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ORIGINAL ARTICLE

# Are transport networks in low-income countries prepared for climate change? Barriers to preparing for climate change in Africa and South Asia

**Sarah Greenham[1] · Robin Workman[2] · Kevin McPherson[2] · Emma Ferranti[1] · Rachel Fisher[1] · Stephen Mills[1] · Roger Street[3] · John Dora[4] · Andrew Quinn[1] · Clive Roberts[1]**

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**Abstract**
Climate change, through extreme weather events and slow onset climatic changes, disrupts the operation of transport networks, and those in low-income countries (LICs) across Africa and South Asia are particularly vulnerable to climate change. This paper explores the barriers that LICs face across Africa and South Asia regarding preparedness of transport infrastructure to climate change, with the intent of addressing the knowledge gaps and consequential needs of LICs to support the delivery of more climate-resilient transport. Literature on climate change adaptation and transport resilience among LICs is reviewed to identify the broad challenges and barriers regarding climate change adaptation. Semi-structured interviews with 13 transport stakeholders across Africa and South Asia were also conducted to understand the challenges specific to the transport sector in the regions. Several barriers were identified, including a lack of data and knowledge on climate change impacts, design and prioritisation of remedial actions, budgeting and planning for climate change, and identifying and engaging with stakeholders. Findings from this paper and the wider research project it comprises inform policy guidance that calls for greater national and international coordination to develop practical, relevant and usable data, tools, advice and support for some of the most at-risk transport networks to climate change in the world.

**Keywords** Climate change · Transport resilience · Adaptation · Low-income countries · Africa · South Asia

✉ Sarah Greenham
s.greenham@bham.ac.uk

[1] School of Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK

[2] TRL, Wokingham, Berkshire, UK

[3] University of Oxford, Oxford, UK

[4] John Dora Consulting Limited, Charlbury, UK

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## 1 Introduction

Weather and climate change can severely affect transport infrastructure. Weather and climate change impacts transport through both sudden shocks (extreme weather events) and slower onset changes (e.g. gradual temperature increases that begin to exceed design specification thresholds). Extreme heat can buckle railway lines, lead to overhead line sagging, overheat electrical equipment (Palin et al. 2013; Ferranti et al. 2016, 2018), and damage road surfaces through rutting, cracking or expanding. Heavy rainfall can cause floods and landslides, obstructing roads and railways (Jaroszweski et al. 2015). Storms and high winds can cut off power supplies that transport infrastructure is dependent on, as well as also causing obstructions. Coastal infrastructure risks damage from sea level rise, storm surges and high winds (Dawson et al. 2016). The socio-economic consequences of climate change impacts to transport can be substantial, such as the direct incurred costs to restore transport services and the indirect costs and humanitarian impacts caused by the loss of access to critical goods and services such as food and medicine supplies. It is therefore imperative that transport networks adapt infrastructure, considering current and projected changes in weather and climate.

Low-income countries (LICs) in Africa and South Asia are vulnerable to and less prepared for climate change (Notre Dame Global Adaptation Initiative 2021). Consequently, the climate risk of transport infrastructure in LICs is high. Cascading socio-economic impacts strongly linked to transport disruption has the potential to affect future development prospects within LICs, which are currently defined as countries with a gross national income (GNI) per capita of up to $1085 in 2021 (World Bank 2023). LICs comprise 28 countries globally: 23 in Africa and 4 in Asia. Fourteen of these LICs are both in fragile and conflict affected situations and classified as heavily indebted poor countries, all located across Africa and South Asia (World Bank 2023).

The global climate is already changing (IPCC 2021), with varying effects on regional climate around the world. In Africa, temperature has risen in recent decades comparably to other continents, but recent high temperature anomalies were greater in the south (WMO 2020a). In Asia, temperatures have also increased, with more frequent heat extremes across most regions of Asia (IPCC 2021). In future, there is a high level of confidence in increased mean temperature and extreme heat, as well as decreased cold spells across all regions of Africa and Asia (IPCC 2021).

Precipitation trends were more complex and variable. Across Africa, the south recently recorded below average rainfall, but above average in the centre and to the east (WMO 2020a). In Asia, precipitation levels also varied, with an increased frequency in heavy rain events and a decreased frequency in light rainfall (Naveendrakumar et al. 2019). Both regions also recently experienced extensive and widespread flooding (WMO 2020b), with heavy precipitation-driven flooding projected to increase in frequency across most of Africa and Asia.

Both Africa and South Asia are highly dependent on their transport infrastructure, and roads are the most important mode of transport across these regions. Roads carry at least 80% of goods and 90% of passengers in Africa (AfDB 2014) and, similarly, the majority of freight and passenger traffic in South Asia (AIIB 2018). The risk of accelerated degradation of infrastructure owed to climate change may increase maintenance costs, as well as necessitating earlier or more frequent replacements, and these costs are greater proportionately for LICs. For example, costs to maintain existing road networks could equivalate to double or triple the existing paved road inventory (Schweikert et al. 2014), as well

as costing a greater share of annual gross domestic product (GDP) compared with more developed regions (AIIB 2018). These cost estimations do not account for other modes of transport such as railways, waterways and airport infrastructure, which are arguably more costly to maintain, where they do reside in LICs.

LICs may also lack the funds or resources to prepare or implement large-scale and/or long-term adaptation projects. Domestic funds are low; reliance on international donors (i.e. bilateral or multilateral funds or loans) are a necessary, though unstable, source of support. Challenges accessing funds also relate to capacity challenges across governance and stakeholders in LICs. Their knowledge and skills can be insufficient to secure the necessary funding due to the complexities and technicalities in accessing it (Timperley 2021). Furthermore, the awareness of, and capacities of, key decision-makers in assessing climate risks to transport is low. As a result, LICs continue to face barriers in adapting transport infrastructure and services, with delayed action further increasing costs and consequences on transport systems and those who depend on them.

The Adaptation for Transport Resilience to Climate Change (AfTR-CC) project, as part of the High Volume Transport (HVT) Applied Research Programme, is funded by UK Aid from the Foreign, Commonwealth and Development Office (FCDO) and aims to ascertain the current state of knowledge of climate change adaptation for transport infrastructure resilience, focused on LICs in Africa and South Asia. This was achieved by conducting a desk-based review of the knowledge, interest, challenges and barriers pertinent to the adaptation of transport to climate change, covering multiple transport modes such as road, rail, urban and waterway transport. Primary data was collected from interviews with key transport stakeholders across LICs and low–middle-income countries (LMICs). LMIC stakeholders were interviewed to balance the data collection between stakeholders in Africa and South Asia, as there is only one LIC in South Asia (World Bank 2023), but also to account for countries most at-risk to climate change in the world, which includes LMICs (see Table 2). Secondary data was collected from academic and grey literature, policy, tools and resources relevant to LICs in Africa and South Asia. Findings from this project supported the development of a policy guide aimed at LICs in these regions on ways to progress adaptation for transport resilience (Greenham et al. 2022b).

The AfTR-CC project outputs 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' (UN DESA 2021a) and, more broadly, SDG 13 to 'Take urgent action to combat climate change and its impacts' (UN DESA 2021b).

## 2 Materials and methods

This paper is based on key findings from the AfTR-CC project State of Knowledge report (Greenham et al. 2022a), which was a desk-based study that reviewed the most up-to date literature on the impacts of climate change on transport in LICs and the current resources available to them to prepare for it. Transport stakeholder interviews were conducted in parallel to the literature review, bringing together the current state of knowledge and level of stakeholder preparedness for climate change in the transport sector across several LICs and LMICs in Africa and South Asia.

### 2.1 Literature review

Several events pertinent to improving climate resilience occurred in recent years. The Intergovernmental Panel on Climate Change (IPCC) has published its Sixth Assessment Report on climate change. Recent extreme and unprecedented weather events, particularly in the global north and high-income countries (HICs), have raised the profile of climate change internationally. This is due to the scale of infrastructure damage and economic loss, including the record-breaking heatwaves across the Pacific Northwest of North America in June 2021 (NOAA 2021) and across Europe in July 2022 (Met Office 2022), as well as the widespread flash floods across Europe in July 2021 (Davies 2021). The Glasgow Climate Pact (UNFCCC 2021a), agreed at COP26 in November 2021, highlights that adapting to the impacts of climate change should be scaled up and adaptation funding increased, particularly from developed nations to support developing nations.

Under the Paris Agreement (UNFCCC 2015) Article 7, adaptation components of Parties' nationally determined contributions (NDCs) are increasing; however, transport as a sector is not well represented compared to sectors such as agriculture, freshwater resources or human health (UNFCCC 2021c). In the context of developing nations, the submission of national adaptation plans (NAPs) has grown in recent years and the number of published NAPs is expected to increase (UNFCCC 2021b). NAPs are important as they set the national position on climate change, the current and projected impacts on the economy and society, as well as the approach to address risks and vulnerabilities by regions and/or sectors. NAPs can also indicate the capacities of a nation, their level of understanding of the climate issues and highlight the challenges they face in meeting their adaptation needs. There are linkages between NDCs and NAPs. They have overlapping content, particularly in identifying adaptation priority needs, with both NDCs and NAPs feeding into the Paris Agreement Global Stocktake (UNFCCC 2021b). Therefore, the growing incorporation of transport in NDCs infers a likely increase in the inclusion of transport in future NAPs.

Similarly, under the Paris Agreement Article 9, climate finance available to LICs has grown, but falls short of commitments by developed nations ($100 a billion a year by 2020) according to different organisations' estimates (Roberts et al. 2021); thus, adaptation remains underfunded. Multilateral and bilateral climate finance, a major proportion of global climate funds, primarily supports climate mitigation, with only 20–25% allocated to adaptation (UNFCCC 2021d). In addition, in 2017–2018, the least developed nations and Small Island Developing States (SIDS) received a combined share of 34% of multilateral funds, 24% of bilateral funds and 14% of all multilateral development bank funds, and adaptation finance as a share of all climate finance in these regions is higher than the global share of adaptation funds (UNFCCC 2021d). Of cumulative approved adaptation funds (2003–2020), Sub-Saharan Africa received 41% and South Asia received 13% (Watson and Schalatek 2021). Moreover, only one funded project explicitly on transport sector adaptation in an LIC in Africa or South Asia was approved among these funds (Climate Funds Update 2020). LICs and SIDS are projected to experience greater risks to climate change even at 1.5℃ mean global surface temperature warming relative to pre-industrial levels (IPCC 2018) and the warming estimation in the last decade (2011–2020) was already at 1.09℃ (IPCC 2021). Therefore, the financial needs of LICs in Africa and South Asia to take transport adaptation action is, and continues to be, of high importance.

International-scale resources for adaptation planning and action in the transport sector have increased. The International Union of Railways (UIC) published the Rail

Adapt report, including a strategic framework to build long-term resilience of railway infrastructure (Quinn et al. 2017). The World Road Association (PIARC) updated its International Climate Change Adaptation Framework for Road Infrastructure from 2015 (PIARC 2015, 2019). Most recently, the World Association for Waterborne Transport Infrastructure (PIANC) published its report on Climate Change Adaptation Planning for Ports and Inland Waterways (PIANC 2020). Each of these organisations' frameworks incorporate an iterative and flexible approach, with an adaptation plan inception, assessment of climate change impacts and vulnerabilities, development and implementation of adaptation options, and processes to monitor and evaluate what was implemented to inform the next framework cycle as part of a continuous learning and improvement adaptation process. The fundamental principles in these frameworks are similar and reinforce transport stakeholder recommendations in avoiding reinvention by building on what already exists (Quinn et al. 2018).

In the wider context of climate change adaptation, other standards are emerging, such as ISO 14090 (2019). However, the intended audience of international guidance is broad and thus may not support the specific needs of LICs. While these resources may offer guidance regarding who needs to act, what type of action is required, when and where actions need to take place, there is less focus on *how* to undertake action—which is particularly important for LICs whose limited funds and resources could inhibit their ability to implement climate adaptation measures effectively. The challenge remains in how to improve knowledge, resource and funding capacities in LICs to break down the barriers they face in achieving more climate-resilient transport systems.

A systematic literature review collected academic and grey literature related to climate change adaptation and transport topics, focusing on LICs in Africa and South Asia. Literature sourced comprised peer-reviewed articles, non-governmental organisation reports, government policy/publications and online media. Literature search methods were a keyword search (e.g. 'climate change adaptation', 'transport', 'Africa', 'South Asia', 'government policy', 'transport resilience', 'climate change', 'extreme weather', 'low-income countries'), snowballing from relevant documents' reference lists, or the literature that referenced the document, recommendations provided by the project key experts and advisory group, and resources mentioned during stakeholder interviews. Databases accessed using these keyword searches to obtain literature included the Web of Science, Google/Google Scholar and ResearchGate. Document titles and abstracts and/or executive summaries were screened for relevance in the context of the project. The literature search focused on the last 10 years of publications; however, earlier literature was considered where relevant. NAPs and NAPAs were particularly important to collect as part of this activity. Eighteen NAPs and NAPAs, published in English from LICs and LMICs in Africa and South Asia,

**Table 1** Literature reviewed in the AfTR-CC State of Knowledge Report by type of literature

| Literature type | Count |
|---|---|
| Peer-reviewed research article | 48 |
| Grey literature (research) | 52 |
| Grey literature (government publication) | 33 |
| Grey literature (other) | 12 |
| Website (tool/data/resource) | 34 |
| Website (other) | 25 |
| **Total** | **204** |

were reviewed in this project. A breakdown of all literature used in the State of Knowledge Report (Greenham et al. 2022a) is shown in Table 1.

### 2.2 Stakeholder interviews

Transport stakeholders, particularly those responsible for the management and operation of transport systems, will likely have procedures in place to manage the impacts of weather and climate change on their assets and infrastructure. However, transport stakeholder engagement procedures in LICs in Africa and South Asia may fall short of what they need to achieve climate resilience due to gaps in knowledge, resources and money. Engaging with stakeholders in these regions was therefore essential to accurately identify the activity and challenges on the ground and ascertain the barriers they face to improve transport resilience to climate change, relative to overarching adaptation-related strategies and plans.

Semi-structured stakeholder interviews were conducted virtually, via video calls with each stakeholder organisation, between July and September 2021. Countries shortlisted for interviews were selected according to their membership of the Climate Vulnerable Forum (2021) and their Climate Risk Index (CRI) score (Eckstein et al. 2021), as these countries across Africa and South Asia are deemed to be the most vulnerable to climate change (shown in Table 2). Stakeholder organisations were classified as Ministry of Environment (or equivalent), Ministry of Transport (or equivalent), infrastructure practitioner (such as road authorities, transport owners or railway operators) or urban planning/urban transit authority. Following contact with transport stakeholders in the shortlisted countries, 13 interviews took place with 20 participants, representing 11 countries in total. Stakeholder organisations were predominately responsible for either road or railway infrastructure and operations.

**Table 2** Countries shortlisted for interviews, with their current income class according to the World Bank (2021a) and CRI ranking (Eckstein et al. 2021), where the lower the ranking, the greater the climate risk to the country (asterisks denote countries represented in stakeholder interviews)

| Country | Region | Income class | CRI ranking 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 |

The participants of each interview received a pre-interview questionnaire, with a set of structured opening questions aligned to the project research questions. These questions primarily comprised a simple 'yes' or 'no' response, utilising the interview to elaborate on these responses. Due to the number and range of research questions, each stakeholder received a different subset of interview questions, selected to be most appropriate to their organisation and stakeholder classification. Most interviews took approximately 45–60 min, but some took longer (up to 80 min) if the participants had not responded to the pre-interview questionnaire.

## 3 Results

### 3.1 Broad challenges and barriers from literature

Transport stakeholders in LICs may lack understanding and knowledge of the scale of climate change as an issue and the potential impacts it may have on the transport sector. Even where there may be some level of understanding, the literature reviewed suggests that there is often a failure to act as existing policies and strategies are inadequate in the context of addressing climate risk. The reasons for not achieving adaptation for transport resilience to climate change according to Head et al. (2019) are primarily due to.

- *A lack of knowledge*. Transport stakeholders in LICs may not be familiar with or are unable to understand the form or scale of the problem pertaining to transport resilience and climate change adaptation.
- *A lack of options*. There may be inadequate or insufficient information for transport stakeholders in LICs regarding appropriate adaptation measures for transport systems and infrastructure.
- *A failure to act*. Transport stakeholders in LICs may be unable to put appropriate measures in place or to address the problem.
- *Insufficient funds*. Transport stakeholders in LICs may not be appreciative of the scale of the problem for the transport sector or are unable to secure funding for transport systems and infrastructure.

The literature identified common themes that could explain why LICs have not progressed in adapting transport to climate change. The barriers identified may underpin the reasons for not progressing adaptation to improve transport resilience and cut across multiple reasons, with examples shown in Table 3. First, there are challenges in LICs' ability to collect, access and interpret data at the appropriate scale to understand climate risk, especially meteorological data, in terms of both past observations and climate projections. Second, the institutional arrangements in governance across LICs may be a limiting factor in the prioritisation of climate adaptation action. Third, barriers to accessing financial resources significantly limits adaptation progress. Fourth, the synergies between climate change adaptation and disaster risk reduction can lead to confusion within LICs regarding who should act. Finally, there are physical barriers in terms of geography that may limit the capacity of some LICs due to dependencies on neighbouring countries. The following subsections investigate these barriers in more detail. As these are broad findings from literature, they do not focus on factors specific to a country or an area. However, future

**Table 3** Examples of how each barrier underpins the reasons for LICs' lack of progress in adapting transport to climate change, based on the literature reviewed in this project

| | | Underpinning reason for not achieving climate change adaptation | | | |
|---|---|---|---|---|---|
| | | Lack of knowledge | Lack of options | Failure to act | Insufficient funds |
| Barrier in progressing climate change adaptation | Accessing and interpreting meteorological data | Limited human and technological capacity | Lack of, or missing, downscaled and relevant data | Lack of understanding of adaptation data needs | Reliance on ad hoc projects and other sources |
| | Institutional arrangements in governance | Limited awareness of transport risks in the context of climate change | Insufficient human resource to investigate and identify options | Absenteeism, corruption, lack of motivation by stakeholders in the public sector | Unable to recruit public sector workers to increase productivity |
| | Accessing sufficient financial resources | Limited awareness of where and how to apply for and access funds | Specificity of earmarked arrangements for climate finance | Reluctance to act due to greater upfront costs | Limited resources to access funds and train those to utilise them |
| | Climate change adaptation synergies with disaster risk reduction | Confusion between departmental responsibilities | Resource competition | Siloed operations | Resource competition |
| | Transboundary partnerships | Dependency on neighbouring countries | Dependency on neighbouring countries | Dependency on neighbouring countries | High transport and import costs between country borders |

research could consider the contextual differences between and among LICs across Africa and South Asia to further research and policy recommendations in a more targeted way.

### 3.1.1 Barriers in accessing and interpreting meteorological data

LICs in Africa and South Asia lack reliable or sufficient meteorological data on which to base effective decision-making for adaptation planning. A review of national adaptation programmes of action (NAPAs)—which are initial, shorter-term plans to NAPs—and NAPs across the regions indicated that weather and climate observational data presented was predominantly at a national scale. This limits the ability of LICs to contextualise impacts at a local level, which is problematic as a country or regions within a country can have significant spatial and temporal differences in weather and climate.

Likewise, climate projections are typically available at global and regional levels, but there are a lack of local and downscaled data (Mall et al. 2019). Interpreting climate projections can be particularly problematic for countries affected by the intertropical convergence zone (including countries across central Africa and parts of South Asia), as they lie astride multiple climatic regions with varying climate drivers that are challenging to simulate in climate models, as reported by the Republic of Rwanda (2011). LICs, therefore, may rely on neighbouring country data representative of its country's climate, as done by the Republic of Liberia (2018). Transport is not considered in the development of climate projection toolkits (Jaroszweski et al. 2014), limiting the support mechanisms available to transport stakeholders.

Human and technological capacity issues in LICs can affect stakeholders' abilities in interpreting data. Regional or national climate centres (e.g. the Inter-Governmental Authority on Development Prediction and Climate Applications Centre in Nairobi, Kenya) may provide seasonal or sectoral data, but interpretation of data are often the responsibility of individual countries (Republic of Rwanda 2011). The lack of higher spatial resolution (i.e. local level) data provided by these centres implies that LICs have an increased dependency on data provision from other sources such as from ad hoc projects or research institutes. Nevertheless, the usefulness of data for LICs is dependent on the skills of those interpreting them. For example, in Madagascar, weather bulletins provided by their meteorology department within the Ministry of Transport and Meteorology exclude probability, as there is no capacity to articulate and interpret them (USAID 2018). Data interpretation in decentralised governments may also be particularly challenging where data are too vague to apply practically at the local level.

### 3.1.2 Barriers due to institutional arrangements in governance

Gap analyses across the reviewed NAPs (see Greenham et al. 2022a) clearly indicated where changes were necessary to grow capacities at the institutional, technical, material and human levels to achieve the implementation of adaptation plans. The gaps that require addressing are at all levels of governance, as adaptation requires locally inclusive, bottom-up approaches to complement the top-down mobilisation of resources (Sterrett 2011).

Some of the capacity issues leading to challenges in achieving transport resilience relate to the retention of government staff. Poor job satisfaction, low pay and lack of motivation in the job in the public sector (Abugre 2014) may lead to high vacancy rates in such roles in LICs (Republic of Malawi 2019). Low pay can affect productivity if government employees are compelled to obtain more money in the form of bribery through corruption.

Growing absenteeism, moonlighting and corruption lead to further demoralisation, continuing a cycle of poor productivity at the expense of national output (Abugre 2014). As a result, the public sector becomes ineffective in carrying out its role for citizens.

At the national scale, government can allocate funds and resources for climate change adaptation. However, where there is poor institutional organisation, national funds are likely to be unsustainable and difficult to allocate, as there may be no centralised coordination to deliver long-term planning (Somali Inter-ministerial Public Works Coordination Mechanism 2018). Even with structured decision-making processes in place, scattered sector responsibilities may make implementation challenging, as reported from experience in Afghanistan. Donor concerns took precedent in the planning process and investments were implemented as 'off-budget', which has implications for the coherence of planning—those which follow budget processes are easier to allocate resources to, according to strategic priorities (ADB 2017).

Responsibility for adaptation planning is most likely within the ministerial level of government. As such, they are motivated to promote adaptation (UNDP 2018) and therefore largely responsible for NAPs and NAPAs. Adapting transport to climate change will require those ministries responsible for the transport sector to understand areas of knowledge they may not otherwise be formerly acquainted with, such as change management and climate science. However, LICs can also have fragmented institutional landscapes, whereby several ministries are involved in the operation and regulation of the sector. Consequently, the existing institutional arrangements can be challenging for delivering cohesive adaptation plans across the transport sector.

Local government is particularly important regarding adaptation as it has the closest links with the communities directly affected by climate change. There are, however, numerous obstacles preventing local government from contributing effectively to adaptation, as identified by the United Nations Capital Development Fund (2020):

- Climate finance is often only available through application to national programmes with specific, earmarked arrangements.
- There are insufficient budgetary allocations from the national level.
- Local governments are unable to absorb the incremental costs of climate change.
- There are weak or a lack of capacities in local government to deal with climate change issues.

Nationally and regionally led strategic decisions may be responsible for the local level barriers to adaptation. For example, focusing on technological or managerial solutions may fail to consider other socio-political factors such as inequality, discrimination or lack of access to resources (Stock et al. 2021). In addition, by overlooking the needs of marginalised communities, decision-makers could miss critical information that would benefit action at the local level. For example, Patel et al. (2020) identified that women usually have indigenous knowledge of managing their environment that would be particularly helpful in adapting to extreme weather events.

### 3.1.3 Barriers in accessing sufficient financial resources

Inadequate financial resource is considered the biggest barrier in implementing adaptation countermeasures (Pauw and Pegels 2013). The literature highlighted four key challenges in the ability of LICs to implement climate-resilient transport. First, there is a reluctance

to implement adaptation measures due to greater upfront costs, despite the long-term benefits. Monetary valuation of transport infrastructure adaptation countermeasures is the traditional approach, but may not incorporate socio-economic valuation, nor the consultation of community stakeholders (Moretti and Loprencipe 2018). Therefore, with both financial and human capacity challenges in LICs, any transport adaptation countermeasures requiring a high-cost investment would unlikely proceed. Second, national governments may be unaware of funding sources available to them, and unsure of ways to access them, which links to barriers due to institutional arrangements in governance. Third, where there are local level recipients of funds, those on the ground require adequate training to utilise the funds effectively, further emphasising the human capacity challenges faced by LICs. Finally, funding is often prioritised for climate change mitigation over adaptation, which is not only a LIC-centric challenge, but a global challenge.

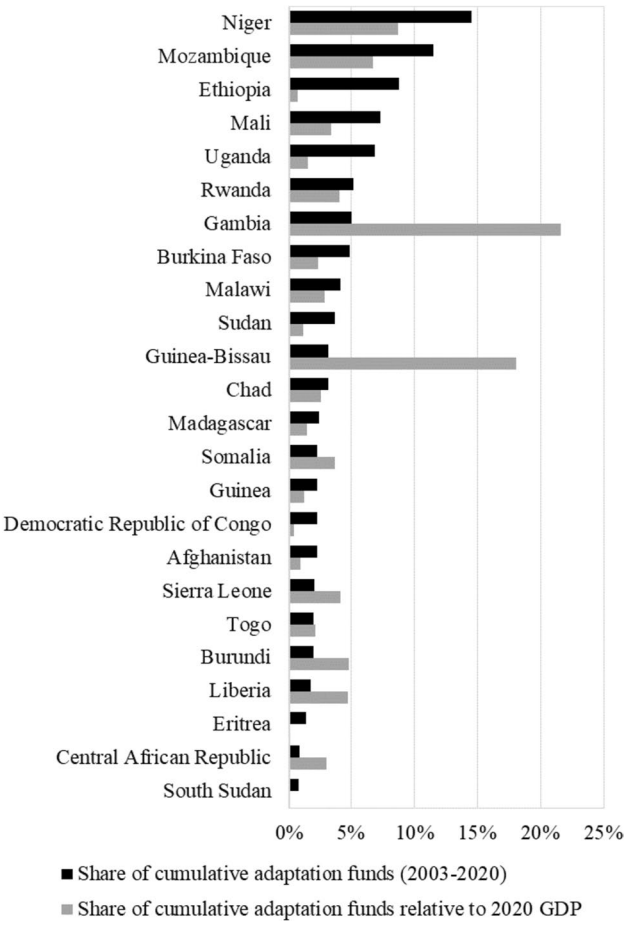


**Fig. 1** Share of cumulative multilateral climate adaptation funds approved by LICs in Africa and South Asia, 2003–2020, and the funds relative to total country GDP in 2020 (Climate Funds Update 2020; World Bank 2021b). Note: missing data for share of cumulative adaptation funds relative to 2020 GDP for Eritrea and South Sudan due to lack of GDP figures for 2020

LICs are eligible for international financial resources, such as multilateral and bilateral funding. Figure 1 shows the distribution of approved multilateral funds across LICs in Africa and South Asia between 2003 and 2020, as a total and relative to GDP. It shows that LICs did not equitably receive multilateral funds. Approximately US$1.2 billion was allocated during this time, with almost half allocated to five LICs (Niger, Mozambique, Ethiopia, Mali and Uganda). However, relative to GDP, some countries (e.g. The Gambia and Guinea-Bissau) received a greater proportion of funding, whereas others (e.g. Ethiopia and Uganda) received a disproportionate level of funds. Some countries manage larger portfolios of funding sources than others, which can explain the variation in funding allocation. For example, the Republic of Rwanda (2011) identified 30 sources of funds across all sectors and allocates projects within the country via its own national centralised mechanism. On the other hand, SIDS, which have small economies and are often highly indebted, are classified as middle-income countries (MICs), limiting their access to financial resources (UNCTAD 2014).

Insurance-linked loan package financial services for LICs have recently become operational, such as the InsuResilience Solutions Fund (ISF). However, the NAPs and NAPAs reviewed were published before the ISF became operational and therefore there is little evidence of LIC awareness, except for insurance-linked funding for crops in the agriculture sector by three countries (Ethiopia, The Gambia and Rwanda). Arguably, adaptation may not be considered a loan-giving situation since its circumstances in dealing with climate change impacts does not generate revenue for LICs compared with the return on investment of mitigation projections such as solar farms and electric vehicles (Timperley 2021). There is, however, a growing understanding of the economic returns on adaptation investment in that adaptation actions are cheaper than recovery and rebuilding, such as strengthening early warning systems (Global Commission on Adaptation 2019).

Funding from the private sector is an opportunity for LICs. NAPAs address the need for engaging the private sector, but the role they should play has historically been unclear—possibly as an intentional approach to avoid distraction from the need to scale up public funding; a lack of awareness of the potentials of the private sector in adaptation; and that NAPA guidelines focused primarily on public funding, thus increasing LIC dependency on it. Nonetheless, private sector involvement in adaptation projects can now enhance access to multilateral funding such as the Green Climate Fund; however, LICs have not yet utilised this opportunity (Fonta et al. 2018). There is also the issue of the private sector and transparency, as the level of transparency required from a public–private-partnership for Green Climate Fund provision may be unfavourable to the private sector (Kalinowski 2020) and are consequently less willing to engage. Incentives would therefore be required to motivate the private sector to engage in adaptation, which may require efforts from the public sector that lacks the capacity to design or implement them.

#### 3.1.4 Barriers due to climate change adaptation synergies with disaster risk reduction

Government departments or agencies in LICs may not have integrated responsibilities between climate change adaptation and disaster risk reduction. Therefore, their siloed operations could lead to competition for resources such as funding, albeit addressing a similar or same issue (e.g. a severe flood event). Both climate change adaptation and disaster risk reduction have common policy goals to incorporate preparedness and reduce damage that affects society. While disaster risk reduction often focuses on short-term and reactive response, it can contribute to climate change adaptation by reducing vulnerability to

climate change (building better and building back better). In addition, while these interventions can build adaptation capacity potential, such as through improving infrastructure resilience, it does not contribute to improved levels of knowledge and information (Gebreyes et al. 2017). Integrating these functions could release overlapping funds and resources; however, it would require significant institutional change; aligning scope of work, addressing administrative differences in values and principles; the communication of risk and planning tools, agreeing policy approaches and funding sources, and addressing issues related to community involvement (Hasan et al. 2013).

#### 3.1.5 Barriers due to transboundary partnerships

The barriers an LIC can face in implementing adaptation plans can also be subject to geography. Landlocked countries who are dependent on neighbouring countries for sea access can face operational and resource issues, influencing import costs. This can be particularly problematic for LICs with limited transport options (Republic of Rwanda 2011). Subsequently, high transport and import costs between country borders can limit funds elsewhere—including funds for adaptation planning and improving transport resilience.

### 3.2 Transport-specific barriers from interviews

Transport stakeholder interviews across Africa and South Asia highlighted the extent of participants' awareness of climate issues in the context of their organisation, how they currently manage the impacts of weather and climate upon the infrastructure they are responsible for, and plans to improve climate resilience. Barriers discussed in the interviews can be categorised into four themes: financial and economic, social and political, technical, and institutional and regulatory. Largely, the stakeholders interviewed recognise that climate change is affecting transport, but a widespread level of awareness is in its infancy. There are clear aspirations to improve resilience and keep transport assets functioning. However, these organisations face several challenges both internally and externally that limit their ability to achieve more climate-resilient transport infrastructure and operations.

#### 3.2.1 Financial and economic barriers

Insufficient funding was a theme across multiple organisations. There was a reported lack of funding for routine maintenance and emergency maintenance related to weather damage. Maintenance and repair budgets require increasing, but not all respondents could attribute increased costs directly to climate change. Two respondents provided key statistics related to their budget spend:

- Ninety percent of the current year's maintenance was spent on damage attributable to climate change (Zimbabwe).
- Annual maintenance budgets are increasing year-on-year by 15% due to higher infrastructure demands as well because of climate change (Bangladesh).

Respondents also mentioned a need for more capital injection to improve the resource levels for increased transport resilience. No organisation mentioned having a business recovery plan in place, which could be possible with additional resources and there is an appetite for increased funding to implement early warning systems. As shown in Fig. 2,

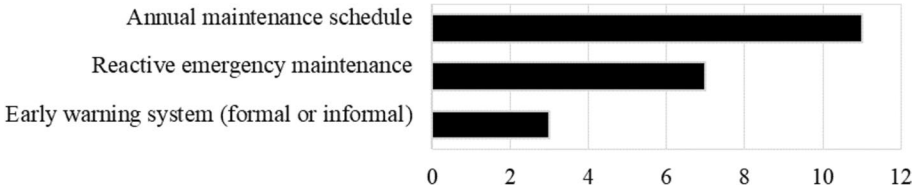


**Fig. 2** Count of operational activities related to weather and climate change mentioned by stakeholders

while most organisations have annual maintenance schedules, fewer have the capability to undertake sufficient reactive maintenance activities where necessary or implement an early warning system. A lack of skilled workers contributes to the inability to manage and assess transport infrastructure.

Raising funds is a challenge for transport stakeholders. For networks that generate their own income, the coronavirus pandemic has exacerbated resource issues due to the loss of funds. Therefore, these stakeholders cannot prioritise monitoring and maintenance activities. As for other funding sources, there was limited evidence that stakeholders were able to access funds from development partners. Only three organisations from three countries had accessed these types of funds (Bangladesh, Nepal, Uganda). In addition, two organisations from two countries had received funding for non-climate resilience projects (Pakistan, Zimbabwe). On the other hand, the stakeholder in Madagascar reported that there was minimal disaster funding available for infrastructure, with most resources directed towards humanitarian relief. Stakeholders reported having not been directly involved in accessing funds where applicable, as well as expressing that such development funds are available in a different sector (e.g. agriculture). Furthermore, stakeholders reported not knowing the mechanisms available to approach funders.

### 3.2.2 Social and political barriers

There was little explicit mention of social or political barriers relating to transport resilience by stakeholders; however, seven organisations mentioned there is a general low level of awareness about climate issues within government ministries and agencies. One stakeholder (Uganda) did provide a general perspective on the social and political challenges of climate change. Their view was that climate topics need bringing into the mainstream and political debate to raise its profile with the public; linking to people's quality of life and how the issues affect poorer people, as they may not be able to afford to be climate aware when they struggle to feed themselves—their priorities lie elsewhere. It needs bringing to the attention of the public and part of the collective conscience.

### 3.2.3 Technical barriers

Technical challenges experienced by transport stakeholders coalesced around two areas: data and knowledge/expertise. First, with data, most stakeholders (all except two) used historic meteorological observations to some extent within their organisation, primarily for planning and asset design, monitoring the impact of weather on infrastructure and/or project-based analyses, as well as setting design standards and preparing environmental impact assessments (EIAs). The most common data used are temperature and precipitation. The formalised use of data in these organisations are limited, and the data can be

fragmented or incomplete and therefore unreliable. Twelve of the 13 organisations were asked whether they formally monitor climate impacts on their transport infrastructure: four formally monitored them, while six did informally (in that, data were collected or accessed but little in terms of parameters or extent of analysis defined) and two did not undertake any monitoring. As for climate projections, these are far less used. Only one respondent (Bangladesh) referred to climate projections in the scope of approving designs, but not to a high-emissions scenario. Using higher emissions scenarios is perceived as costly to the organisation—only a consideration in extreme cases. Data sharing across other authorities or organisations was not common; not all stakeholders felt it was of benefit to themselves to do, although some were aware that doing so can help raise awareness and provides a greater regional perspective on climate issues in transport.

Second, regarding knowledge and expertise, six organisations highlighted that they experience technical barriers. While all the stakeholders observed and recognised changes in weather and climate in recent decades, this is not representative of the whole organisation. One respondent (Zimbabwe) who does not currently use meteorological data mentioned that it was only following the impacts of a recent strong cyclone that the organisation realised the necessity and urgency of addressing climate change. Nevertheless, stakeholders were able to identify a range of impacts of weather upon the transport infrastructure they are responsible for, as shown in Fig. 3. Most of the organisations were aware of flood- and precipitation-led damage, such as bridge and road washouts, as well as drainage issues. While there are some road- and rail-specific impacts (e.g. pavement deterioration and derailment, respectively), a large share of the impacts raised by stakeholders cut across multiple transport modes and social cohesiveness more generally.

Examples of the needs of transport stakeholders to address the knowledge and expertise barriers included training engineers to understand climate change so it can be better incorporated into infrastructure standards and specifications, and understanding what new technology is available and whether it is suitable. A comment from one transport stakeholder

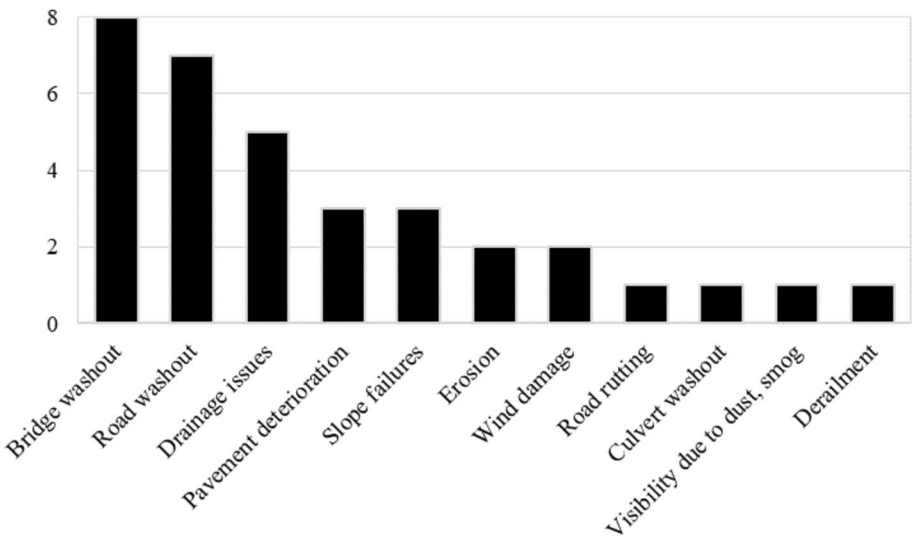


**Fig. 3** Count of types of infrastructure damage experienced by transport stakeholders that were mentioned in interviews

(Bangladesh) emphasised that 'investing money is not enough, we need international technical support'.

#### 3.2.4 Institutional and regulatory barriers

There are distinct institutional and regulatory challenge areas for transport stakeholders. One is regarding awareness of climate change. Climate change awareness needs to translate into systems and regulation changes that respond to the challenge. However, only four organisations had accessed guidance to support such transformation—for instance, publications by PIARC, UIC, TRL, The Resilience Shift or the World Bank. Those who had not accessed any guidance gave no reasons. Two organisations mentioned the PIARC adaptation framework, but one (Zimbabwe) felt that it was more relevant for HICs and would require localisation for their country. Three stakeholders also mentioned the ReCAP project (e.g. Head et al. 2019) but felt that additional training was necessary in order to use the guidance.

Another challenge is regarding design standards and guidance, as they lack the embedment of weather and climate change. Most stakeholders mentioned the use of design standards in their transport infrastructure, with some explaining that some standards are currently under revision, implying that design standards are of importance. Current standards used vary by organisation, and by local, regional and national scale. Some organisations acknowledged that the standards used are aged, up to 30 or 40 years old. One organisation (Nepal) explained that deviating from the standards is difficult, and therefore there is inflexibility in transport infrastructure design, even if in doing so may support adaptation. Furthermore, no stakeholders could provide any non-compliance consequences in the event of violating regulations, which further gives transport stakeholders less incentive to act.

## 4 Discussion

The barriers identified require specific actions to address them and these are the core principles throughout the policy guide developed as part of the AfTR-CC project outputs (Greenham et al. 2022b). This discussion reframes the underpinning reasons for the lack of progress in transport adaptation into the gaps and needs of LICs, to achieve more climate-resilient transport systems. Table 4 summarises the knowledge gaps identified from the literature and stakeholder interviews in improving transport resilience to climate change. Required actions fall under three themes: improved government coordination, capacity building and stakeholder engagement.

### 4.1 Improved government coordination

There are challenges across all levels and sectors of governance in LICs, as identified through the literature and stakeholder interviews. Therefore, addressing them will require cross-sectoral cohesion across national and local governments. This is important to acknowledge as the impacts of climate change and adaptation measures cut across sectors and geographic boundaries, regardless of the division of authority and governance (Brown et al. 2012). Sectoral working groups, such as that established in the Republic of Malawi (2019), can improve government coordination through facilitating cross-sector dialogues on policy revisions, strategy and programming. It could also bring together climate change

**Table 4** Needs of LICs across Africa and South Asia to achieve more climate-resilient transport

| Underpinning reasons | Needs of LICs in Africa and South Asia |
|---|---|
| Lack of knowledge | **Capacity building**: enough trained staff in national, ministerial and local government who understand the impacts of climate change on transport and adaptation and resilience processes<br>**Capacity building**: support to select and access appropriate knowledge, tools and resources<br>**Stakeholder engagement**: collaboration with groups or institutions with relevant knowledge |
| Lack of options | **Capacity building**: support to select and access appropriate tools or frameworks<br>**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<br>**Improved government coordination**: updated design standards incorporating weather and climate change<br>**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<br>**Capacity building**: mechanisms and support to apply for and mobilise multi- and bilateral funds<br>**Stakeholder engagement**: collaboration with private sector for additional funding |

adaptation and disaster risk reduction authorities to seek synergies and streamline their activities.

### 4.2 Capacity building

The adaptive capacity of LICs in Africa and South Asia is low—they do not currently have the social or economic means to address the impacts of climate change, which is linked to low levels of competency in governments (IPCC 2014). Therefore, support to improve the capacity of transport stakeholders could lead to transformative change. Three key areas could support capacity building.

First, LICs in Africa and South Asia need support to improve their climate and technical knowledge, and this originates from good data. Instead of developing new systems (due to financial and resource constraints), transport stakeholders would benefit from data-sharing via joint data repositories, with responsibility at the national level. Inclusion of very local data within these could also strengthen local institutions (UNDRR 2020). Private sector involvement could also support technical capacities via their inclusion on projects to lessen the burden on existing resources, as well as allowing decision-makers to tap into their tacit knowledge on specialist subject areas.

Second, there is a need for improved access to and allocation of financial resources for adaptation in the transport sector. The climate adaptation financing gap is wide in less developed countries (LDC Group on Climate Change 2019) and transport as a sector is almost entirely absent from bilateral and multilateral funded projects in LICs. Upskilling is required to secure more sustainably funded, long-term projects, linking back to the need to improve climate and technical knowledge. Incentivising the establishment of

public–private partnerships, as encouraged by the Green Climate Fund, could also lead to greater likelihood of securing funds.

Finally, integrating processes between climate change adaptation and disaster risk reduction agencies could support long-term resilience whereby resources are more efficiently utilised. This would involve activities such as collaboration between the agencies and their relevant stakeholders, undertaking training and peer-learning exchanges, utilising national and international processes to support integration (e.g. NAPs) to facilitate structural integration, national statistic offices to centralise shared and relevant data, and the Sendai framework to standardise monitoring and reporting processes (UNDRR 2020).

### 4.3 Stakeholder engagement

Some transport stakeholders are underrepresented in LICs, particularly at the local level and among the most vulnerable groups. Local communities should arguably be at the heart of adaptation—what they value in terms of current and future improvements in quality of life and standards of living can inform the priority actions for long-term resilience planning (Brown et al. 2012). The private sector can also support local engagement as they may provide additional capacity to work with communities where both national and local government have difficulties in participating. Rethinking the purpose of the private sector from the perception of a funding body to an innovation resource could support growing capacities for LICs as a means to an end, not an end in itself (Stoll et al. 2021).

It is also important to note that climate change awareness and the need for climate action have also grown in recent years among stakeholders across society, so engagement now and in future may improve compared to with the past. Although climate change dialogue has become somewhat politicised and public perception of climate slightly polarised over time, those who consider climate change a serious threat requiring action has grown greatly overall (Baiardi and Morana 2021). However, the extent of different types of awareness of climate action (i.e. mitigation, adaptation, impact reduction, early warnings) may also vary by different sectors of society such as the public, government, industry and academia (Hwang et al. 2021). Some sectors of society may therefore have a less balanced or well-rounded level of awareness of the different aspects of climate action than others, implying a bias that may affect the holistic perception of responding to climate change. This emphasises the importance of engaging with a wide range of stakeholders on climate change issues.

## 5 Conclusion

At present, LICs in Africa and South Asia are not fully prepared for the impacts of climate change to their transport systems, and this is an increasing risk as the climate is already noticeably changing. However, the literature and stakeholder interviews from this study show that while there is an emerging level of understanding of the issues responding to climate change may bring, the necessary human, technical and financial resources have not reached the appropriate actors to effectively plan and implement more climate-resilient transport. These resources are not in reach due to a range of barriers in accessing them, for example: critical data to identify hazards and vulnerabilities is insufficient or unavailable to better understand the climate situation; stakeholders do not know what resources are available, or how to access them; other sectors take precedence over transport for available

resources; and existing design standards and adaptation guidance are insufficient to meet specific LIC needs. LICs in Africa and South Asia may address the barriers to improve transport resilience to climate change through improving government coordination, growing human, technical and financial capacities, and increasing stakeholder engagement, but is not a straightforward process. LICs in Africa and South Asia require support and relevant and usable guidance to take steps towards transport resilience through climate change adaptation. Addressing these barriers 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. Future research could focus on differentiating the context of these barriers among LICs in Africa and South Asia, targeting specific needs that accelerate the development of more climate-resilient transport.

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**Data availability** Stakeholder interviews were anonymised for this study, so due to ethical reasons the supporting data are not available.

## Declarations

**Conflict of interest** The authors declare no competing interests.



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