action for Climate Change (174)	2009
Bangladesh	South Asia	National Adaptation Programme of Action (175)	2005
India	South Asia	National Action Plan on Climate Change (176)	2008
Maldives	South Asia	National Adaptation Program of Action (177)	2007
Nepal	South Asia	National Adaptation Programme of Action to Climate Change (178)	2010
Sri Lanka	South Asia	National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025 (111)	2016

APPENDIX D: REFERENCE GUIDE FOR POLICY CAPABILITY ASSESSMENT

Criteria	Evaluation score: 5	Evaluation score: 1
Impact assessment	A high-quality impact assessment, prioritising impacts through a thorough, detailed and wide range of present and future, chronic and acute impacts due to extreme weather, including systemic cross-cutting issues with direct and indirect impacts, and opportunities where relevant. Impact assessment methodology is clearly defined (e.g. risk assessment, vulnerability assessment, threshold analysis) in order to assess current adaptive capacity of financial, human, technical and other resources, and identify gaps and required adaptive capacity. Documents potential influence of uncertainties upon the impact assessment, along with sources of data and information.	Little or no impact assessment undertaken.
Adaptation plan	A high-quality plan that takes from varied sources of knowledge, information and data, and a broad range of stakeholder engagement: in the context of existing policies, strategies, planning and decision-making processes. Includes a range of potential adaptation objectives and actions with prioritisation that also addresses adaptive capacity gaps, required resources, necessary key stakeholders, uncertainties, baselines, indicators, timescales and costs. Sets out a collaborative approach to decision-making, recognising the differing capacities of short-, medium- and long-term decisions. Clearly aligns to multiple relevant international policies and guidance e.g. Paris Agreement Article 7, NDCs and SDGs.	Little or no adaptation plan in place.
Implementation plan	Accountability is clearly defined with the expectations to support delivery, including an organisational structure identifying roles and responsibilities in implementation. Excellent demonstration of how it embeds with other policies, strategies and processes. Documents processes to ensure actions in the adaptation plan are deliverable, and adjustable if necessary, and engages in timely dialogue with interested parties. Has a clear process to update the plan as required, setting out contingencies where actions are incapable of delivering desired outputs. Has specified improvement objectives (incremental and/or transformation-based).	Little or no implementation plan in place.

Criteria	Evaluation score: 5	Evaluation score: 1
Monitoring and evaluation	Assesses clearly against implementation plan concerning actions, inputs, outputs, resources, roles and responsibilities, processes and capacities. Demonstrates effectively that its use will determine whether adaptation and implementation plans are still valid in order to update policies, strategies and plans using its outcomes. Provides a clear timeframe and periodicity for monitoring and evaluation, acknowledging ad-hoc monitoring and evaluation if required, which are set out at appropriate stages during the implementation cycle. Sets out quantitative (and where it cannot, qualitative) indicators for adaptation plans, with a baseline to measure progress, which supports the delivery of long-term outcomes.	Little or no monitoring and evaluation structure in place.
Reporting and communication	Intentions to clearly communicate climate change adaptation to interested parties, which is accurate, verifiable, relevant and not misleading or misinterpretable, and clearly states the scope of the climate change adaptation. Any external communications are supported by an adaptation report that is easily interpretable, open and comprehensive, and all actions justified, as well as explaining the monitoring and evaluation plan and results, if available.	Little or no reporting and communication structure in place.

APPENDIX E: LIST OF TOOLS AND FRAMEWORKS ASSESSED

Name	Purpose	Target group	Geographic scope	Adaptation planning steps	Functionality
Adaptation M&E Toolbox (160)	Methodologies and assessments	Operators and managers, Planners and policymakers	National, Local, Organisational	Implementation and monitoring	Decision support
Africa RiskView (179)	Software	Planners and policymakers	National, Local	Vulnerability assessment	Visualisation, modelling
AP-PLAT: Asia Pacific Climate Change Adaptation Information Platform (180)	Informative guidelines	Planners and policymakers	Regional, National	Information engagement and scoping, Adaptation planning, Implementation and monitoring	Decision support
C40 Vertically Integrated Action tool (181)	Methodologies and assessments	Planners and policymakers	Local	Adaptation planning	Decision support
CaDD: Capacity Diagnosis & Development (182)	Software	Operators and managers, Planners and policymakers	Local, Organisational	Vulnerability assessment	Decision support
Climate Adapt Tool (EU) (183)	Methodologies and assessments	Planners and policymakers	National, Local	Information engagement and scoping, Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
Climate Change Adaptation toolkit for transport, U.S. Federal Highway Administration (184)	Methodologies and assessments	Operators and managers, Planners and policymakers	Local, Organisational	Information engagement and scoping, Scenario building, Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
Climate Change Knowledge Portal (32)	Informative guidelines	Planners and policymakers	Regional, National	Information engagement and scoping	Decision support
Climate Finance Knowledge Hub (Ghana) (185)	Informative guidelines	Operators and managers	Local, Organisational	Implementation and monitoring	Decision support
Climate Funds Update (131)	Informative guidelines	Planners and policymakers	National	Implementation and monitoring	Visualisation
Climate impact explorer (186)	Software	Planners and policymakers	National	Vulnerability assessment, Scenario building	Modelling
CommunityViz (187)	Software	Operators and managers, Planners and policymakers	Local	Adaptation planning	Visualisation, decision support

Name	Purpose	Target group	Geographic scope	Adaptation planning steps	Functionality
Designing Climate Change Adaptation Initiatives: A UNDP Toolkit for Practitioners (188)	Methodologies and assessments	Planners and policymakers	National	Information engagement and scoping, Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
ECONADAPT (189)	Methodologies and assessments	Planners and policymakers	National, Local	Information engagement and scoping, Adaptation planning	Decision support
Gender Tool Kit: Transport (190)	Informative guidelines	Planners and policymakers	National	Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
Green Climate Fund Proposal Toolkit (191)	Methodologies and assessments	Planners and policymakers	National	Implementation and monitoring	Decision support
Hazus (192)	Software	Operators and managers, Planners and policymakers	Local	Vulnerability assessment	Decision support
IPCC interactive atlas (95)	Informative guidelines	Planners and policymakers	Global, Regional	Information engagement and scoping	Visualisation, modelling
KE4CAP: Knowledge Exchange between Climate adaptation Knowledge Platforms (193)	Informative guidelines	Planners and policymakers	Regional, National	Information engagement and scoping	Decision support
Local Sea-Level Projections (194)	Software	Designers and engineers, Operators and managers, Planners and policymakers	Local	Vulnerability assessment, Scenario building	Modelling
Mowe-it (195)	Informative guidelines	Operators and managers	Local	Information engagement and scoping, Adaptation planning	Decision support
National Disaster Risk Reduction Portal (Nepal) (196)	Informative guidelines	Operators and managers	National, Local	Information engagement and scoping	Visualisation
ND-GAIN: Notre Dame Global Adaptation Initiative (197)	Informative guidelines	Planners and policymakers	National	Information engagement and scoping, Vulnerability assessment	Visualisation
Oasis loss modelling framework (114)	Software	Designers and engineers, Operators and managers,	Local	Vulnerability assessment, Scenario building	Modelling, decision support
PIANC Adaptation Framework (96)	Methodologies and assessments	Operators and managers	National, Local, Organisational	Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support

Name	Purpose	Target group	Geographic scope	Adaptation planning steps	Functionality
PIARC International Climate Change Adaptation Framework for Road Infrastructure (154)	Methodologies and assessments	Operators and managers	National, Local, Organisational	Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
Planning for Climate Change: A Strategic, Values-Based Approach for Urban Planners – Toolkit (198)	Methodologies and assessments	Planners and policymakers	Local	Information engagement and scoping, Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
Rail Adapt (59)	Methodologies and assessments	Operators and managers	Organisational	Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
RCP Database (118)	Informative guidelines	Operators and managers, Planners and policymakers	Global, Regional	Scenario building	Visualisation
SDG Climate Action Nexus tool (SCAN-tool) for adaptation (199)	Informative guidelines	Planners and policymakers	National	Information engagement and scoping, Adaptation planning	Visualisation
Stocktaking for National Adaptation Planning (SNAP) Tool (200)	Methodologies and assessments	Planners and policymakers	National	Information engagement and scoping	Decision support
The economic damages of 3°C warming for SIDS and LDCs (201)	Software	Planners and policymakers	National	Scenario building	Modelling
Transport Co-benefits Calculator (202)	Software	Planners and policymakers, Designers and engineers	National, Local	Information engagement and scoping, Adaptation planning	Decision support
UKCIP Adaptation Wizard (203)	Methodologies and assessments	Operators and managers, Planners and policymakers	Local	Information engagement and scoping, Scenario building, Vulnerability assessment, Adaptation planning, Implementation and monitoring	Decision support
World Bank Climate and Disaster Risk Screening Tools (204)	Software	Planners and policymakers	National, Local	Vulnerability assessment	Decision support

APPENDIX F: REFERENCE GUIDE FOR TOOLS AND FRAMEWORKS CAPABILITY ASSESSMENT

Criteria	Evaluation score: 5	Evaluation score: 1
Salience	Information and purpose are directly relevant in real-world terms for stakeholders to adapt transport to the impacts of climate change. This may be because of co-development with intended users in order for the tool to be fit for purpose in the context of the decision-making process. There is evidence of its usability by transport stakeholders through examples or case studies.	Information and purpose are not directly relevant for stakeholders to adapt transport to the impacts of climate change. May be supply- or science-driven with little engagement of the intended users during development. May be generic rather than bespoke.
Credibility	Extensive evidence that information comes from reputable scientific sources, stakeholders and organisations, with technical adequacy.	No references to sources used.
Legitimacy	Strong indication of inclusivity and consideration for transport stakeholders in LICs in terms of access and understanding of their capacity challenges and culture.	No indication of explicit inclusivity or consideration for transport stakeholders in LICs.
Communication	Shows or offers inclusive, open, two-way communication between tool provider and transport stakeholder. This may include transparency, offering more than a “black box”, so users are able to see and learn how the tool operates.	No access to contact tool provider available. What is offered is more like a “black box” – information in and results out.
Translation	Clear, jargon-free language understood by transport stakeholder groups. Where technical terms are used, they are clearly defined.	Language is not appropriate for transport stakeholder groups.
Mediation	Different stakeholders in the transport sector can benefit from using the tool and its outputs for their specific needs, through a balance of salience, credibility and legitimacy.	The tools' use and outputs are biased to a particular stakeholder. Salience, credibility and legitimacy are not balanced.

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