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APPLIED RESEARCH

Final Report

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Cardno
IT Transport

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Abbreviations and Acronyms

AASHTO	American Association of State Highways and Transportation Officials
ADB	Asian Development Bank
AEC	ASEAN Economic Community
AfDB	African Development Bank
AITD	Asian Institute of Transport Development
ANOVA	Analysis of Variance
ARTF	Regulatory Agency for Rail Transport
ASEAN	Association of Southeast Asian Nations
ASYCUDA	Automated System for Customs Data
BBC	British Broadcasting Corporation
BDT	Bangladeshi Taka
BOT	Build Operate Transfer
BRI	Belt and Road Initiative
BUET	Bangladesh University of Engineering and Technology
CBA	Cost Benefit Analysis
CDRS	Centre for Development Research Studies
CERRE	Centre on Regulation in Europe
CDS	Customs Declaration Service
CGE	Computable General Equilibrium
CHIEF	Customs Handling of Import and Export Freight
COMESA	Common Market for Eastern and Southern Africa
CoST	Construction Sector Transparency Initiative
CO_2	Carbon Dioxide
CPS	Crown Prosecution Service
CSIR	Council and Scientific and Industrial Research (South Africa)
CTC	Chinese Signalling System
DB	Deutsche Bahn
DFC	Dedicated Freight Corridor
DFID	Department for International Development
DfT	Department for Transport (UK)
DRC	Democratic Republic of Congo
EAP	Engineers Against Poverty
EIRR	Economic Internal Rate of Return
ENS	Entry Summary Declaration
ETCS	European Train Control System
EU	European Union
EUR	European Union Euro
FESARTA	Federation of Southern Africa Road Transport Associations
GATT	General Agreement on Tariffs and Trade
GDI	Growth in Domestic Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
GIZ	German Society for International Cooperation
GMS	Greater Mekong Sub-region
GPRTU	Ghana Private Road Transport Union
GPS	Global Positioning System
GQ	Golden Quadrilateral
GRA	Global Roadmap of Action

HDM	Highway Development and Management
HIC	High-income Country
HVT	High Volume Transport
IAMM	International Infrastructure Management Manual
IDR	Indonesian Rupiah
IEG	Independent Evaluation Group
IGC	International Growth Centre
IMF	International Monetary Fund
INR	Indian Rupee
IoT	Internet of Things
IRI	International Roughness Index
IRIM	Inter-Regional Implementation Meeting
ICT	Information and Communications Technology
ILO	International Labour Organization
JICA	Japan International Cooperation Agency
LIC	Low-income country
LLDC	Landlocked developing countries
MCLI	Maputo Corridor Logistics Initiative
MDB	Multilateral Development Banks
MDC	Maputo Development Corridor
MESA	million equivalent standard axles
MIC	Middle Income Country
MRIO	Multiregional Input Output
NCTS	New Computerised Transit System
NEN	National Express Network
NESDB	Office of the National Economic and Social Development Council
NGO	Non-Government Organisation
NO_x	Nitrogen Oxide
OBW	On-Board Weigh
OECD	Organisation for Economic Co-operation and Development
ORR	Office of Road and Rail
OSCE	Organisation for Security and Co-operation in Europe
PIARC	Permanent International Association of Road Congresses
PMU	Project Management Unit
PPP	Public-Private Partnership
PSD	Power Spectral Density
RAP	Reclaimed Asphalt Pavement
ReCAP	Research for Community Access Partnership
RFID	Radio Frequency Identification
RMI	Road Maintenance Initiative
RMS	Root Mean Squared
ROCKS	Road Cost Knowledge System
RP	Revealed Preference
SASEC	South Asia Subregional Economic Cooperation
SDG	Sustainable Development Goal
SDI	Spatial Development Initiative
SNCF	French National Railways
SoK	State of Knowledge
SP	Stated Preference
SSATP	Sub-Saharan African Transport Program
SuM4All	Sustainable Mobility for All
TAZARA	Tanzania Zambia Railway Authority

TOC	Train Operating Company
TOR	Terms of Reference
TIR	International Road Transport (system)
TRB	Transportation Research Board
TZS	Tanzanian Shilling
UIC	International Union of Railways
UK	United Kingdom
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNCTAD	United Nations Conference on Trade and Development
UNRA	Uganda National Roads Authority
USA	United States of America
USD	United States Dollar
VECM	Vector Error Correction Model
VOR	Value of Reliability
VOT	Value of Time
WCM	World Customs Organization
WCO	World Customs Organization
WHO	World Health Organization
WIM	Weigh in Motion
WTA	Willingness to Accept
WTO	World Trade Organization
WTP	Willingness to Pay

Executive Summary

Long distance strategic road and rail transport is one of the four themes of the high-volume transport (HVT) applied research programme funded by Department for International Development (DFID). The HVT programme has been set up to identify transport research priorities in low-income countries (LICs) in Sub-Saharan Africa and South Asia and to deliver a research programme to meet these needs. Closely associated with identifying the research priorities is assessment of the capacity building requirements as well as dissemination of the research outcomes to the relevant authorities in the countries of the two regions to ensure maximum uptake.

This final report on long distance strategic road and rail transport provides DFID with information on which to base the decision on the direction and strategy for research to be carried out in Part 2 of the HVT Programme. The report sets out the findings of literature reviews and the research priorities identified for long distance road and rail transport in LICs in Sub-Saharan Africa and South Asia.

The research priorities are directed to ensuring long distance transport contributes more effectively to economic and social development. They are closely aligned with the development goals for these regions and specifically with the approaches advocated by UK Aid Direct in support of DFID strategic objectives. The research priorities identified in this study also contribute to achieving the UN Sustainable Development Goals (SDGs) and to the goals of the World Bank initiative of Sustainable Mobility for All (SuM4All).

Long distance road and rail transport

In the context of high volume transport, the theme long distance road and rail transport covers infrastructure and services to transport people and freight between and within cities and large urban areas and the long distance transport of freight and bulk commodities. Based on these considerations, the theme long distance strategic road and rail was divided into four areas for the literature reviews and identification of research priorities. The focus areas are:

> road infrastructure;
> rail infrastructure;
> road and rail services;
> HVT Corridors and Networks.

Literature reviews

Extensive literature reviews were carried out on the state of knowledge in each of these four areas of HVT transport in LICs in Sub-Saharan Africa and South Asia. For comparison, studies in high and medium income countries and other regions were also reviewed.

Road infrastructure

The literature review of road infrastructure focused on sustainable high-volume road networks, specifically on reducing whole life-cycle costs, securing financing and improving governance. Research indicated that new approaches and methods could reduce road construction and maintenance costs, make roads more resilient and contribute to reducing greenhouse gas (GHG) emissions from the transport sector in these regions.

Regional and strategic national roads carry more than 80% of freight and passenger traffic in Sub-Saharan Africa and South Asia. However, current practices in road construction and maintenance do not deliver resilient roads required for long-term economic and social development.

Financing construction and maintenance of long-distance road corridors and strategic national roads presents difficult choices for indebted and resource-limited LICs. With population growth forecast to continue in both regions, LIC governments face ever greater challenges in balancing expenditure on road infrastructure and other services including education, health and welfare safeguards. Scarce domestic resources will have to be used more effectively and efficiently, and new ways explored to attracting funding from private investors, and from traditional and new development partners.

Rail infrastructure

The review centred on fundamental aspects of rail infrastructure in Sub-Saharan Africa and South Asia, namely interoperability, connectivity, the permanent way infrastructure, operational capacity and Chinese involvement.

LICs have difficulties in securing finance to construct new, and to rehabilitate, rail infrastructure that crosses country borders. Moreover, higher costs of rail operations and maintenance compared to roads often coupled with shared ownership make rail operations more complex. Many countries in Sub-Saharan Africa have introduced rail concessions through public-private partnerships but the results have been mixed. In South Asia, rail companies largely remain in public ownership with high levels of government subsidy. Furthermore, there is scepticism about the long-term affordability and technical interoperability of externally funded projects, such as the Chinese-funded, standard gauge railway routes in Sub-Saharan Africa. Thus, LIC governments need to find appropriate and cost-effective solutions that meet regional requirements, and that are capable of incremental improvements.

Road and rail transport services

The literature review of road and rail transport services was wide ranging and covered franchising and concessioning, safety and economic regulation, and border transit. The review makes clear that LICs face considerable challenges in these areas, and that resolving these challenges is important to their development.

Overall, studies indicate that journey time and reliability of journey time impact on freight choices. This is the case in LICs as well as high-income countries (HICs) with evidence for direct impacts of increased delay at borders on cross-border freight. Further, the literature review suggests that cross-border freight issues are a major concern for LICs, particularly landlocked countries. Delay and unpredictability of transit times restrict potentially beneficial trade. This limits economic development and social mobility and thus, evaluation of measures to minimise time and uncertainty at borders is a key research area.

HVT corridors and networks

The review of HVT corridors and networks considered their socio-economic impacts and means of assessing these impacts and corridor management. Transport corridors contribute to regional and local development but such multi-sectoral development initiatives are a new concept in most countries in Sub-Saharan Africa. A range of issues need to be addressed to ensure the national and transnational transport corridors operate efficiently and contribute to economic development in their immediate vicinity and further in the surrounding region.

Transport corridors and their multiple economic and social impacts inevitably involve trade-offs. Thus, the potential impacts must be taken into account in planning and designing major transport infrastructure investments. Research is proposed to gain insights that will contribute to transport infrastructure planning and development that support more balanced, sustainable and inclusive development.

Priority research areas

Priority research areas have been identified from the extensive literature reviews of the four key areas in long distance road and rail transport in LICs in Sub-Saharan Africa and South Asia. These priority research areas were discussed in depth with key stakeholders in both regions during workshops held in November 2018 in Dhaka, Bangladesh; Nairobi, Kenya; and Dar es Salaam, Tanzania. The workshop outcomes were also substantiated in the responses of 51 stakeholders in the two regions from a detailed online questionnaire.

The eight priority research areas are listed in Table E.1. Each of the priority research areas is closely aligned with the development goals for LICs in the two regions, specifically UK Aid Direct approaches to support DFID strategic objectives. The research priorities contribute to the SDGs and to the World Bank initiative, Sustainable Mobility for All (SuM4All).

State of knowledge papers

Based on seven abstracts, the research priority areas identified and the need for academic rigour, four topics have been selected for state of knowledge papers to be submitted to a peer-reviewed journal:

> designing pavements sustainably: how to include non-standard or recycled materials without compromising whole life-cycle performance;
> adapting and adopting state-of-the-art technology for safer and reliable train operations;
> reducing transport costs by strengthening competition, regulatory and institutional reforms;
> unlocking the potential of transport corridors to generate wider socio-economic development.

The papers are to be presented for publication in a special issue of Sustainability, an online peer-reviewed journal. This single, open-access source will facilitate discussion of key long distance road and rail research areas which are required to address UN SDGs and affordable, safe and environmentally resilient transport to support mobility for all.

Capacity building

A range of research organisations, transport authorities and government ministries will be responsible for the practical uptake and implementation of the research findings. As research capacity will vary between countries and organisations, a strategy for capacity building assessment has been developed. This strategy supports the institutions responsible for, or best suited to, the uptake and implementation of research findings for self-assessment and gap analysis of their research capacity. Subsequently, capacity-building programmes will need to be developed and implemented to meet requirements, preferably timed early in the second part of the HVT programme.

Country ranking/selection

A multi-criteria approach has been used to make a preliminary ranking of LICs in Sub-Saharan Africa and South Asia for participation in Part 2 of the HVT programme. Three pre-selection criteria were used: a DFID priority country in Sub-Saharan Africa or South Asia; willingness to engage in the HVT programme; and sufficient research capacity to engage in the research programme.

Based on the country ranking exercise, the following countries are recommended for consideration as partners in the research: Nigeria, Kenya, Tanzania and Zambia in Sub-Saharan Africa; and Indonesia, Bangladesh, Afghanistan and Pakistan in South Asia.

Table E.1: Summary of priority research areas identified in long distance road and rail transport and alignment with development goals

	Priority Research Areas	UK AID supportive approaches[1]	Relevant SDGs[2]	SUM4ALL Ambition[3]
ROAD INFRASTRUCTURE				
1	**Affordable high-volume roads that are low maintenance and resilient to climate change**	4. Improve access, supply and quality of basic services 6. Increased economic empowerment - job creation, income generation, and market access. 7. Strengthen response to conflict and local-level crisis in fragile and conflict-affected states.	**Targets 9.1** **Target 11.2** Targets 9.4, 9.5 Targets 12.1, 12.4, 12.7 Targets 13.1, 13.2, 13.A	Universal access Efficiency Green mobility
2	**More effective expenditure on roads by maximising local participation**	1. Partnerships to promote greater accountability 3. Strengthen advocacy actors to hold decision makers to account. 4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access.	**Target 11.2** Target 9.5 Target 10.2 Targets 16.5, 16.6, 16.7	Universal access
RAIL INFRASTRUCTURE				
3	**New affordable and sustainable approaches to increase railway network capacity**	4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access. 7. Strengthen response to conflict and local-level crisis in fragile and conflict-affected states.	**Targets 3.6, 3.9** **Target 9.A** **Target 11.2** Target 9.5 Targets 12.1 Target 13.A	Universal access Efficiency Green mobility
4	**New approaches to improve the commercial viability of railway networks**	4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access. 7. Strengthen the response to conflict and local-level crisis in fragile and conflict-affected states.	**Targets 3.6, 3.9** **Target 9.A** **Target 11.2** Target 9.5, Targets 12.1, 12.4 Target 13.A	Universal access Efficiency Green mobility
ROAD AND RAIL SERVICES				
5	**Improving rail network performance to deliver competitive services**	4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access.	**Targets 3.6, 3.9** **Target 11.2** Target 9.5 Targets 12.1 Target 13.A	Universal access Efficiency Green mobility

Priority Research Areas		UK AID supportive approaches[1]	Relevant SDGs[2]	SUM4ALL Ambition[3]
6	**Improving transit transport along corridors and across borders**	4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access. 7. Strengthen response to conflict and local-level crisis in fragile and conflict-affected states.	**Targets 9.1, 9.A** **Target 11.2** Target 9.5 Target 12.1	Universal access Efficiency Green mobility
HVT CORRIDORS AND NETWORKS				
7	**Stakeholder governance structures for smart transport corridors**	1. Partnerships to promote greater accountability 3. Strengthen advocacy actors to hold decision makers to account. 4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access.	**Targets 9.1. 9A** **Target 11.2** Target 9.5 Target 10.2 Targets 16.5, 16.6, 16.7	Universal access Efficiency Green mobility
8	**More equitable distribution of the economic and social benefits of transport corridor development**	4. improve access, supply and quality of basic services. 6. increase economic empowerment - job creation, income generation, market access.	**Targets 9.1, 9A** **Target 11.2** Target 9.5 Target 10.2	Universal access Efficiency Green mobility

[1] **UK AID Supportive Approaches. For complete statement, see Chapter 1.** https://www.ukaiddirect.org/about/fund-priorities-2/.

[2] **SDG targets in abbreviated statement. For complete statements, see Chapter 1.** The targets emboldened are those most specifically relevant to long distance strategic road and rail. Improvements in road and rail transport will contribute to achieving the targets. These are:

3.6: Halve global road traffic deaths and injuries by 2020.

3.9: Reduce deaths and illnesses from hazardous chemicals, pollution and contamination.

9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure to support economic development and human wellbeing for all.

9.A: Facilitate sustainable and resilient infrastructure development in developing countries.

11.2: Access to safe, affordable, accessible and sustainable transport systems for all.

For the details of the SDGs, see https://sustainabledevelopment.un.org

[3] **SuM4All - Sustainable Mobility for All. For complete goal statements, see Chapter 1.**

1 Introduction

Long distance strategic road and rail transport is one of the four themes of the High-Volume Transport (HVT) applied research programme funded by Department for International Development (DFID). The HVT programme has been set up to identify transport research priorities in low-income countries (LICs) in Sub-Saharan Africa and South Asia and to deliver a research programme to meet these needs. Closely associated with the research priorities is building the capacity of the relevant authorities in the countries of the two regions and disseminating the research outcomes to ensure maximum uptake.

Most research on HVT to date has been undertaken to address problems in middle and high-income countries with little focus on LICs in Sub-Saharan Africa and South Asia. Thus, this DIFD-funded High Volume Transport (HVT) programme is key to determining appropriate investment in high volume transport in these countries.

As well as long distance strategic road and rail, the four-year HVT programme (2017 to 2021) covers three other transport themes: urban transport; low carbon transport; and road safety, gender, vulnerable groups and inclusion in high volume transport. There are clearly overlaps and cross-cutting issues between these themes.

The first part of the long distance strategic road and rail HVT programme (seven months duration) has identified the priority research areas, and the requirements for a capacity building strategy to support the research. A multi-criteria analysis has been developed to facilitate the identification of partner countries in Sub-Saharan Africa and South Asia to participate in Part 2 of the HVT programme. The findings of Part 1 will be disseminated via a number of peer reviewed journal articles.

Thus, this report sets out the findings of the in-depth review and assessment of the current state of knowledge and the research priorities identified to enable long distance road and rail transport to contribute more effectively to economic and social development to LICs in Sub-Saharan Africa and South Asia. These research priorities are closely aligned with the approaches advocated by UK Aid Direct in support of DFID strategic objectives. The research priorities also contribute to achieving the UN Sustainable Development Goals (SDGs) and to the goals of the World Bank initiative of Sustainable Mobility for All (SuM4All).

The report also describes our strategy for the capacity building assessment of research organisations, transport authorities and government ministries selected for participation in Part 2 of the HVT programme. Preliminary recommendations are made for the selection of countries in both regions using a multi-criteria selection approach.

1.1 Long-distance strategic road and rail

In the context of high volume transport, the theme long distance strategic road and rail covers road and rail infrastructure and services to transport people and freight between cities and large urban areas, and the long distance transport of freight and bulk commodities. In long distance transport, transport corridors and intermodal hubs outside urban centres play key roles and were included in our State of Knowledge reviews.

Based on these considerations, the theme long distance strategic road and rail has been divided into four focus areas for the literature reviews and identification of research priorities. The focus areas are:

> road infrastructure;
> rail infrastructure;

> road and rail services;
> HVT corridors and networks.

HVT road transport covers roads carrying traffic above the thresholds set for low volume road by the Research for Community Access Partnership (ReCAP, 2016). Thus, long distance road and rail covers the research needs and priorities for roads carrying more than 300 vehicles per day and more than 1 million equivalent standard axles (MESA). However, a similar definition cannot be applied to rail transport because of rail systems are high capital intensive and most long-distance rail systems are high volume by nature.

Road infrastructure

Road infrastructure is the physical structure of the road pavement including earthworks and structures (e.g., bridges, culverts drainage assets and fords) and ancillary furniture (e.g., road markings and road signs) and is either a single road or a road network. Research areas are associated with the appraisal, design, financing, construction, rehabilitation, maintenance and management of road infrastructure.

Rail infrastructure

Rail infrastructure consists of the railway track, earthworks, structures, catenary, switches and crossings and signalling. Traditional ballasted railway track comprises rail, rail fastenings, rail pads, sleepers, under sleeper pads, ballast, sub ballast (a granular layer), a sand blanket (in some cases) and the underlying subgrade. These components together form a structural system designed to withstand the damaging effects of repetitive dynamic train loads and the environment so that the subgrade is adequately protected and train operation, passenger comfort and safety are within tolerable limits. In concrete railway track systems (slab track), the sleepers are often not present and the ballast and sub-ballast layers are replaced by a concrete construction. The major research requirements for railway are investment appraisal, geometric and structural design, financing, construction, rehabilitation, maintenance and management of railway infrastructure.

Road and rail transport services

Road and rail services for the transport of goods and people are essential for economic and social development. Efficient services provide maximum return on transport infrastructure investments and require state involvement to ensure safe and effective provision. The primary research areas are associated with rail policies and regulations, railway concessions, the competitiveness of rail services with respect to road transport and cross-border movement.

HVT corridors and networks

In the context of the present study, a transport corridor refers to a combination of road and rail networks linking major origins and destinations within a geographic region defined by its economic potential rather than its political or geographic boundaries. A transport corridor may be confined within national boundaries or may stretch across national boundaries. HVT networks carry the major share of passenger and freight traffic volumes of a country and thus play a major role in economic and social development. At the macro level, the transport network is linked to national output, employment and income. At the micro level, the transport network links producers and consumers, and contributes to poverty alleviation and facilitates access to education, employment, health, and social and cultural facilities. The research areas focus on stakeholders, governance, corridor operations and economic and social benefits.

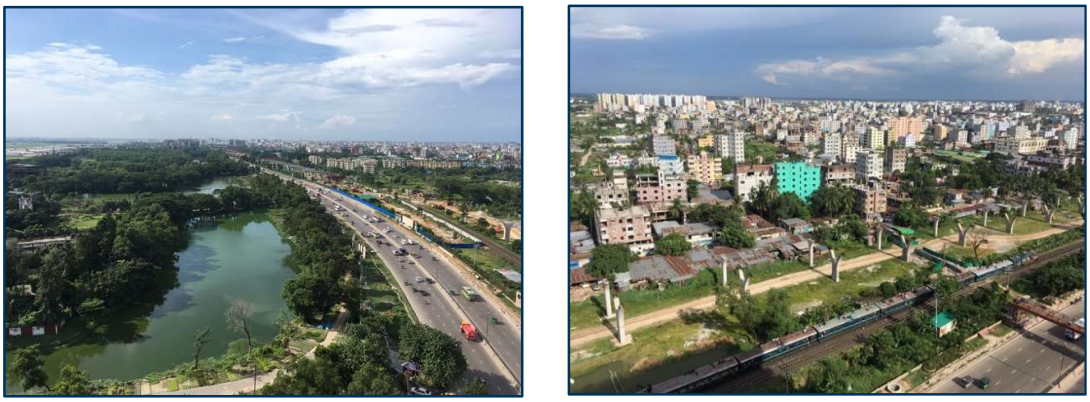

Figure 1: Example of high-volume road and rail link sharing urban space in Dhaka, Bangladesh

1.2 Global development agenda

As one of the four themes of the DFID initiative on HVT programme, the research priorities in long distance road and rail transport need to align the investment priorities of DFID and the Multilateral Development Banks (MDBs), as well as those of LICs in the two regions. These priorities are to achieve:

> **impact** - to help reduce poverty through inclusive economic growth and by reducing climate impact in Africa and South Asia;
> **outcome** - to provide evidence to assist policy makers and investors on investing in sustainable high volume road and rail infrastructure and services in LICs.

DFID - UK AID supportive approaches

Research under the HVT programme supports strategic objectives set out in the DFID single departmental plan (DFID, 2018), and specifically supports Promoting Economic Development and Prosperity (objective 3.1):

"Help unlock opportunities for economic development in sectors such as energy, infrastructure, urban planning, manufacturing, commercial agriculture and financial services."

The research for long distance rail and rail transport supports DFID operations in developing countries, UK AID, to achieve their wider strategic objectives, by contributing to their supportive approaches to:

> develop and use partnerships to promote greater accountability;
> strengthen the ability of existing and new advocacy actors to enable decision makers to be held to account;
> improve access, supply and quality of basic services;
> demonstrate increased opportunities for economic empowerment through job creation, income generation and improving market access;
> strengthen the response to conflict and local-level crisis to improve resilience in fragile and conflict-affected states.

UN Sustainable Development Goals

The HVT programme contributes to achieving United Nations Sustainable Development Goals (United Nations, 2019). These SDG goals are directed to ending poverty, fighting inequality and stopping climate

change and are thus similar to DFID strategic objectives. By responding to these goals explicitly, the HVT research programme demonstrate the role of transport research in advancing economic and social development in LICs.

The SDGs and the targets specifically relevant to long distance road and rail transport are as follows:

Target 3.6: By 2020, halve the number of global deaths and injuries from road traffic accidents.

Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Target 9.1: By 2030, develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human wellbeing, with a focus on affordable and equitable access for all.

Target 9.A: Facilitate sustainable and resilient infrastructure development in developing countries

Target 11.2: Access to safe, affordable, accessible and sustainable transport systems for all.

In addition, improvements in long distance road and rail transport will contribute to a range of other SDGs including:

9.4: Upgrade infrastructure and retrofit industries to make them sustainable.

9.5: Enhance scientific research and technology capabilities in developing countries.

10.2: Social, economic and political inclusion of all.

12.1: Implement a 10-year framework of programmes on sustainable consumption and production.

12.4: Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle.

12.7: Promote public procurement practices that are sustainable, in accordance with national policies and priorities.

13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters.

13.2: Integrate climate change measures into national policies, strategies and planning.

13.A: Mitigation actions and transparency on Green Climate Fund in developing countries.

16.5: Reduce bribery and corruption.

16.6: Develop effective, accountable and transparent institutions.

16.7: Ensure responsive, inclusive, participatory and representative decision-making.

SuM4All initiative

The Sustainable Mobility for All (SuM4All) initiative is convened by the World Bank and supported by 50 leading organisations and agencies in the transport sector, including DFID and ReCAP who are part of the 15 member steering committee.

SuM4All is committed to implementing the SDGs and its Global Roadmap of Action (GRA) directly relates to the objectives of the HVT applied research programme (SuM4All, 2018a). SuM4All has four policy goals that need to be addressed in the HVT programme. The goals are:

> Universal Access: Connect all people, including women and communities to economic and social opportunities;
> Efficiency: Optimise the predictability, reliability and the cost effectiveness of mobility;
> Safety: Drastically reduce fatalities, injuries and crashes;
> Green: Minimize the environmental footprint of mobility (GHG emissions, noise and air pollution).

2 Study Overview

This chapter gives an overview of the study on Theme 1 long-distance strategic road and rail transport leading to the study deliverables presented in this report. These deliverables are an identification of research priority areas for LICs in Sub-Saharan Africa and South Asia; recommendations for the selection of countries to participate in Part 2; and a methodology for capacity assessment of the participating research organisations. The study comprised four in-depth literature reviews to establish the basis for setting priority research areas and abstracts for State of Knowledge (SoK) papers, international stakeholder engagement, research capacity assessment, and country selection criteria.

2.1 Literature review

SoK literature review was conducted in the four areas of long distance strategic road and rail transport. Reports, journal and conference articles were identified using key word searches of the websites of organisations involved in the road and rail sectors, on-line bibliographic databases, subject-specific databases, internet search engines and books and journals. Priority research areas were identified based on these reviews.

The focus of each of the four literature reviews is presented below.

Road infrastructure

The literature review on road infrastructure, focused on two areas, namely reducing whole life-cycle costs, and securing finance and improving governance. Under reducing whole life-cycle costs, making roads more affordable and resilient to climate change in Sub-Saharan Africa and South Asia were reviewed with respect to road infrastructure design, construction, maintenance, management and operation. In securing finance for road infrastructure, studies were analysed on road funds and public-private partnerships to identify success factors that could be applicable to Sub-Saharan Africa and South Asia. The road infrastructure governance literature was assessed with respect to increasing transparency, and physical and financial audits as instruments to reduce corruption.

Rail infrastructure

The review compared statistics on the size and performance of railways in Sub-Saharan Africa and South Asia with countries that have highly developed railway networks. Issues considered were interoperability and connectivity, the permanent way infrastructure and operational capacity. Chinese involvement in rail infrastructure development in both regions was reviewed and discussed. The review concluded with a discussion of the principal challenges facing LICs in Sub-Saharan Africa and South Asia, and how these challenges could be addressed with the introduction of local technical standards and technologies.

Road and rail transport services

The review focused on regulation, franchising and institutional restructuring of railway transport services and border issues faced by road and rail freight services.

Lessons to be learned from countries with railway franchises in terms of design and delivery procurement mechanisms were assessed for LICs in Sub-Saharan Africa and South Asia. The review included the role of public bodies in monitoring concessions and providing regulation and strategic direction.

Mechanisms to reduce overloading, and approaches to provide incentives and enforcement were reviewed and discussed. Studies on cross-border road and rail freight were analysed to identify

approaches to facilitate inter-country trade. The review considered the use of e-border technology and standardised documentation as well as benefits of, and mechanisms for, reducing border time uncertainty.

HVT corridors and networks

The literature review identified and discussed the impacts of investment in corridors and networks. Methods were assessed for evaluating investments relevant to evaluating impacts on economic growth, welfare, trade and investment, the rural economy, poverty reduction, social impacts and equity, inclusive development, employment and the environment. The review also considered transport corridors, and in particular efficient management structures for the coordinated development and operation of corridors.

2.2 State of Knowledge papers

A workshop at the University of Nottingham on 17 December 2018 agreed to provide seven SoK abstracts. From these four, journal papers are to be prepared for publication in a peer-reviewed scientific journal. This decision increased the number of papers specified in Terms of Reference (ToR) because it was considered that the additional papers were needed to cover the research priority areas identified in the literature reviews. Thus, it is proposed to present four review papers for publication in a special issue of Sustainability, an online, open access journal, providing a concise source of information.

2.3 Stakeholder engagement

Workshops

Stakeholders were consulted about the priority research areas in four international workshops, a micro-workshop with the Gambia Roads Authority and a questionnaire distributed to a wide range of stakeholders over a two-month period. The four workshops are as follows:

Workshop 1: Long distance road and rail transport in Dhaka, Bangladesh on 6 November 2018.

Workshop 2: Rail infrastructure and transport services in Nairobi, Kenya on 23 November 2018.

Workshop 3: Road infrastructure and transport services in Dar es Salaam, Tanzania 23 November 2018.

Workshop 4: Validation workshop in London, UK on 8 February 2019.

A micro-workshop with the Gambia National Roads Authority was conducted at the University of Birmingham, UK, from 24 to 28 September 2018.

Summaries of the workshops are presented in Appendix 1.

Stakeholder questionnaire

A questionnaire for stakeholders to express their views on the research priorities in long distance road and rail transport was made available online (Survey Monkey: https://www.surveymonkey.co.uk/r/2ZX69J8) from 26 November to 20 December 2018

Employees from 70 government organisations and universities were invited to participate, and 55 responses were received including 40 from Sub-Saharan Africa and 10 from South Asia. The questionnaire is presented in Appendix 2.

2.4 Research capacity assessment

A methodology to assess the research capacity of organisations in the countries to be selected to participate in Part 2 of the HVT Programme was developed as follows:

> identify the major institutions in the partner countries with the responsibility for or best suited to up take and implement research findings;
> carry out a gap analysis of research uptake and implementation capacities of these organisations;
> identify generic capacity building programmes that may be suitable for the institutions according to their needs identified by the gap analysis.

A self-assessment approach was developed to assess research capacity based on the external environment, institutional issues, technical capability, research dissemination and research uptake.

The self-assessment questionnaire is described in Chapter 9 and provided in Appendix 3. The questionnaire was piloted with delegates at the ReCAP IRIM conference in Nepal during 25-27 February 2019.

2.5 Country selection methodology

Countries participating in Part 2 of the HVT programme need to meet three pre-selection criteria as follows:

> DFID priority country in Sub-Saharan Africa or South Asia;
> willingness of the relevant rail and road authorities to engage in the HVT programme;
> demonstrated sufficient research capacity.

Countries that met the pre-selection criteria were ranked using a multi-criteria analysis that included:

> size of road or rail network;
> investment (by GDP) in long-distance road and rail transport;
> demonstrable improvement in transport links as part of a wider poverty reduction strategy;
> potential to maximise benefits of HVT in terms of demographics and urbanisation rate.

3 Literature Review: Road Infrastructure

Except for the Democratic Republic of the Congo (DRC), most countries in Sub-Saharan Africa and South Asia are rapidly expanding their high-volume road infrastructure. For example, Cameroon is currently building approximately 1,500 km of new roads every year, and Ethiopia's target expansion is 8,000 km in three years.

This expansion is fuelled by competition between traditional funders, such as multilateral Development Banks (MDBs), and other investors backed by governments, the most active of which is China. In much of Sub-Saharan Africa, the flood of Chinese capital has led to massive and rapid growth of road networks, paralleling the dramatic transformation of China itself in recent decades.

However, such rapid growth inevitably brings challenges. Large amounts of capital leads to large incentives for corruption. Several high-profile cases have occurred where organisations have been awarded contracts under questionable circumstances. The projects themselves have either never materialised or been substantially delayed and/or of poor quality. World Bank has identified substantial variations in average construction costs, with news outlets in Bangladesh reporting that their country had been named at a briefing in June 2017 as the costliest of all. These variations can only be partly explained by different physical conditions or material costs. Several commentators (e.g., Locatelli et al., 2017) have ascribed the remainder of the variability to corruption within various systems.

The rapid expansion of high volume road networks raises enormous challenges in looking after the rapidly expanding asset. In all countries, including low-income countries (LICs), strategic highways are a very valuable asset. All countries find it difficult to allocate sufficient resources to maintaining the serviceability of these assets, which, unfortunately, means that the long-term condition is often much poorer than the originally constructed state. Thus, sound asset management is critical to continuing development.

With the above in mind, aspects of road infrastructure were reviewed with regard to the provision and preservation of high-volume road network.

3.1 Reducing whole life-cycle costs

Worldwide, there is pressure for more efficient use of available physical and financial resources, and at the same time, to maintain safety standards and to minimise environmental impacts. In planning, financing, designing, constructing and maintaining road networks, there is a need to optimise the whole life-cycle costs and benefits of the road (ISO, 2008). In addition to appropriate procurement practices (considered later in this report), this requires:

> economic geometric and pavement design and maintenance standards;
> efficient construction and maintenance;
> selection of cost effective and sustainably sourced (including recycled) materials;
> effective and efficient asset management practices;
> use of modern technologies to support these processes.

3.1.1 Road geometric, pavement and drainage design standards

Geometric pavement (structural) and drainage design standards adopted in LICs vary from country to country. In many countries, international design standards have been adopted, including those developed in the UK, USA, South Africa and increasingly in China. There is no reason to question the validity of these design standards in engineering terms, provided they are applied appropriately. For

example, the South African standards (e.g., Theyse et al., 2012) are based on world-class research by the Council for Scientific and Industrial Research (CSIR), including novel analytical techniques and full-scale testing. All standards are based on a combination of the laws of physics, experience, and a degree of interpolation and extrapolation, all of which can be improved with experience. However, technical geometric and structural correctness of a design does not mean the design is economically justifiable.

Road geometric design

Beuran et al. (2015) argued that interfaces, such as at ports and borders, are responsible for most delays in road freight transport rather than the means of transportation itself. This suggests that insistence on geometry suited to high speed may not always be economically necessary. Studies are inconclusive on the link between road geometry and traffic speed. In a roads study in Canada, Yagar and Van Aerde (1983) evaluated the effects of the numbers of corners, sight distances, lane widths and road markings. They concluded that lane width was the only statistically significant variable, with a 6 km/h speed increase per metre increase in lane width.

While the link between infrastructure quality and transport costs is clear (e.g., Limão and Venables, 2001), this link appears to have less to do with the design geometry than with the road surface condition. Storeygard (2016) found no clear link between transport costs in Tanzania and whether a road was paved or not. Similarly, in a comparison of transport costs between Pakistan and Africa, Rizet and Hine (1993) found that the substantially higher costs in Africa were not related to road standards. Average truck speeds were higher in Africa than in Pakistan.

There is considerable disagreement about safety (e.g., Downing et al., 1991). In a study on road data in Iran, Aram (2010) found only very slight effects on safety of factors, such as curve radius, sight lines and shoulder width. They highlighted disagreement between investigators about the effect of most variables on safety. Some have found curves to increase safety because curves effectively act as traffic calming elements and inhibit overtaking, which has also been suggested by a UK study (Wang et al., 2013). Another subject of conflicting reports is whether increasing width of shoulders increased or decreased safety. These conflicting findings are to be expected because geometric factors cannot be separated from road usage factors, such as pedestrian use of the road.

Although evidence from road planning models, such as the Highway Development and Management Model (HDM-4), suggest that road roughness is an important determinant of vehicle maintenance costs, a high degree of variation in effect has been found (Cundill et al. 1997). A study of feeder road transport in Ghana by Taiwo and Kumi (2013) found that transport charges on poor condition roads, were two to three times higher than on roads in good condition. However, the study did not explicitly study other factors such as density of demand or trip distance, which also may have influenced the result.

A study of forestry roads by Svenson and Fjeld (2015) found a 107% increase in fuel consumption from their lowest to highest road category. Limão and Venables (2001) found that deterioration from a mean condition to a 75th percentile of roughness increased transport costs by 12% in Sub-Saharan Africa. Perhaps more significantly, this change in road condition decreased freight tonnage by 28%.

In addition to direct economic effects, Mashoko et al. (2014) calculated greenhouse gas (GHG) emissions due to poor road surface condition in South Africa and found that an increase in International Roughness Index (IRI) of 1 m/km leads to between 4 and 10% increase in GHGs. In terms of wider economic and social effects, Kiprono and Matsumoto (2014) made a clear link between a good road and raised local productivity.

Changes in longitudinal highway geometry and cross sections can have substantial impacts on construction and maintenance costs, vehicle operating costs, travel time, safety, and reliability. Standards

in place generally allow for variations in geometric characteristics in a stepped way, where this is desirable for economic or other reasons. Standards will only be considered in the context of new cross section implications related to the outcomes of drainage research

In summary, relatively little is to be gained from insistence on the highest specification for road geometry (e.g. curvature), from either an economic or safety standpoint. Maintenance of road surface condition is a much more critical geometric factor with regard to transport economics.

Road pavement design

Roads are structural systems designed to withstand the combined effects of traffic and the environment for a pre-determined period of time to keep road use costs and safety within acceptable limits and to adequately protect the underlying subgrade (McElveany and Snaith, 2002). As stated above, nothing is intrinsically wrong with the designs currently used, such as those in South African standards and the recent Ethiopian design manual (Ethiopian Roads Authority, 2013). Both standards include accumulated experience of decades of performance monitoring. Furthermore, research is ongoing in South Africa (Jordaan et al., 2017) to make improvements that will allow materials that are currently non-standard to be incorporated into road design.

This last point is often associated with the use of lateritic materials that are not found in the temperate climates where most specifications originate. Pinard et al. (2014) has stated that evidence has accumulated since the work of Grace and Toll (1987) to indicate lateritic gravels can perform just as well as traditionally specified crushed rocks. They recommended use of standards developed in Brazil (see Table 2).

Table 2: Summary of Brazilian national specification for laterite base course

Property	Limits		Comments	
Silica sesquioxide ratio	≤ 2			
California Bearing Ratio (%)	≥ 60		DNER ME 49/74 (56 blows per payer compaction at design moisture content)	
Liquid Limit (%)	≤ 40			
Plasticity Index (%)	≤ 15			
Los Angeles Abrasion	≤ 65			
Grading (% passing sieve)	Grading A	Grading B	Tolerances specified:	
50.8 mm	100		Sieve size:	% passing:
25.4 mm	75-100	100	9.5-25.4	± 7
9.5 mm	40-85	60-95	0.42-4.8	± 5
4.8 mm	20-75	30-85	0.075	± 2
2.09 mm	15-60	15-60		
0.42 mm	10-45	10-45		
0.075 mm	5-30	5-30		
Grading modulus	1.65-2.70	1.65-2.70		
Dust ratio	≤ 0.67	≤ 0.67		
Sand Equivalent	≥ 30			

Source: NORMA DNIT 098/2007 – ES (Instituto de Pesquisas Rodoviárias, 2007)

Koranteng-Yorke et al. (2015) made a similar point about lateritic soils in Ghana and suggested that an analytical approach to pavement design would open the way to more appropriate design. This has been echoed by Rasul et al. (2016) in relation to the use of stabilised soils. Thus, while current structural design

standards are fit for purpose for conventional materials, the development of more flexible methods, suited to new and alternative (e.g., recycled) materials would bring significant benefit.

While many countries still use design methods, such the AASHTO and Asphalt Institute methods from USA, and Overseas Road Note 31 from UK, work is in progress that should result in increasingly more appropriate design standards. These methods have potential for other parts of the world, as proposed by Visser (2017) in relation to China. However, road structure design cannot be considered in isolation, and must be combined with appropriate drainage design, as well as construction quality and maintenance management.

Drainage design

Drainage requirements are closely connected to precipitation. Rainfall in excess of ground absorption or the capacity of drainage systems and rivers will cause flooding in peak events. Water held near the ground surface reduces soil strength, stiffness and resistance to plastic deformation. These problems can be addressed by drainage and/or soil stabilisation (see below). In most LICs, climate change is expected to increase precipitation and flooding risks, and reduce return periods of stipulated high flows in drains and rivers.

For Sub-Saharan Africa alone, climate change is estimated to increase road maintenance costs by 270%, if action is not taken (Cervigni et al., 2016; Figure 2). Design and construction to standards that do not take future climate change into account can be expected to have significant cost impacts. However, quantifying the impacts of climate change solely on a financial basis does not cover the wider economic and social impact, for instance, of flooding cutting off access to health care, education and markets.

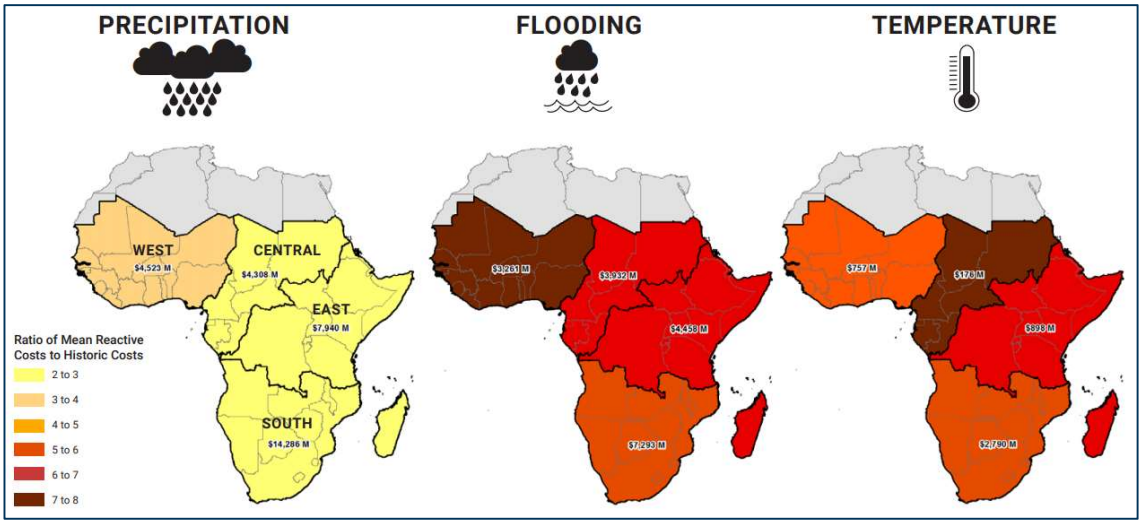

Figure 2: Increased cost of road maintenance from 2015 to 2050 due to anticipated climate changes (predictions taken from Cervigni et al., 2016)

Thus, the response of soils to drainage has to be assessed and appropriate techniques and methods selected to achieve the required drainage. Such techniques have been well explored by researchers, and textbooks and guidance are readily available (Morgan and Rickson, 2004; Dawson, 2008; Nicholson, 2014; Mousavi, 2016; Shukla, 2017; Saran, 2017). However, these publications generally consider the engineering problem in a static way without consideration of future climate change. Therefore, design, construction and maintenance has to be adapted to incorporate risk analysis of uncertainty of future climate stressor levels and economic logic (Hearn and Burrow, 2014). Knowledge and best practice on

such adaptation principles and processes is still at a relatively early stage of development. This is an area for worldwide research and specifically application in Sub-Saharan Africa and South Asia (see Table 3).

In addition, even without the complications caused by climate change, much of the knowledge about the drainage of soils has been derived from a developed country perspective and in temperate climates. Accordingly, better characterisation is needed of the application for the geological and climate conditions that can be expected in south Asia and Sub-Saharan Africa.

Table 3: Climate stressors and adaptation measures (adapted from Cervigni et al., 2016)

Climate stressor	Effect	Proactive adaptation measures
Precipitation	Increased precipitation leads to increased average moisture content in subgrade layers and reduced load carrying capacity	Add wider paved shoulders to improve surface drainage. Increase base strength (thickness and/or quality) to increase protection of subgrade layers.
Flooding (in excess of design flood)	Washaways and overtopping of road	Increase flood design return period by increasing the size or number of culverts.

Sub-surface highway drainage

There is a large body of knowledge backed by substantial research on sub-surface highway drainage as it affects pavement performance, embankment and cutting stability. Dawson (2008) presented comprehensive coverage of research and practice, much of which is state-of-the-art. However, it was prepared from a European perspective and does not specifically address issues in climates and geologies not common in Europe.

Design guidance for pavement sub-drainage in wet tropical climates is provided by Anon (2014) for the South China context but is applicable to tropical regions subject to deeply weathered soil profiles and intense rainstorms. The background research on which the design guidance is based appears to be dated. The situation in Southern Africa is similar. Anon (1994) has provided design guidance for South Africa, which is applicable to other parts of Southern Africa. However, this document is also rather dated because it does not consider climate change issues.

More broadly, sub-surface drainage systems appear to be a mature engineering aspect of roads, with few major changes in design approach for many years (e.g., Christopher and McGuffey, 1997). However, specific research needs have been identified on 'daylighting' drainage bases (TRB, 2009). Such research may be particularly relevant to South Asia and Sub-Saharan Africa because benefits could be delivered at low cost, giving potential improvement to drainage performance of construction layers (TRB, 2014a). In general, the developments are much more to do with the input to drainage systems (in terms of changing flow patterns due to climate change) and in environmental concerns and their alleviation when disposing of water.

Earthworks drainage

Similarly, the drainage of earthworks has been extensively researched and is well covered in transportation geotechnics literature (Forrester, 2001; Pohll et al., 2013). These drainage aspects include

cuttings and embankment slopes, and sub-surface drainage of embankments and the pre-existing ground.

Road surface drainage

Surface water removal continues to be a research interest worldwide (Sanders et al., 2012; Tang and Flintsch, 2015) because of increased intensity of rainstorms depositing thicker water films on road surfaces and the increased need for road safety. The latter requires reducing the water film thickness to prevent the likelihood of hydroplaning and to reduce traffic water spray that hinders the view of drivers. The drive to reduce road crashes is still very strong and the anticipated impact of climate change is predicted to cause more intense rainfall events, further increasing concern.

Water from the road surface has to be drained by pavement edge details, such as gullies, pipes, ditches and culverts. These structures may need debris control structures and/or chemical traps to prevent release of fuel spills into the wider environment. Sedimentation disposal is required on roads passing through areas where vegetation is not dense, for instance, in savannah zones, where human activity has removed vegetation from slopes and where land adjacent to the road is under cultivation. Heavy rainstorms wash sediment onto the road margins and block engineered drainage routes and resulting in washouts and contaminated water courses.

The need for research in these areas has been identified by TRB (2010; 2014b). A parliamentary enquiry into floods that killed six people in South Africa in November 2016 identified blocked culverts as a contributing factor (Maswanganyi, 2017). Given the wide range of maintenance guides available to road owners and operators (Hitch et al., 1985; Roughton, 2000), it is doubtful whether research is needed on better maintenance techniques or better drainage details and routings. Instead, more investigation is required on drainage infrastructure resilient to defects and which is low maintenance. More theoretical developments are needed to improve predictions to help to underwrite more reliable drainage in the future (TRB, 2016b).

Runoff estimations

Numerous methods are available to estimate runoff that have rainfall and the ground surface characteristics as the main inputs. Research should address the calculation methods but importantly should focus on the uncertainties in estimating rainfall and ground surface characteristics, appropriately. This research is necessary for areas where these data are not known or not reliable. As data must be usable in a watershed evaluation process (FAO, 1998), research will have to be reasonably wide-ranging and not over-specific to limited, highly localised, issues.

Water quality

Water released from drainage systems (surface and sub-surface systems) will either percolate down to groundwater or pass through a constructed drainage system to a watercourse. In both cases, the runoff must not contaminate groundwater or watercourses (Dawson, 1998). This is a key issue in LICs where water for drinking and cooking is taken from boreholes and streams and consumed without purification. However, road runoff may contain contaminants from motor vehicles and their cargoes, or from road construction materials, particularly those sourced from non-geologic origins. The level of contamination associated with alternative construction materials requires further study (TRB, 2016a).

Some natural improvements to water quality can be achieved by the systems over which, or ground through which, runoff percolates but this is not easily quantifiable and has been identified as a research need (Ashley et al., 2017). UK advice is available (Digman et al., 2014), but substantial research is required to develop and extend advice on design and practice suitable for LICs.

3.1.2 Construction and maintenance practices and materials

Kamanga and Steyn (2013) cited material costs and/or material shortages as a key reason for project delays in Malawi because the design and specifications did not permit use of more readily available materials that did not meet the exact specification. They recommended more research on alternative and marginal materials, such as lateritic gravels instead of crushed rock.

Advances have been made in the prediction of the performance of pavements that incorporate non-standard materials. Such materials include emulsion bound material (Liebenberg and Visser, 2004), in situ recycled layers (Paige-Green and Ware, 2006), and bituminous seal coat (Milne and Jenkins, 2005). Research has also addressed the performance of stabilised soils. Nevertheless, uptake of some technologies has been patchy, and this implies the need for updating standards across the region.

A further question about standards is whether they lock contractors into using expensive but potentially unnecessary machinery. A study by Grobler et al. (2000) on Choice of Technique Analysis for drainage installations proposed that employment-intensive techniques are often acceptable, provided the functionality of the product is not impaired. Even on strategic high-volume roads, elements of construction, such as earthworks, foundations and drainage, may not require specialist machinery.

An infrastructure project can generate jobs in poor communities during construction, operation and maintenance. A local work force requires investment in skills training. Research reported by NGO, Engineers Against Poverty (EAP) showed that skills training is successful for low volume roads (EAP, 2013), and some aspects are applicable to high-volume roads. However, procurement practices are required that encourage participation by local companies (EAP, 2008).

Alinaitwe et al. (2014) made the point that constructability is often neglected at the design stage in Uganda. They suggested a formal constructability review should be standard practice that takes into account ease of procuring and sourcing materials that are climate-sensitive and site accessibility.

Stabilisation

Stabilisation improves the strength, stiffness and resistance to plastic deformation of the natural soil (subgrade) on which a road is founded by adding a material that changes the soil properties. The material may work as a chemical or biological modifier of the soil minerals or their interaction, a cementing agent binding the soil minerals together or by physical insertion of load bearing members (e.g., fibres). Each is considered below.

Cement, lime and bitumen

The most common treatment of highway subgrades is to mix soils with cement or lime. These materials are widely available, and their use is well documented. Jenkins and Collings (2017) have prepared design procedures for bitumen stabilisation, which is a halfway house between soil and asphalt. Their procedures developed in a Southern African context could usefully be extended in Sub-Saharan Africa and South Asia.

Other hydraulic treatments and soil modifiers

Chemical processes between industrial by-products and clay soils mirror some of the chemical processes achieved with lime or cement. Collectively, this type of stabilisation is known as hydraulic binding. Products that have hydraulic binding capabilities when used alone or in some combinations include slag, (steel, blast furnace, phosphor-gypsum), ash (coal, rice husk, municipal solid waste, incinerator, olive, groundnut shell), silica fume, gypsum, cement kiln dust, crushed concrete and volcanic ash. Inert soil

modifiers have potential use, such as marble dust, waste shells, quarry fines, waste metal casting sand, reclaimed marine sands, ceramic discards, demolition waste and mine waste (tailings).

The challenge is to establish where these additives can be used and to estimate the medium to long-term benefits. Few additives work well in all soils and determining the preferred stabilisation on the basis of both economics and engineering properties is not straightforward. Most by-products are attractive not because of their engineering efficiency but because of their low cost (even, perhaps, a negative cost). However, this cost benefit is negated if the material has to be transported long distances. Although many combinations of soil and treatments have been studied, an overall strategy for all types of soils is needed to assess and implement preferred combinations based on economic and engineering considerations. The literature on soil treatment is extensive and reflects the large range of options available. See, for example, Canakcia et al., 2015; Firat et al., 2012; Hossain and Mol, 2011; Kolay et al., 2011; Salahudeen et al., 2014; Amadi, 2014; Madurwar et al., 2013; Ramesh et al., 2010; Yadu et al., 2011; Osinubi et al. 2008; Trandafir et al., 2008; Ray et al., 2010; Ng and Shi, 1998; Anupam et al., 2014.

Appropriate models of material performance in mechanistic pavement designs need to be developed that accurately replicate environmental loading so that deformations are not underestimated (Rasul et al., 2018). Very little research has been done in this area.

As identified by Parkman (2014), recycled and locally available materials are a technical research priority for road planning, design and construction. Research is particularly required on their potential use as stabilising agents.

Chemical and bio-activation

A wide variety of chemical and bio-activating additives is available. Almost all are proprietary and often come with glowing testimonials. Some of these materials can have major benefits but insufficient reliable information about their composition and a lack of case histories pose serious barriers to their reliable, beneficial application (Kolisoja, 2010; Uys et al., 2011; Steyn and Visser, 2011). TRB (2016c) highlighted this topic as a research need.

Mechanical reinforcement options

Mechanical reinforcement is well established, for example, using geosynthetics and metallic reinforcement, whether proprietary systems or designer/contractor led. It is supported by widely accepted design standards and product accreditation procedures (Manceau et al., 2012). Therefore, research on these materials should focus on aspects of local and specific application, such as soil type and extreme rainfall locations in parts of South Asia.

Below pavements, reinforcement inclusions are seldom needed for high-volume roads once in service because strain levels (required to exploit the strength of the reinforcing inclusion) are low. They are more likely to play a role during the construction of roads built on soft soils, allowing construction to proceed where otherwise it would have been difficult or impossible. However, reinforcing inclusions are often the preferred stabilisation technique for slopes and embankment bases.

Recycling

Despite high-income countries having only one-sixth of the world's population, they are responsible for two-thirds of the world's greenhouse gas emissions, but developing countries will suffer the most from the effects of weather extremes (World Bank, 2010).

Globally, the transport sector is estimated to contribute about 25% of total carbon dioxide (CO_2) emissions, of which road transport contributes 80% (WRI, 2007). Hence, sustainable development and maintenance of road infrastructure must be a major consideration.

All road paving operations - maintenance, rehabilitation and new construction -require the use of finite resources. The present trend in most developed countries is recycling of road materials. Recycling road materials is a well-established practice not only for environmental reasons, but also to save material costs. Less material equals less quarrying, resulting in reduced energy consumption as well as reduced environmental impact. It means using less fuel and less transport, thus reducing damage to road networks as well as noise pollution.

Experience has shown that in-situ recycling is up to 50% faster than conventional reconstruction (Oke, 2013). This brings benefits through reduced site supervision costs. Also, reduced construction periods minimise traffic delays caused by road works, and thus contributes to the economic benefit of recycling. Reusing road and footway materials (RAP) also leads to reduction in waste to landfill. This produces environmental and economic benefits (Oke, 2013).

The use of reclaimed asphalt pavement (RAP) is well accepted in the asphalt industry for the lower pavement layers, and 100% recycling can be achieved when cold recycling techniques are used (Jenkins, 2017). However, its use is still limited (<30%) on surface courses (AllBack2Pave, 2015). Recycled asphalt mixtures need accurate selection, classification and handling of RAP together with appropriate design, manufacturing and paving operations.

South Africa is a world pioneer in road pavement recycling, and associated regulations have existed since the late 1980s (CSIR, 1987). Hot recycling of asphalt is now also done by combining warm mix technology and recycling up to 40% RAP. In recent years, several trials have incorporated recycling practices for road base courses. These recycling practices have extensively improved sustainability by both using high modulus mixes and pioneering the use of cold asphalt mixes (National Asphalt, 2015). Contractors have also tackled technology issues, and there are examples of asphalt plants with parallel drums that can incorporate even 70% RAP content for hot mixes (National Asphalt, 2015). South Africa continues to pioneer cold recycling (Jenkins, 2017).

In contrast, when a road has failed completely in Nigeria, the failed asphalt layers have been discarded, largely because environmental laws are not fully enforced. The foundation is reworked and overlaid with fresh asphalt pavement. Where an asphalt pavement has structural failure, though still passable, an overlay is often applied to strengthen it and to cater for greater traffic loading. This is done despite being expensive, time consuming and not eco-efficient (Oke et al., 2013). Oke (2007) reported asphalt recycling in northern Nigeria but that the recycled material was only used for patching.

3.1.3 Asset management

In the 1990s, several LICs supported by the Multilateral Development Banks (MDBs) reformed their road sectors. This included setting up of road funds and semi-autonomous road authorities (Heggie and Vickers, 1998). The reforms have led to:

> recognition of the benefits of commercial management practices;
> need for increased maintenance funding;
> partial arrest of declines in the quality of road networks;
> need for improved efficiency and effectiveness of road management (Pinard, 2012).

At the same time, asset management practices were adopted by road agencies in LICs in Sub-Saharan Africa and South Asia. Advances made in asset management practices are briefly reviewed and suggestions made on how to address remaining issues.

Asset management consists of 'systematic and co-ordinated activities and practices through which an organisation optimally manages its physical assets, and their associated performance, risk and expenditures over their life-cycle for the purposes of achieving its organisational strategic plan' (BSI, 2004). Such management practices can be considered in terms of basic and advanced activities.

Basic road asset management is associated with meeting minimum statutory obligations and organisational requirements for financial planning and reporting (Robinson, 2008), and includes the following activities:

> identifying levels of service;
> predicting demand;
> assessing condition and monitoring performance;
> maintenance and its management;
> financial management;
> preparing an asset management plan.

Advanced asset management builds on basic asset management and aims to optimise activities and programmes to realise levels of service. The advanced approach incorporates a more sophisticated analysis of current and future asset condition and performance, and considers total transport whole life-cycle costs, customer expectations, the environment, current and future demand, risks, treatment options and asset value (IAMM, 2011; Robinson, 2008). Advanced asset management includes the following attributes (Robinson, 2008):

> failure mode analysis;
> risk assessment and management;
> demand management;
> optimised decision making including consideration of social, political, environmental and economic costs;
> valuation.

With the support of donor agencies and the MDBs as mentioned above, many road authorities were early adopters in the 1980s of basic and some advanced asset management practices. Some LIC road agencies had done so earlier and to a greater extent than their high-income country counterparts.

LIC practices in basic asset management

To enable basic asset management, the functional and structural condition of the road network should be assessed periodically. As data collection and processing is expensive, a stepped data collection process could be used as suggested by Snaith (1998). This process should include measurement of road roughness annually because this is a reliable indicator of the road functional condition and data are relatively inexpensive to collect. These data can be used to trigger non-structural maintenance. Road structural condition can be assessed less frequently, depending on the road construction and traffic volume, but ideally should be done at least once during a periodic maintenance cycle (Snaith, 1998).

Since the early 1980s, considerable research has been done worldwide to develop automated tools for road condition assessment. These include sophisticated instrumented vehicles travelling at normal traffic speeds to assess road functional and structural condition (DRI, 1999). According to Wang (2019), devices to measure roughness are categorised into four levels according to their accuracy and include non-

contact laser profilers (class 1, the most accurate), profilometers (class 2), bump integrators (class 3) and visual inspection (class 4). However, many road agencies in LICs still assess road functional condition manually (class 4) and structural condition not at all. Other road agencies in LICs use automated equipment to assess road roughness. See Uganda, UNRA (2017) and Bangladesh, HDM Circle (2017). However, equipment cost and upkeep are often prohibitive and therefore private contractors are used.

Research is ongoing worldwide to develop low-cost and robust approaches to road condition assessment, particularly road roughness, that are likely to be relevant to LICs and suitable for HVT and feeder road networks. These approaches include inexpensive robust versions of instrumented vehicles equipped with sensors that use ultrasound, acoustic, laser, ground penetrating radar or visual technologies (Li et al., 2018). Other approaches to be considered include the use of smartphone, drone and satellite technologies (Workman et al., 2017; Wang, 2019). The claim is made that some smartphone-based products can be used to measure road roughness and identify potholes (see Table 4). Research by Wang (2019) and Workman et al. (2017) suggest that smartphone and satellite-based technologies could be considered to be class 3 or 4 devices when used to measure road roughness. This would enable them to be used for strategic road management.

Furthermore, computer-based machine learning and deep learning data processing techniques can be used relatively easily to analyse large datasets and thus to reduce the costs of data analysis and potentially improve asset management system performance. However, capacity building is essential to ensure availability of trained personnel for computer-based processing, to understand asset management fundamentals and to assess the information provided.

Snaith (1998) described implementation of pavement management systems in LICs over a 15-year period starting in the early 1980s. At that time, systems were in their infancy and the availability of computer hardware was a challenge (Snaith, 1998). Many of these pavement management systems and their updated derivatives are still in use. The advantages described by Snaith (1998) include transparency, ease of use and low cost. These factors should be borne in mind when considering the sustainability of a computerised asset management system.

This raises key questions. What has enabled many road agencies in LICs to be early adopters of asset management practices and technologies? What specific system characteristics and environments have enabled the sustainable use of these systems? What are the lessons to be learned?

Various supporting factors or building blocks need to be in place for road management to be sustainable (e.g., Pinard, 2012; Burrow et al., 2013; Burrow et al., 2016). More than 25 years ago, the Road Maintenance Initiative (RMI), part of the multi-donor funded Sub-Saharan African Transport Program (SSATP), investigated issues associated with maintenance of the region's road networks. A road agency's ability to maintain its road networks was strongly influenced by a road authority's institutional structure, planning and management capabilities, and the external environment (World Bank, 1991). These building blocks are at least as important as the organisation's technical asset management capabilities and approaches in road network maintenance. Pinard (2012) developed an approach to determine the performance of road agencies in Sub-Saharan Africa. He found that these building blocks are essential to sustainable roads and thus to sustainable road asset management.

Ongoing work under the DFID-funded RECAP programme (Geddes et al., 2018; Burrow et al., 2016) builds on the assessment approach developed by Pinard (2012) to address how the building blocks can be considered in the context of low volume rural roads.

The approach adopted by Geddes et al. (2018) aims to foster self-reliance in rural road agencies and encourage greater accountability to road users and other sector stakeholders. Four local rural road authorities are engaging in the programme which is demonstrating significant gains in road asset

management practices. The approach focuses on improved performance in road asset management. The advocated approach is highly relevant to the HVT sector because the challenges and building blocks are broadly similar, and could be adopted in the HVT Programme.

LIC practices in advanced asset management

At the same time as pavement management systems were being developed, economists were developing optimised decision-making tools for the justification and ranking of major road schemes. These economic models allow serviceability standards to be set for road networks together with an indication of the required level of maintenance strategy and expenditure (Snaith, 1998). The most well-known and widely adopted of these models is the World Bank Highway Design and Maintenance Standard Model (HDM), which has had substantial uptake in LICs (UKCS, 2014).

Since 2008, the World Bank has used the HDM methodology to assess over 200 funded projects, with an estimated total value of approximately USD 55.16 billion, of which approximately USD 29.5 billion was in World Bank loans, credits and grants (UKCDS, 2014). For example, the World Bank used HDM-4 to assess the EUR 306 million Northern Corridor Transport Improvement Project, 225 km sections of Mombasa–Malaba/Kisumu roads in Kenya. HDM-4 was also used to assess the feasibility of alternatives for the rehabilitation of the Lodwar–Nadapal, 248 km highway in Kenya.

HDM-4 has been used by lead organisations in developing countries to justify proposals to attract investment from international donors. For instance, in 2009 HDM-4 was used to determine the costs and benefits of the long-term maintenance of the African North-South Corridor Aid-for-Trade road network. This 8,600 km system connects Dar-es-Salaam in Tanzania to the copper belt of Zambia and ports in Southern Africa. The resulting analysis and further assessment through HDM-4 was used to prioritise road upgrading projects on the network and to determine the financial and economic rates of return on projects in the wide context of the Corridor. This latter aspect formed part of the case put forward by Common Market for Eastern and Southern Africa (COMESA), the regional economic body, to win more than USD 600 million investment in the corridor from international donors by June 2013 (Odoki et al., 2009).

Road agencies in most LICs use HDM-4 routinely for road investment appraisal. In Uganda, HDM-4 has been used since 2010 to review the design, cost and economic benefit of upgrading 836 km of roads to bituminous standard. In Bangladesh, the Roads and Highways Department has used HDM (III, then 4) for the last 18 years to assess annually the maintenance requirements of its highways and district roads, and to prioritise maintenance expenditure (HDM Circle, 2017).

A number of factors contribute to the success of HDM. Fundamental to its success is the backing by the World Bank, other donor agencies including DFID, and PIARC. This has enabled research to develop the HDM model to continue for over 40 years. Most recently, a new variant, HDM Sentry, has been developed to simplify data input requirements and to facilitate use of HDM by non-technical users. The principles and analytical framework of the full version of HDM-4 are still in HDM Sentry (HDMGlobal, 2018).

Emerging research areas of potential interest to LICs is associated with the use of big data to support asset management decision-making. Associated technologies can improve asset management decision-making and reduce system data costs. One example is the development of machine learning approaches to predict road failure risk from road condition data sets (Schlotjes et al., 2015) and road failure analysis (Schlotjes et al., 2013). However, there is a pressing need to build capacity and ensure a sufficient number of trained personnel to work with these technologies and to assess the outputs.

Allied to the above, much information used in road asset management decision-making is unreliable in LICs. Despite technological advances, the accuracy and availability of road data are uncertain. To facilitate asset management under these circumstances, risk assessment and management approaches can be adopted, as described by ElCheikh and Burrow (2016) in asset management to deal with uncertainties in forecasting maintenance costs.

Table 4: Summary of current smartphone technologies for assessing road condition (after Wang, 2019)

Reference	Defect	Description
Street Bump (Carrera, et al., 2013)	Potholes	Web-based crowd sourcing to enable verifications by different drivers. A spike in acceleration exceeding a threshold is reported as a pothole.
(Byrne et al., 2013)	Potholes	Vehicle vertical accelerations are processed using a band pass filter of 0.5 – 6 Hz to identify and quantify the defects in terms of major and minor. The effects of low vehicle speeds (5 km/h), cornering, accelerating/decelerating are eliminated
"RoadLab" (Wang, Guo, 2016)	Road roughness	Uses a regression model to determine IRI from vertical accelerations. Takes into account the effects of the position of the smartphone, vehicle speed and suspension. Was found not to be an accurate predictor of the condition of unpaved roads
Roadroid (Forslöf, 2012)	Road roughness	A multiple linear regression model is used to determine IRI from RMS of measured vertical accelerations. The model was developed using 3 vehicle types travelling at speeds between 20 and 100 km/h. The accuracy of estimated IRI from the correlation was found to be 70-80%. Measuring frequency of 100 Hz.
Bump Recorder (Koichi, 2014)	Discrete defects and road roughness	The prototype application was developed using vertical acceleration data obtained from a smartphone fitted in a Toyota Prius. The application claims to determine both roughness and the height of discrete defects. The estimated vehicle un-sprung elevation is assumed equal to the road profile. Measuring frequency of 100 Hz.
(Islam et al., 2014)	Road roughness	Uses a linear regression model to relate IRI to vertical acceleration. The model was developed from data captured from a smartphone inside a Honda CRV travelling at 50 mph. The system was found to have a high repeatability (coefficient of variance less than 15%). Vehicle sprung mass and suspension were found to affect the accuracy.
(Douangphachanh, Oneyama, 2013)	Road roughness	An empirical model which relates IRI to vertical acceleration. The data to develop the model was obtained from studies undertaken with two types of smartphones fitted inside a Toyota VIGO 4WD pickup truck and a Toyota Camry. Measurements were conducted at capture frequencies of 100 Hz.
(Du et al., 2014)	Road roughness	A multi-linear regression model was developed between IRI and the Power Spectral Density (PSD) of measured acceleration data. A Lexus sedan was used, travelling at speeds of up to 60 km/h. The estimated and actual IRI were compared and the error was found to be less than 15%.
(Belzowski, Ekstrom, 2015)	Road roughness	Multi-regression models based on empirical data obtained from 9 different smartphones at sampling frequency of 100 Hz. Roads of 5 different IRI values were considered. Differences were found between smartphones.

3.2 Road financing

Road agencies in LICs face large maintenance backlogs and central government budget allocations are insufficient to meet periodic maintenance needs. The impact on transport costs and wider costs to the economy are estimated to far exceed the money 'saved' through insufficient maintenance spending

(Heggie, 1995). The insufficiency of budget allocations for road maintenance has provided a rationale for the establishment of road funds.

3.2.1 Road funds

The traditional model for financing road investment is the Road Fund, a dedicated fund controlled by national or local government for road construction and maintenance. The first generation road funds set up in the 1960s and 1970s earmarked government funds for roads agencies to increase budget allocations for road maintenance. The second generation road funds were established later (Potter, 1997; Gwilliam and Shalizi, 1999). Heggie (1995) noted that first generation road funds undermined overall government budget management. Furthermore, payments to these funds tended to be erratic, withdrawals often delayed, expenditure loosely controlled, and governments borrowed money to finance spending in other areas.

McCleary (1991) argued that earmarking revenues for road funds has been unsuccessful in Central African Republic, Colombia, Ghana, Mali and Zaire for a variety of reasons. Inflation quickly erodes road funds based on earmarking of ad valorem taxes (typically on fuel prices). Allocations are sensitive to the general condition of the budget and adequate funding does not guarantee that funds are spent appropriately. These conclusions are echoed by Gwilliam and Shalizi (1999).

Subsequent studies assessed the performance of second generation road funds. Kumar (2000) found that road funds increased and stabilised road funding, and increased works programming efficiency in Benin, Ethiopia, Ghana, Kenya, and Zambia. Further, road funds encouraged growth of domestic contracting. Kumar (2000) also found that funds fell short of requirements and recommended increasing the capacity of road funds and contractors to improve performance.

In assessing road funds in Africa, Gwilliam and Kumar (2003) also highlighted improved efficiency, more secure funding, and increasing use of private contractors, but they pointed out that most were unable to attain their desired maintenance levels because of residual ministerial control over levies. Brushett (2005) found that in almost all road funds in Africa, road user charges took the form of fuel levies. Over half of the funds relied primarily on road user charges rather than budget allocations. All but one fund had a management board, and over half had a private sector majority. Brushett (2005) described how the indirect channelling of funds leads to delays and uncertainties in work programming, and how despite further improvement, most were still short of the required level of maintenance.

In Sub-Saharan Africa, Benmaamar (2006) found that road funds helped secure more stable funding for road maintenance, but that funds (mostly from fuel levies) were insufficient particularly with respect to periodic maintenance (e.g., regravelling and resurfacing). In many cases, limits on fund administration and financial autonomy are linked to structural problems that undermine performance. His recommendations were greater autonomy from government, clarification of roles and responsibilities, and improvement of employment conditions.

Several studies have reported on the efficacy of road funds. Haule (2005) reviewed the sources of finance for road funds in Tanzania including fuel tax, vehicle licenses and overloading fines, and fund distribution between the competing needs. Haule reported misuse of funds and the strategies to overcome this, such as denial of further funds until monies were accounted for.

Sub-Saharan Africa is moving to more autonomous road funds based on levies collected directly by the fund, and to clearer responsibilities and objectives. This is resulting in increased and more secure funding for road maintenance. However, funding and maintenance activities are insufficient and not uniform, with considerable variation between countries in autonomy and performance.

Road fund models have also been adopted in developing countries outside of Africa. Dornan (2016) assessed the impact of the road fund in Papua New Guinea in 2003. This followed years of reduced infrastructure spending and dramatic deterioration of the road network. Dornan stated that an independent revenue source was never established and road fund revenue represented less than 1.5% of total government spending on road maintenance and rehabilitation. As a result, the road fund was sufficient to maintain only 443 km of the 2,200 km it officially manages. The rest of the network is maintained using earmarked funds from central government, which declined as the economic situation of the country weakened. Dornan (2016) also cited unclear and overlapping roles of the road fund and the Department of Works, and insufficient capacity in the road fund. The road network in Papua New Guinea has continued to deteriorate, which Dornan has attributed to a lack of political support for the road fund, and to falling short of the second generation model.

According to Zietlow (2004), road maintenance spending in Latin America has also fallen short of requirements, and has relied on earmarked funds from fuel taxes which governments have exploited for other purposes. As a result, the road agency model has been adopted in several countries in the region. Based on this experience, Zietlow (2004) recommended a fee-for-services model in which the road fund has greater independence from government and recommended that road users be included in the management of road funds.

Chalise (2005) reported on management of the road fund in Nepal and drew similar conclusions. Tolls are a further source of revenue that some countries are beginning to exploit, for example India (Gupta, 2005).

3.2.2 Foreign investment

The financing landscape has changed in the last two decades. Strange et al. (2013) estimated that Chinese investment in Africa was about USD 18 billion between 2000 and 2011 and the rate has not slowed. This financial influx has led to tremendous development. However, direct funding by agencies of the Chinese government, such as the China-Africa Development Fund, leads to insufficient accountability because the usual reporting rules do not apply, as highlighted by Strange et al. (2013).

Foreign finance can lead to exclusion of local companies. For example, Flores (2017) reported that 72% of road contracts in Tanzania are currently awarded to Chinese contractors, almost all of which are state owned. This brings the risk of dependency similar to past dependencies on colonial powers. In Uganda, Chinese capital has recently led the government to commission a new road from Kampala to Entebbe Airport. Currently, about 70% of road construction contracts are awarded to Chinese companies and only 4% to local companies. Similarly, Hanlin and Hanlin (2012) reported a tendency for contracts for major external investment to 'lock in' large external companies and exclude local companies.

3.2.3 Public-Private Partnership

An alternative encouraged by many commentators (e.g., Kociemska, 2019) is the public-private partnership (PPP) model. In Pakistan, Build Operate and Transfer (BOT) contracts, such as the 296 km Hyderabad-Sukkur highway, have become popular in recent years. BOT is a form of PPP used for many years in high-income countries, but there is no consensus that this is a cost-effective means of funding construction projects in the long term. Advantages are sometimes short term in that governments can initiate infrastructure developments and leave the full payment plus interest to their successors.

Farlam (2005) did a detailed review of PPPs in Africa and highlighted the complexity often involved and that a PPP is not an automatic solution. He suggested that PPPs are successful where government has carried out thorough and appropriate feasibility studies in advance and has maintained oversight. Furthermore, the principles of a successful PPP (affordability, cost-effectiveness, transparency, risk

management) are the same as those that should permeate the public sector. Ten years later, a review by Trebilcock and Rosenstock (2015) endorsed many of Farlam's findings. Transparency is the principle with the potential to be most transformative in many LICs, and is linked to the corruption issue discussed below.

Applying experience in Chile to the developing world, Melville (2017) suggested that domestic or local involvement in PPP consortia is essential for PPPs to truly support national development objectives. In an evaluation of the potential for PPPs in the African context, Ajacaiye and Ncube (2010) supported this method of finance, but largely because of the shortage in public finance in most countries.

With regard to value for money, Meduri and Annamalai (2013) reported on 521 projects in India, 356 using various forms of PPP and 165 fully funded by the public sector. They concluded that PPP contracts had marginally higher unit costs but these were often offset in road contracts by economies of scale. They made the point that costs always escalate where foreign investment is involved or when any form of corruption is present.

Various studies have been done on regulation of tolls and the design of contracts for BOT concessions for road infrastructure. Chen and Subprasom (2007) considered several scenarios in a case study in Thailand. They showed that the case without regulation led to the highest tolls, while equity regulation yielded the lowest. Concession period extension, cost subsidy or both were shown to increase the financial feasibility of the project. There was some trade-off between the objectives of regulation and social welfare maximisation, and financial feasibility. The Guangzhou–Shenzhen superhighway in China was used by Yang and Meng (2000) to consider the trade-off between profitability and social welfare in the choice of toll levels and capacity in BOT design.

Bousquet (1999) discussed road concession design and toll charges in Europe. At that time, about a third of European motorways were concessioned, most financed by tolls. Bousquet (1999) emphasised the relationship between network density and commercial risk and argued that private operators may not be able to bear all the risk. He recommended risk sharing between private contractors and public authorities as appropriate and that contract design should control risk without eliminating incentives. Based on experience in Argentina, Estache and Carbajo (1996) emphasised the need for simple and transparent bidding criteria, clear rules for renegotiation of contracts, and coordination between the agencies involved.

Osei-Kyei and Chan (2016) reported on lessons learned from major PPP schemes: toll roads in Nigeria; a toll road connecting South Africa and Mozambique; and Maputo port in Mozambique. They concluded PPP requires strong government regulation and effective stakeholder management and that all processes and documentation must be transparent. Ngoma et al. (2014) concluded that the trend in Zambia to PPP contracts is probably sensible, but highlighted numerous risks that could lead to cost inflation.

Although PPPs in the transport sector are widely perceived to be a success, there have been concerns that PPPs may be socially costly involving a higher cost of private capital than had the project been financed by the government. Hence the need for a Public Sector Comparator (Quiggin 2008). Against this, there may be strong efficiency advantages (for example in management) through using a commercial approach, as mentioned above.

Another issue is the very high proportion of PPP projects that have been subjected to renegotiation. For example, a study of Latin America showed this amounted to 78% of projects. In most instances, renegotiation was at the request of and to the benefit of the private partner (Guasch et.al., 2014). Renegotiation may be the result of a combination of poor traffic forecasts, exchange rate issues being opportunistic, and part of a strategy after winning a contract with a low bid (Fatokun et.al., 2015).

3.3 Governance

3.3.1 Corruption

Corruption is a concern in many countries. For example, in Liberia, concern has been raised about single sourcing in the unopposed appointment of a consortium to construct a large Coastal Corridor project funded by the World Bank. The similar concerns were raised about the Chinese-funded Lusaka-Ndola road in Zambia.

There is a large body of literature on corruption in the roads sector (e.g., Zedillo et al., 2013). Links to political patronage have been documented (Lehne et al., 2018) and are endemic in the procurement sector (Mahmoud, 2010). Ntayi et al. (2013) noted that an estimated USD 107 million is lost to procurement-related corruption annually in Uganda. Ntayi et al. (2013) also studied the associated moral and social drivers, and the factors that make an individual prone to corruption.

A study by Kenny (2009) on corruption in the road sector referred to experience in Eastern Europe and Central Asia. The study suggested that private companies were generally less corrupt than public sector institutions but the act of privatisation can be hijacked by corrupt practice. Use of sub-contractors often increases efficiency (Wales and Wild, 2012) and may also be linked to the benefits of private sector involvement. Snaith and Khan (2008) found that effective unit rates for roadworks varied as a function of the source of funding. They developed a module to quantify the effects of this corruption on national wealth.

During the mid-2000s construction costs increased substantially worldwide. This was most apparent in Africa. In the five years between 2003/4 and 2008/9, the costs of upgrading a main road in Tanzania increased from around USD 200,000 per km to nearly USD 800,000 (Ministry of Infrastructure Development, 2009).

The increase in construction costs was not fully understood at the time, but coincided with a worldwide construction boom and a steep rise in oil prices. There may also have been a change in competition for contracts. The major influx of Chinese contractors in previous years may have initially held down prices and driven out international competitors.

Numerous factors have been documented as being responsible for cost overruns (defined as the difference between construction cost and original engineer's estimate) and for delays on road projects. A study in Kenya by Seboru (2015) noted that almost all projects were delayed and that over 70% had overruns of at least 50%. Various reasons were given but a consistent theme was that the client's financial system frequently led to interruption in cash flow, forcing the contractor to delay work. The same theme was apparent in a study by Kamanga and Steyn (2013) in Malawi. Both studies and another in Botswana (Segawa-Kaggwa et al., 2013) found that client actions also contributed, such as late instructions, specification changes, and design changes.

To gain better understanding of the issue of cost overruns in Africa, Africon (2008) analysed 24 road projects undertaken in the period 2002 to 2006. Real 2006 USD values were used. The average project had a cost overrun of 35% but exceeded 50% in a third of projects, and was over 100% in a few cases. Four factors were examined:

> Domestic inflation and currency appreciation;
> The extent to which oil prices rises were passed on in domestic diesel prices, three-quarters of the price rise was passed on in 60% of countries;
> Tight construction markets: the rate of real growth in domestic investment (GDI) was used and increased by more than 50% between December 2002 and December 2006 in seven countries;

> A competitive index: competition was considered to be effective when the price spread of the lowest three bidders fell within a 10% range.

Overall, meaningful tender competition was the strongest factor, affecting 78% of projects. In contrast, inflation and currency movements affected 27% of overruns, the tightening construction industry affected 32% of overruns, and oil price rises affecting diesel prices in 45% of cases.

An analysis of road works contracts and unit rates by Alexeeva et al. (2008) examined governance issues in Sub-Saharan Africa. Data were drawn from 109 road and bridge contracts financed by the World Bank between 1999 and 2007. Constructions costs and unit rates were found to vary considerably, as shown in Table 5.

By value, 18% of the contract amount was awarded to local contractors, 45% to Chinese, 24% to OECD based contractors and 4% to other Africa contractors. African contractors tended to have a price advantage, a shorter period to evaluate bids and sign contracts, a narrower margin between engineer's estimates and contract value. However, they tended to lag behind in implementation, incurring higher cost overruns and longer delays. Chinese companies tended to be awarded the largest contracts. The average cost of road works was considerably higher for European companies than for other contractors.

Table 5: Examples of average construction costs and unit rates (converted to USD prices 2007) for road projects from 1999 to 2007, drawn from 109 contracts (Alexeeva et.al., 2008).

Country	Inter-Urban 2-lane reconstruction (USD/km)	Inter-urban 2-lane upgrade to paved (USD /km)	Asphalt concrete (USD/m^3)	Portland cement concrete (USD/m^3)
Congo (DRC)	228,872		275.9	
Ethiopia	388,207	322,373	131.2	200.2
Ghana	261,052		139.2	108.6
Kenya	955,755		180.0	170.7
Mozambique	278,661		154.4	191.9
Malawi	420,838		220.6	136.3
Nigeria	329,909		290.2	
Tanzania		348,209	182.8	177.8
Uganda		420,220		

To investigate corruption issues, various indicators were identified, including:

i) The period between bid opening and contract signing was more than 7 months, as happened in 32% of all contracts, with a maximum delay of 573 days;
ii) The time overrun was more than 30% of the original contract period, as happened in 26% of all contracts;
iii) 20% or more of pre-qualified companies did not tender, as happened in 27 out of 32 contracts where there was pre-qualification;
iv) The contract value was 20% higher than the engineer's estimate, as happened in 24% of all contracts, with the maximum increase 65% above the estimate.

Based on an analysis of 211 infrastructure projects in 29 developing countries, Estache and Iimi (2008) found that increasing competition in infrastructure procurement would lead to an overall 8% reduction in

construction costs. If the number of bidders is reduced from six to two (where competition is minimal) road unit costs would increase by 40%.

Kenny (2010) found that the average cost for road rehabilitation was USD 36 per m^3. However, where the reported average bribe for a government contract was less than 2% of the contract value, the cost was USD 30 per m^3, and where higher than 2% of their value, the average cost was USD 46 per m^3.

In an analysis of 25 World Bank funded projects where complaints had been received by the Bank's Integrity Department, collusion was substantiated in ten cases, and reasonably suspected in four cases. Fraudulent implementation was found in ten cases and suspected in one case. While false documentation was found in 12 cases (Messick, 2011).

Messick also quoted a wide range of defects reported in a Government of Zambia audit report of 18 jointly funded government and donor-funded road projects (see Table 6).

Table 6: Results of an audit of Zambian road projects (Government of Zambia, 2010)

Defect found in projects	Percentage of projects affected (%)
Improperly sized aggregate	44
Too much clay	75
Aggregates did not meet crushing strength	67
Surface dressing layers thinner than required	82
Cement content less than specified	100
Concrete samples weaker than required	50

Collier, Kirchberger and Soderbom (2015) analysed the World Bank's Road Cost Knowledge System (ROCKS) road construction database. Wide differences were found in construction costs for the same activity undertaken at the same time. For instance, 40 to 59 mm asphalt overlay for a 100 km cost USD 3.3 million in the Dominican Republic in 1997 compared to USD 11 million in Tanzania in 1996 and USD 10.5 million in Pakistan in 1998. A one point increase in corruption on the ten point scale of Transparency International is associated with a 7% increase in cost. Similarly, unit costs in countries above the median by the Worldwide Governance Indicator of corruption are on average 15% higher.

Other factors were analysed. Countries in conflict have 30% higher costs while countries above the median for political instability face 15% higher costs. Increased costs were also associated with the ruggedness of the terrain, the country's surface area and the population density. Unit costs were found to be between 15 and 20% lower when road works exceeded 50 km. Work undertaken by a foreign companies cost on average 24-28% more, which could reflect a lack of competition.

A wide body of literature suggests that transparency makes corruption more difficult and almost inevitably increases cost-effectiveness. An analysis of e-procurement by Lewis-Faupel (2016) concluded that quality goes up in India, and delays are reduced in Indonesia. Neupane et al. (2012) concluded that e-procurement increases the level of trust in the procurement process and reduces opportunities for secret meetings of bidders and public sector officials.

To combat corruption, Kenny (2009) recommended physical audits of built assets alongside financial audits to identify where materials were lost in contract and construction processes. This approach is included in the World Bank recommendations (2007). Such audits need to be conducted by suitably qualified auditors with a knowledge of construction. However, anti-corruption frameworks, such as

Construction Sector Transparency Initiative (CoST) do not guarantee reduction in corrupt practices in roads projects (e.g., EAP, 2015).

3.3.2 Other issues

Another issue is the practice in some countries of contractors 'low balling', significantly under-pricing in the knowledge that subsequent claims and renegotiations will make up the financial shortfall. As explained by Limi (2013) in the context of Nepal, this practice can only lead to inefficiencies and delays, and clearly the client is responsible. Practices, such as acceptance of the second lowest tender or inclusion of a quality submission, are used in various parts of the world. The structure of the client's organisation is critical to satisfactory performance on site. Kamanga and Steyn (2013) recommended that if the contractor is expected to give a performance guarantee then the client should be expected to give a payment guarantee.

At a broader level, Wales and Wild (2012) observed that a road network is effectively a monopoly with no alternatives. Who owns the road is key. If it is the government, then financing is at the mercy of political realities in which new construction has high political capital because it is highly visible whereas maintenance is not. The World Bank has repeatedly called for cost sharing which implies sharing ownership. Kenny (2009) addressed the concept of 'community oversight' of road construction. Haule (2005) raised a similar concept in relation to road fund management, but this has not been easy to implement. However, the International Growth Centre (IGC) claims on the basis of an ongoing study that such schemes have been effective for rural roads in parts of Afghanistan, and provide a powerful performance incentive/deterrent to contractors (IGC, 2019). Therefore, this concept is worthy of further study and development.

Optimism bias, outturn against expectations

Optimism bias relates to the inaccuracy of forecasting costs and traffic flows when planning new investment. Optimism bias occurs in all sectors but the issues and consequences will be more important for large complex projects that have long lifespans. For transport it usually takes the form of underestimating construction costs and overestimating traffic volumes. There is often strong pressure on consultants to provide answers the client wants. Wachs (1990) found that "success in the consulting business requires the forecaster to adjust results to conform with the wishes of the client".

Drawing on a large worldwide database for a 70-year period, Flyvbjerg (2005) found that the average cost overrun, in real terms, was much higher for rail (45%) than for roads (20%) or bridges and tunnels (34%). In the first full year of rail operations, there was 51% shortfall in rail passenger traffic, while for roads the outturn was 10% higher than expected. There are substantial variations in the outturn of construction costs and traffic volumes, which are given by the standard deviation. The more complex the project, the greater the variation in actual costs compared to the initial estimate, as shown in Table 7.

Table 7: Inaccuracy in costs and traffic forecasts from worldwide database (Flyvbjerg, 2005)

	Inaccuracy of construction costs at constant prices			Inaccuracy of traffic forecasts (rail passenger and road vehicle traffic)		
	Cases	Average Cost overrun (%)	Standard deviation	Cases	Average inaccuracy (%)	Standard deviation
Rail	58	44.7	38.4	25	-51.4	28.1
Road	167	20.4	29.9	183	9.5	44.3
Bridges/ tunnels	33	33.8	62.4	-	-	-

A more optimistic view is given by the Independent Evaluation Group (IEG) review of World Bank operations (Table 8). The EIRR of road projects at appraisal was the same at construction completion (29%). For rail projects, the EIRR at appraisal fell from 32% to 22% at construction completion. However, substantial uncertainty remains with the estimate of EIRRs at construction completion. The future growth in forecast traffic is not known, the economic evaluation model has uncertainties (such as, vehicle operating cost assumptions, values of time) and the counterfactual assumptions are not tested.

Table 8: Average economic rates of return of World Bank transport projects 1995-2005 (World Bank, 2007)

Mode	Projects at appraisal with EIRRs	EIRR at appraisal (%)	EIRR range at appraisal	Projects at completion With EIRRs	ERR at Completion (%)	EIRR range at Completion
Multiple modes	13	36	(16-91)	11	31	(14-78)
Urban transport	11	26	(13-40)	8	30	(13-60)
Roads/ highways	59	29	(1-65)	53	29	(10-79
Trade facilitation	1	19	19	1	27	27
Railways	7	32	(15-68)	5	22	(-14-64)
Ports/waterways	5	26	(18-37)	4	16	(11-22)
All transport	**96**	**30**	**(12-91)**	**82**	**28**	**(-14-79)**

3.4 Conclusions and recommendations

Based on the foregoing review, the following conclusions are drawn and recommendations made.

3.4.1 Reducing whole life-cycle costs

There is a need to generate design tools for pavement construction using non-standard materials. These materials include cold-mix, such as asphalt (particularly in-situ recycled) and non-standard locally produced base materials. Since this is an issue for all countries, research would benefit from collaboration between universities and highway authorities in Sub-Saharan African and South Asian LICs and HICs.

In addition, mechanisms are needed to encourage uptake of designs appropriate to each location and its economy. This research is best carried out in-country in conjunction with road authorities.

While evidence suggests that road design speed has only marginal influence on transport efficiency, design speed has implications for savings on construction costs. Thus, the relationship between design speed and economic benefit needs to be quantified. Even for very well managed road authorities, drainage is difficult to maintain and repair. Research should target novel systems that are accessible (easy to clear out), inhibit sedimentation (for the expected combination of weather events) and do not readily fail when overloaded (with particular reference to predicted climatic changes).

With the ever-increasing pressure on drinking water resources, there is a growing need to characterise road construction materials with respect to leaching potential, especially where industrial waste or by-product is used. The major research challenge is to combine this information with assessment of soil capability to remove pollutants before they reach aquifer levels.

Improved prediction methods are needed for tropical soils, such as weakly cemented weathered materials that are then re-worked, expansive or collapsible soils, dispersive/erodible soils, saline soils and

soft clays. This leads to investigating stabilisation techniques for each soil type, and specifically, incorporating these materials into pavement design.

Road construction and maintenance need to be re-assessed in which employment-intensive construction techniques are suitable, for instance, crack sealing and repairing potholes. Constructability and potential maintainability should be reviewed in the road design phase to ensure these activities can benefit local economies as much as possible. As well as optimal use of local resources, material recycling should be encouraged.

Smart systems have the potential to reduce the cost of data collection and processing, enabling LIC road authorities to automate assessment of road condition. Currently, few road authorities have automated capabilities. Systems to be explored for this purpose include smartphone-based applications, satellite imagery, drones and private cars and trucks with manufacturer-installed on-board instrumentation. The latter will require dealing with data ownership issues.

Machine learning based on big data has the potential to revolutionise automated data analysis (such as road condition), reduce analysis costs, and human error.

3.4.2 Road financing

Studies indicate road funds are most effective when protected from government interference. Thus, best practice should be disseminated as widely as possible, and sufficient evidence gathered to persuade political authorities.

The recent flood of foreign investment has raised questions of accountability, for instance, with regard to award of contracts. This is important for capacity building. Examples of best practice include strong public sector control and transparency of processes. Dissemination of best practice must be strongly encouraged.

Similar issues relate to PPP contracts. Studies have shown that these forms of contract have a role but are not automatically more cost-effective than keeping the work in the public sector. PPPs may contribute to combating corruption where there is transparency in awarding contracts. However, the claim that private sector involvement increases efficiency and reduces corruption needs to be investigated in a multi-country evaluation to establish the optimum type of involvement for different types of project, such as BOT or contractors and subcontractors.

3.4.3 Governance

A large body of literature suggests that lack of competition, collusion and a lack of transparency are major factors in raising the price of infrastructure construction in low and middle income countries. A small number of bidders and delays between bid opening and contract signing are key leading to high construction costs. An unstable political environment is also a contributing factor. Fraudulent implementation of projects, for example, using below specification quality or quantity of materials is also a cause of concern.

Further consideration should be given to e-procurement and stakeholder representatives to oversee tendering and contract award to prevent practices, such as accepting low tender prices or very high prices due to cartel forming. E-procurement and stakeholder involvement would contribute to developing local capability rather than relying too heavily on foreign companies.

Further research is recommended on shared ownership of road assets to contribute to more efficient management and social development. A greater commitment to transparency is also required. The

Construction Sector Transparency Initiative (CoST) (IMC, 2016) is an example of Non-Governmental Organisations (NGOs) as well as national and local government bodies collaborating to increase transparency and accountability.

Optimism bias whereby planned construction costs are underestimated and traffic forecasts are overestimated need to be addressed.

4 Literature Review: Rail Infrastructure

This chapter reviews research findings in rail infrastructure in low-income countries (LICs) in Sub-Saharan Africa and South Asia. An extensive search and review of the literature was carried out, but very few publications were found on rail infrastructure in the two regions. Those found are reported in this chapter. Thus sources, such as World Bank and African Development Bank (AfDB), have been used to gain insight into the state of knowledge on rail infrastructure in the two regions. This has been done to identify key gaps in knowledge and therefore to identify priority research areas. The literature review has been integrated with unpublished knowledge and opinions expressed by participants at the project workshop with railway stakeholders in Africa held in Nairobi in November 2018.

Over the last few decades, Sub-Saharan Africa and South Asia countries have seen significant increases in road transport demand and supply. The take up of road transport, rather than rail, has been driven by the higher costs of rail operations, maintenance and renewals, and a lack of strategic planning resulting from political instability and conflicts (Bullock, 2009). However, in recent years there has been a 'renaissance' in railway developments through the building of new lines financed by foreign investment.

Railways require dedicated corporations to operate passenger and freight services. The centralised costs for maintaining and upgrading capital assets create the impression that the railways are too costly to compete with road transport, but rail is considerably cheaper when economies of scale are possible (AfDB, 2015).

After decades of road transport dominance, railways are staging a global comeback. Akin to many other regions, the African Union envisions a continent-wide rail network to facilitate inter- and intra-regional trade and to meet the needs of Africa's growing population (African Union Commission, 2014). Meanwhile, and despite the financial challenges, several low-income countries have signed resource-for-infrastructure agreements to construct standard gauge railway networks (Habiyareme, 2016). These countries include Kenya, Ethiopia, and Nigeria. The railway renaissance is driven by various social, economic, and environmental externalities created by the transport sector. For instance, transport's global greenhouse gas (GHG) emissions have more than doubled since 1971, and more than three-quarters of this increase has come from road transport (Borlin and Guivarch, 2017).

According to AfDB (2005), whether powered by diesel or electricity, railways can reduce external transport costs by at least 47% per passenger-km, and 75% per tonne-km (see Figure 3), Rail freight produces between 75 and 85% less GHG emissions than articulated trucks per unit output, putting the monetary benefit of rail at USD 0.1 to 0.4 per net tonne-km (Bullock, 2009). Furthermore, while railways in LICs are still less safe than their European counterparts, the cost of accidents is 50 times less for rail transport than for road traffic (AfDB, 2015).

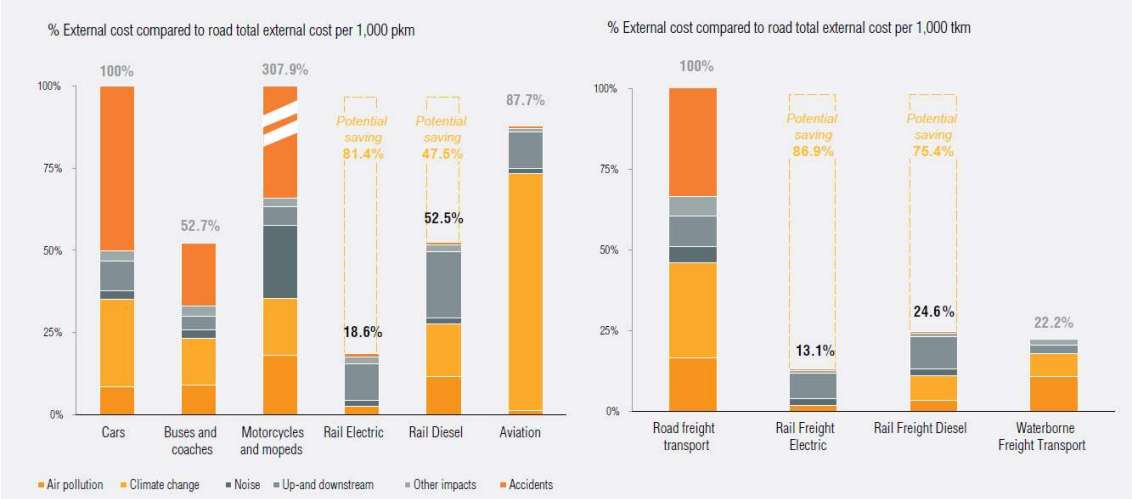

Figure 3: External costs of railways compared to other transport modes (AfDB, 2015)

The compound annual growth of rail freight has been positive worldwide (AfDB, 2015; see Figure 4), with a larger growth in South Asia than in Sub-Saharan Africa. However, growth in passenger services that are more costly and usually require subsidies vary between the regions. While South Asia has seen significant increase in passenger-km, Sub-Saharan African countries have seen a decline.

Figure 4: World rail market evolution, 1996-2005 (AfDB, 2015)

As shown by the International Monetary Fund (IMF, 2018), most LICs in Sub-Saharan Africa have experienced economic growth higher than the global average (Figure 5). When this economic growth is combined with the emerging middle class, explosion in mobile communications, and huge untapped mineral resources in Africa, the railway potential is still to be fully exploited (Olievschi, 2013). Such study findings confirm that growth of the railway sector has been hindered by structural issues, such as poor infrastructure, inefficient financing models, loose regulatory frameworks, and shortage of technical capacity.

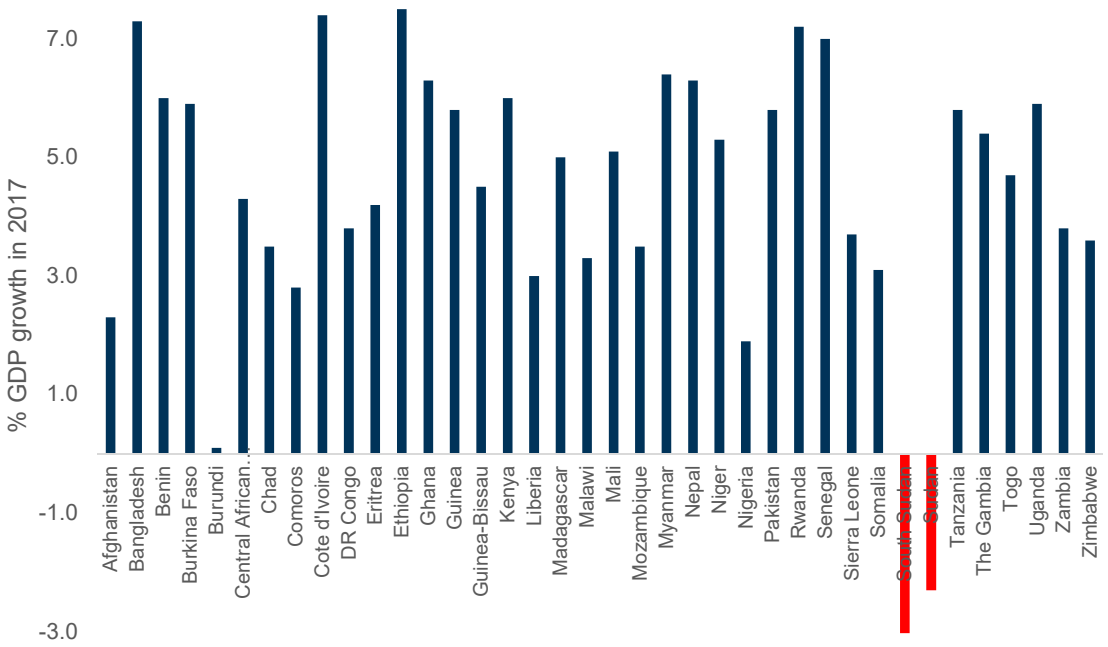

Figure 5: Estimated 2017 GDP growth (IMF, 2018)

4.1 Infrastructure overview

While the railways have the potential to be more cost effective when economies of scale permits, LICs do not seem to be able to reap the benefits.

As a result of decades of poor maintenance and little investment, many countries now have major railway sections that are not in operation and require rehabilitation. For instance, 23% of railways in Benin are not operational and 91% in Uganda (Bullock, 2009). In other countries, many parts of the rail network are idle, such as 60% of the network in Ghana.

Track density in the low-income countries is much lower than the global average and even more so when compared to world leaders (Eurostat, 2018). In Sub-Saharan Africa, track density is even lower at 2.76 km per 1,000 km², while in contrast, Germany has 121 km track per 1,000 km² and carries 43% of the country's freight (Eurostat, 2018, http://appsso.eurostat.ec.europa.eu).

The limited length and quality of railway routes has particularly impacted the regional connectivity of landlocked countries, and imposes higher freight costs for two reasons. Firstly, the limited extent of track reduces the freight volumes that the line can transport. Secondly, the limited length of rail route means that freight has to be transferred to road transport to reach landlocked destinations. As a consequence, transport costs in LICs in Sub-Saharan Africa are the highest worldwide, with freight charges 20% higher than other LICs (Habiyareme, 2016).

For many of these countries, the length of railway infrastructure has an impact on the potential to exploit their substantial deposits of natural resources. Furthermore, rail infrastructure in many LICs dates back to colonial times, and much of the network has not been upgraded since. Each nation post-Independence retained the track gauges that had been selected by their colonisers (World Bank, 2005; Olivieschi, 2013).

4.2 Sub-Saharan Africa

In Sub-Saharan Africa, rail infrastructure is predominantly used to transport freight. This can be partly explained by the vast reserves of minerals and bulk commodities in many countries. Most railways connect major ports to large cities and mining areas because 90% of African imports and exports are transported by sea (Morlin-Yron, 2017; Figure 6). Nonetheless, railways have not been expanded even though the continent has developed quickly, population increased, and large urban areas have emerged. As a consequence, the density of the railway network in these countries is considerably low (Figure 7). While such trends exert pressure on urban transport infrastructure, these trends have led to densification of economic corridors that can make railway services more economically viable (Morlin-Yron, 2017).

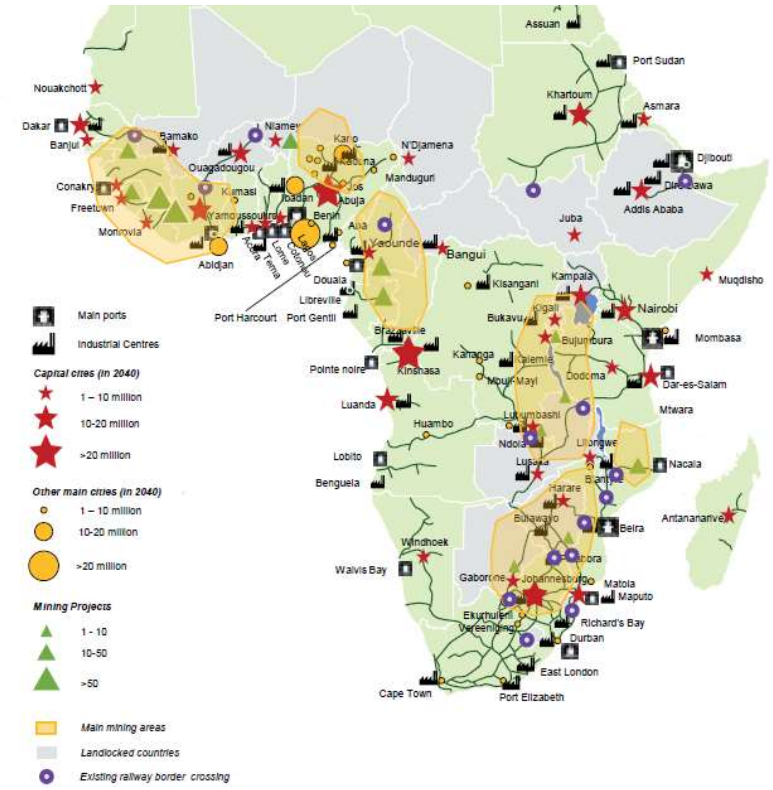

Figure 6: Main railway routes and connection points in Sub-Saharan Africa (AfDB, 2015)

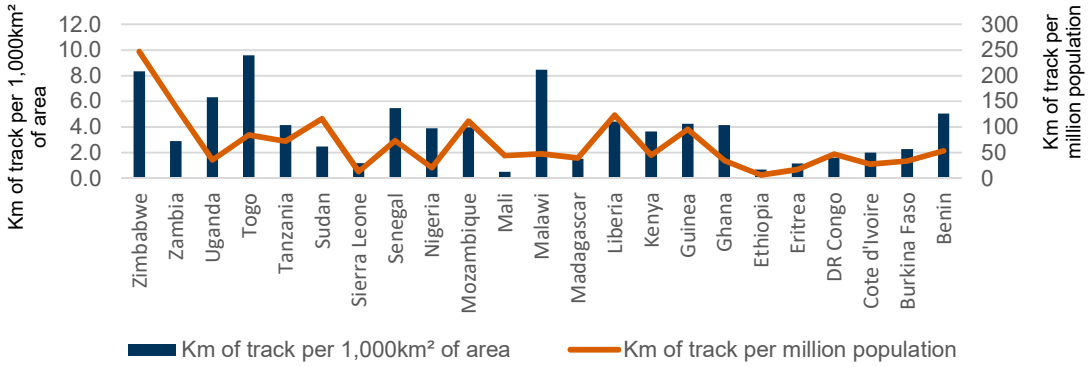

Figure 7: Track density in Sub-Saharan Africa (World Bank, 2005)

4.2.1 Permanent way infrastructure

Not only track length but also track quality is below international standards in Sub-Saharan Africa. Many railway assets in LICs are more than 100 years old and thus the quality of track materials is considerably outdated (Olievschi, 2013). In much of Sub-Saharan Africa, the original rail tracks are mainly ballasted but have not been appropriately maintained. The combination of asset age and inadequate track maintenance and tamping has severely affected the operational performance of railways in the region.

Firstly, the maximum axle load that the railway track structure can withstand in Sub-Saharan Africa is approximately 15 tonnes (Bullock, 2009). In comparison, European standards for axle loads are greater than 25 tonnes (European Union, 2004). The poor track quality affects the maximum speed achievable. In 2009, freight trains in Sub-Saharan Africa reached only 18 km/h (Bullock, 2009).

Secondly, almost all lines are single track, and none of the original lines are electrified (Olievschi, 2013). Sidings and platforms are outdated. In many cases, signalling on networks still relies on manual systems, whether with mechanical signals or manual train orders (Bullock, 2009). With the low train volume on most lines, manual systems are adequate for the current capacity, but human error often creates safety problems. Where electrically powered signalling is installed, often it cannot be used because of short circuits, no electrical power and degraded cable networks as well as cable theft. Telephone exchanges in many railways are obsolete, with limited capacity and spare parts virtually impossible to obtain (Bullock, 2009).

Thirdly, although the commonly used narrow gauge tracks are said to marginally limit the loading gauge of trains, greater loads are carried on South African Cape gauge tracks than on standard gauges in the UK (Kubota, 1995). As smaller gauges tend to be associated with smaller curve radii, rolling stock design and performance are crucial. The main concern with narrow gauges is the lateral oscillation (hunting) because of short-wheelbase bogies. The greater lateral oscillation of narrow gauges impacts passenger comfort, yet there are measures to address this issue (Gopalakrishnan, 2007).

Finally, there are claims of theft and vandalism. During the Nairobi workshop in November 2018, railway operators in Kenya and Uganda highlighted that even sections of tracks are stolen, leading to high risk of derailments. Despite the lower accident rate compared to road transport, safety is still a major concern to the stakeholders interviewed. It was highlighted that the permanent way infrastructure is not segregated from its immediate surroundings, which often leads to accidents involving trespassing animals.

4.2.2 Interoperability and connectivity

There is little rail connectivity between countries in Sub-Saharan Africa. Only a few lines cross borders, such as TAZARA connecting Tanzania and Zambia, and Sitarail between Burkina Faso and Ivory Coast Country railways operate to different standards. While track gauges range from 600 mm to standard (1,435 mm), Cape gauge lines of 1,067 mm predominate, followed by metre gauge lines of 1000 mm, (World Bank 2005; Figure 8). Southern Africa has greater connectivity, where countries connect to the more developed network in South Africa. The East Africa region is connected by a metre gauge line from Mombasa in Kenya to Dar es Salaam in Tanzania.

Until recently, little has been done to improve the railways in Sub-Saharan Africa. Early concessionary frameworks transferred the responsibility for infrastructure maintenance and renewal to operators. Following that, the lines were not extended and connectivity remained very limited (Olivieschi, 2013).

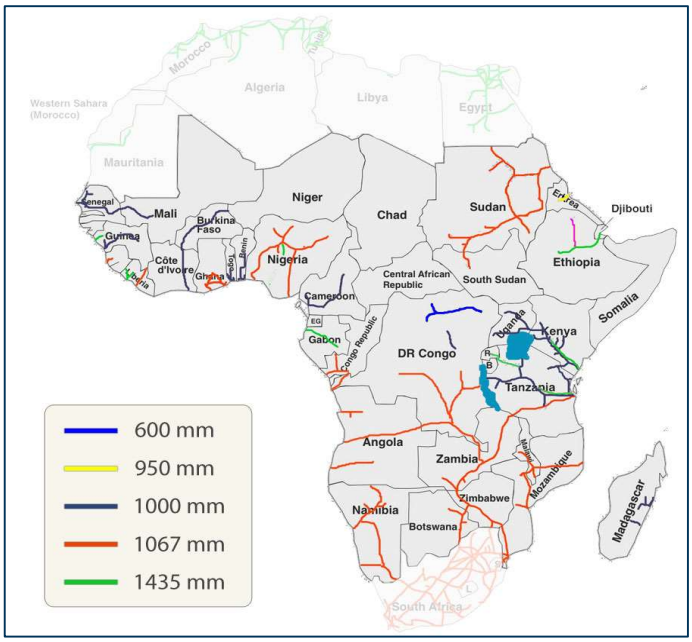

Figure 8: Track gauges in use in Sub-Saharan Africa (World Bank, 2015)

4.2.3 Operational capacity

The combination of low load and speed limits together with limited routes results in reduced volumes and thus in high prices per tonne-km that hinder railway market competitiveness. The rail traffic densities (1,000 transport units/ route-km) in LICs in the region are presented in Figure 9. With the exception of Guinea where private mining companies mainly use their own railway lines, all LICs show traffic densities below 1 million units per route-km. In contrast, countries, such as the Great Britain, France, and Germany, operate at around 4.5 million units per route-km, and countries operating high freight volumes, such as Russia, USA, and China, reach densities up to 40 million units per route-km (World Bank, 2018; Eurostat, 2018; UIC, 2015).

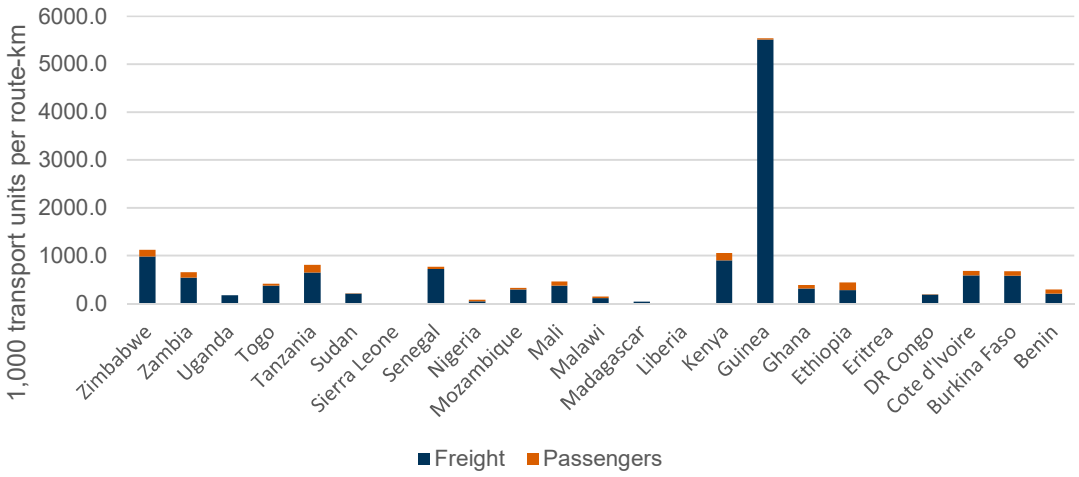

Figure 9: Rail traffic density in Sub-Saharan Africa (World Bank, 2005)

Railways in Sub-Saharan Africa carry predominately freight and a very small proportion of the traffic is passenger service. This can be explained by the fact that it is more difficult to recover the costs of passenger operations without subsidies. In addition to the financial and regulatory environment, infrastructure quality also affects capability for passenger operation. Because of low volumes in these LICs, labour productivity is lower than in developed countries. Under these circumstances, fixed costs are spread over fewer transport units which in turn become expensive compared to other transport modes. This leads to a vicious cycle in which higher unit costs lead to lower demand, which affects the unit costs and return (Olievschi, 2013).

4.2.4 Sino-African infrastructure projects

Rail data for Sub-Saharan Africa are only available up until 2005, and thus are outdated in the context of the extraordinary economic growth in many African countries since then. The workshop in Nairobi in November 2018 updated information on the development and technical specifications of these programmes. The key stakeholders provided insights on their concerns over the long-term sustainability of these projects.

Most projects have Chinese investment (see Table 9). Sino-African trade volumes have grown rapidly since 2006 to reach more than USD 200 billion in 2013 (Habiyareme, 2016). These resource-for-infrastructure investments include several railway projects across the continent. Most projects consist of single-track, non-electrified, standard gauge lines constructed for freight and passenger services for an average maximum speed between 100 and 120 km/h. The exceptions to these standards are:

> Addis Ababa-Djibouti line, which is electrified and includes 151 km of double tracks;
> Mali-Senegal line which is a renovation of the existing infrastructure;
> Abuja-Kaduna section of the Lagos-Kano line, which is double-track and will permit speeds of up to 250 km/h (Railway Technology, 2018).

Table 9: Overview of rail infrastructure construction financed by China

Country	Project	Length (km)	Cost (USD billion)
Chad	Chad Railways(Railway Gazette, 2012)	1,364	5.6
Ethiopia-Djibouti	Addis Ababa-Djibouti line (Delelegn, 2018)	751	4.0
Mali	Mali-Guinea Railway line (Samseer, 2014) Mali-Senegal Railway (Morlin-Yron, 2017)	900 1,286	11.0
Nigeria	Lagos-Calabar line (Odditah, 2016) Lagos-Kano line (Railway Technology, 2018)	1,400 1,124	11.1 8.3
Kenya	Mombasa-Nairobi line (Morlin-Yron, 2017)	485	4.0
Rwanda-Tanzania	Isaka-Kigali line (Mwangasaha, 2018)	571	2.5

These projects are reshaping the regional rail infrastructure towards the vision of a continent connected by modern railway lines. For instance, the journey time between Djibouti and the dry port of Mojo in Ethiopia has been reduced from 84 hours to 10-15 hours (Delelegn, 2018). Similarly, the Standard Gauge Railway has reduced journey times between the port of Mombasa and Nairobi to less than 5 hours. In Nigeria, these projects are expected to provide a long-awaited expansion to reduce congestion on the country's damaged roads (BBC News, 2017).

From an economic perspective, concern is increasing that these large loans will tie LICs to long-term dependency on China rather than promoting internal development (Habiyareme, 2016). These concerns have some support in the case of Sri Lanka, which handed over control of one of its deep-sea ports to

ease its debt with China (Mourdoukoutas, 2018). Moreover, the cost-effectiveness of such large-scale projects is being questioned. For instance, the Mombasa-Nairobi line in Kenya is reported to have cost close to three times the international standard and four times the original estimate (Kacungira, 2017).

From a technical standpoint, these lines have also raised questions. Stakeholders at the Nairobi workshop raised concerns about the link between new rail infrastructure and wider development regional plans. Furthermore, projects are not standardised with regard to maximum axle loads and speeds, and control and communication systems used for different sections are not compatible with lines that cross national borders. Delelegn (2018) highlighted the challenges in connecting railway lines in Ethiopia running on either Chinese signalling systems (CTC) or European systems (ETCS). Similar issues were raised about the proposed extension of the Mombasa-Nairobi line to Uganda during the workshop in Nairobi.

Furthermore, while the technology used may be adequate for the continent's current needs, little has been done to meet future requirements. Even at 120 km/h, single track lines impose bottlenecks in capacity if not planned with consideration for future operations. In addition, experts at the Nairobi workshop highlighted that the new lines run parallel to the original routes where settlements developed but they are not close enough to provide easy connectivity without road transport.

Finally, there is concern about the long-term sustainability and the legacy of these projects. The newly constructed and planned rail lines do not involve specific investment in human capital. Construction and early operations are done by Chinese companies, with little planning for maintenance and future improvements, as mentioned by stakeholders at the Nairobi workshop.

4.3 South Asia

There are significant differences between the railway system in South Asian compared to Sub-Saharan African countries. Railway networks in LICs in South Asia are used more for passenger transport. Since the railways are owned and operated by the government, they are heavily subsidised for social reasons. Railway lines connect major cities in commuting networks across regions and sometimes between countries. With a total of 9.12 km per 1,000 km² LICs in South Asia are almost four times more densely crossed by railway lines than in Sub-Saharan Africa (World Bank 2005; UIC, 2015). Bangladesh has more railway tracks per area than Pakistan and Myanmar. However, Bangladesh has a low track density per head of population, which can lead to severely overcrowded services (World Bank, 2005).

Despite the higher track density, age of assets and infrastructure quality in South Asian LICs are similar to Sub-Saharan Africa. In Bangladesh, only 80 km of railway lines have been constructed in the last 50 years (Ahmed et al., 2015). Similarly, Pakistan has built 13 km of broad-gauge lines since 1973 (JICA, 2017).

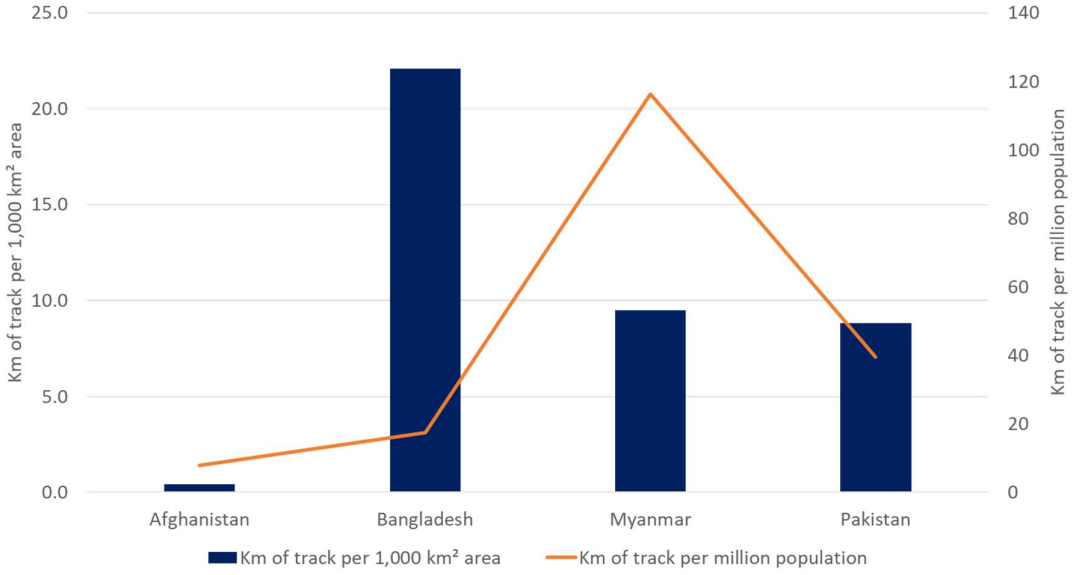

Figure 10: Track density in South Asian LICs (World Bank, 2005)

4.3.1 Permanent way infrastructure

In all four countries in Figure 10 (Afghanistan, Bangladesh, Myanmar and Pakistan), trains are powered by diesel and most lines are single track. In Pakistan, approximately 10% of the track is double track. Track quality varies according to country. For instance, railway infrastructure in Myanmar has an axle load limit of only 12.5 tonnes (Myanmar Ministry of Rail Transportation, 2015). The infrastructure condition in Myanmar limits the maximum speeds of freight trains to 48 km/h and passenger trains to 60 km/h. Pakistan and Bangladesh have upgraded rail track to support 22.5 tonnes per axle in certain sections. In other sections, axle load is limited to 17.87 tonnes (JICA, 2008), which limits connectivity. However, commercial speeds have not improved accordingly. The average speed of freight trains is only 18.5 km/h (Bangladesh Railway Master Plan, 2013) and is likely to be one reason for the low freight traffic in the country.

Signalling is still mainly manual in all countries in the region. Ahmed et al. (2015) have listed the outdated systems as a threat to safe and efficient train operations in Bangladesh. In Myanmar, contracts to upgrade signalling to electronic systems have been signed recently (Railway Gazette, 2015).

4.3.2 Interoperability and connectivity

Due to closer geographical proximity and common colonial influence, track gauges in the region are more homogenous in South Asia than in Africa (Figure 11). Countries bordering India have adopted mainly the same broad gauge (1,676 mm). Nepal has broad gauge tracks but is currently not operating railway services. Further east, trains in Myanmar and east Bangladesh run on metre gauge tracks (1,000 mm). Further west, a short line in Afghanistan runs on Soviet gauge (1,520 mm). Bangladesh also has approximately 365 km of dual gauge track in metre gauge and broad gauge connecting the broad gauge west to the metre gauge east (Bangladesh Railway Master Plan, 2013). Pakistan has 312 km of metre gauge route lines.

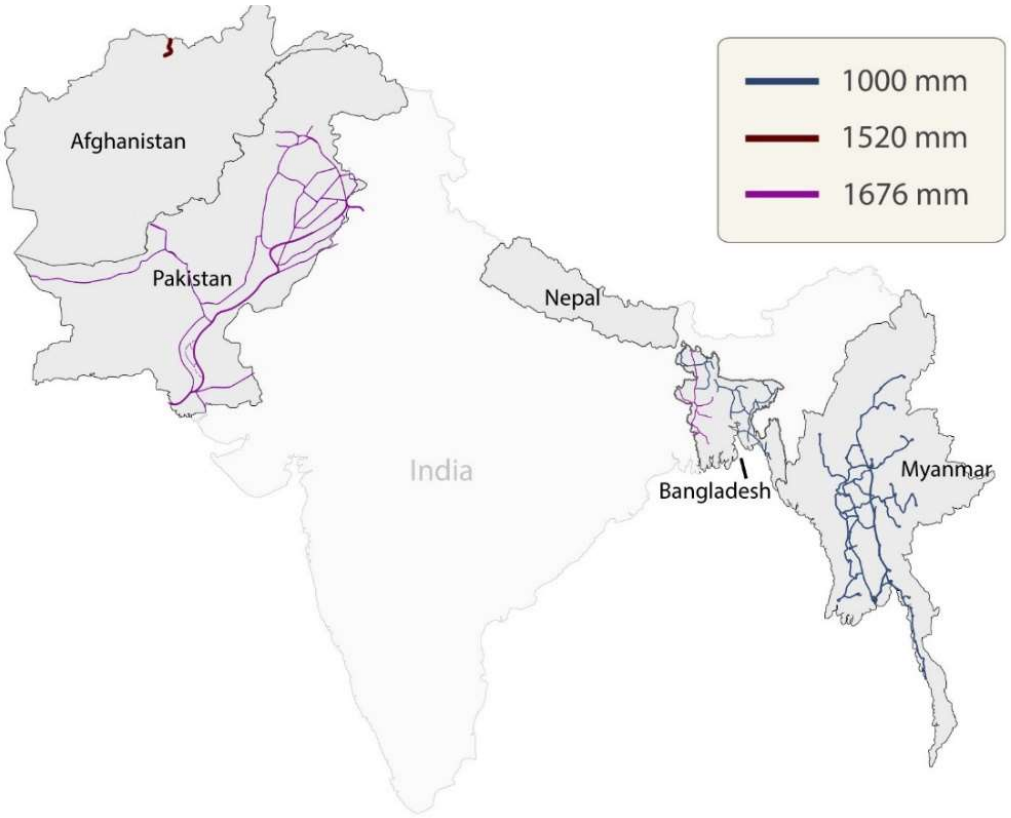

Figure 11: Track gauges in use in South Asia (drawn from World Bank, 2015)

4.3.3 Operational capacity

Traffic densities in LICs are considerably higher than in LICs in Sub-Saharan Africa. While very high passenger volumes bring traffic densities (1,000 traffic units per route-km) in Pakistan and Bangladesh closer to high-income European countries, such as the UK, France, and Germany (World Bank 2018). These high density passenger services rely on hefty subsidies. Even though the proportion of passenger to freight volumes is similar to the other countries, Myanmar has a traffic density below 1 million units per route-km and therefore is considered to be a low volume network. No traffic data were available for the Afghan line, which operates only freight services to Uzbekistan.

However, the small share of freight operations in government-owned railways raises questions over the long-term affordability of operations. Passenger services are unlikely to generate enough revenues. Although labour productivity in South Asian LICs is twice that of Sub-Saharan Africa, it is still very low compared to higher income countries (World Bank 2018; UIC, 2015).

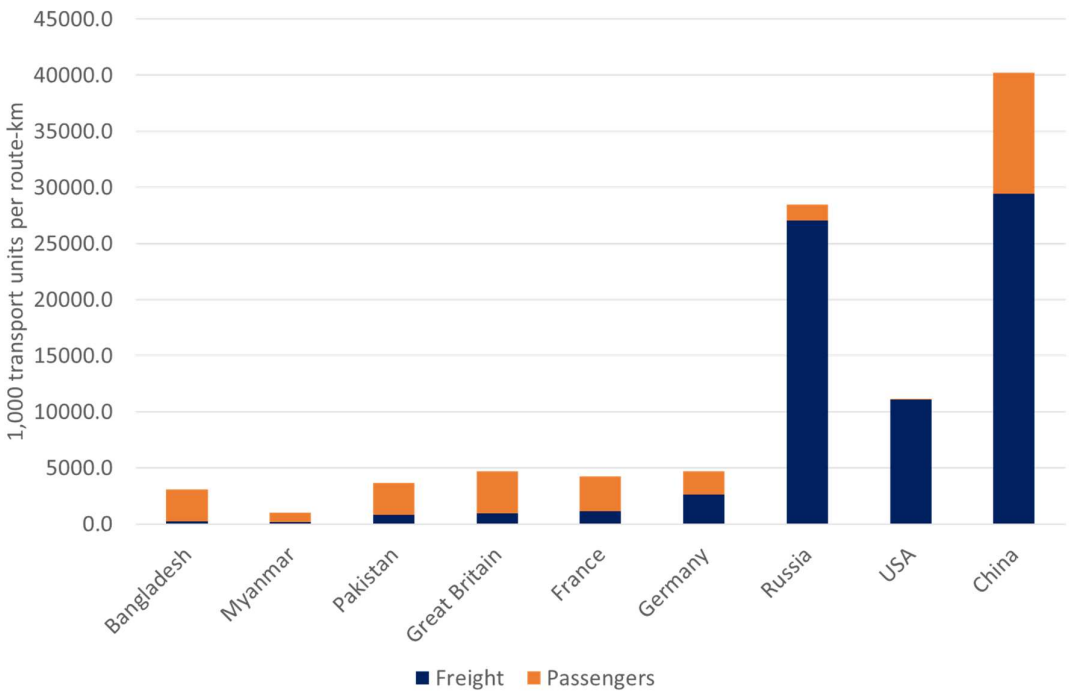

Figure 12: Rail traffic density in South Asia (World Bank, 2015)

4.3.4 Sino-South Asian projects

In a similar manner to the case of African LICs, Chinese-funded projects are also being undertaken in LICs in South Asia. Concerns over their long-term sustainability are shared, yet the scale of these projects seem to be smaller than on the African continent.

The mechanism seems similar to that in Sub-Saharan Africa, although some projects are infrastructure renewal rather than new construction (The Nation, 2018). Work has started in Bangladesh on the Padma Bridge Rail Link, 225 km to connect regions to the port of Payra, for which 168 km of new broad-gauge and single-track line will be constructed. The total cost is expected to be USD 3.14 billion with a loan of 80% (Railway Gazette, 2016).

A USD 6.2 billion railway investment in Pakistan includes renewal of broad-gauge tracks and acquisition of rolling stock. However, the investment has been reduced by USD 2.0 billion because of concerns about the loan costs (The Economic Times, 2018).

4.4 Research challenges

Increasing capacity

Considering the original network, upgrade and rehabilitation of systems seems to be a better option for the long-term. Approximately USD 100 million is needed annually for track rehabilitation and network renewal in Sub-Saharan Africa with a further USD 80 million annually for rolling stock (Bullock, 2009). No comparative figures were found for South Asia LICs, but examples of specific projects have been identified. Rather than building adjacent new lines, doubling and upgrading existing tracks may be more cost-effective in improving capacity for the future, especially where infrastructure supports both

passenger and freight trains. However, further understanding of current asset conditions and service modelling is required.

Data collection and analysis

The biggest challenge found in assessing railway lines in low-income countries is the data shortage. Very few data sources are available to develop technical and performance indicators beyond a few markers. This issue was raised during the Nairobi workshop, where stakeholders highlighted the need for digitalisation and collaboration in regional masterplans to increase connectivity and performance. Data on operational performance are crucial for benchmarking and optimisation strategies.

Most of the performance data available comes from the World Bank database and only extends to 2005. In the considerable gap since then, many projects have been implemented, especially in Africa. In addition, there is little information on the current performance of assets, including permanent way, signalling systems, and rolling stock. For instance, no data were found on drainage and resilience to climate change, especially for the original lines. No data are available on the structural and operational quality of assets, such as track condition and rolling stock availability.

Technical standards and technologies

Recent rail infrastructure projects seem to have been based on little consideration of the specific needs, volumes, and dynamics of the regions they are to serve. Of the projects reviewed from the literature and discussed during the workshop in Nairobi, one common occurrence is the absence of strategic and technical planning to validate the systems built. There is no indication of demand forecasts or models to analyse the best route layouts, and little evidence of in-depth studies on capability to capture appropriate requirements.

Furthermore, resource-for-infrastructure loans mean that railway lines are built ‘off-the-shelf’, thus limiting adaptation to LIC requirements. The high prices associated with the new standard gauge lines raise questions whether operations (which are usually mixed) will recover such costs. In contrast, cheaper renovation of assets and infrastructure together with innovative solutions in design and operational strategies could increase performance more cost effectively.

Large sections of the lines, on both the original network and newly constructed, are single track. This can impose major constraints on operational capacity if not accompanied by appropriate traffic management strategies.

5 Literature Review: Road and Rail Transport Services

Studies on regulation, concession design and institutional skills requirements for planning, design and monitoring of transport services have been reviewed. The focus is largely on the rail sector because of the interplays between infrastructure provision and transport services. The situation in roads is different, where the state provides infrastructure either directly or indirectly via letting tenders, but private users are free to use the infrastructure.

5.1 Railway concessions

5.1.1 Europe

Since Great Britain was an early adopter of rail franchising, much evidence on the impact of franchising comes from studies of rail industry in Great Britain. Other reformers in Europe include Germany and Sweden and to a lesser extent, the Netherlands and Norway. The EU 4th Railway Package includes the requirement for competitive tendering of public service railway contracts. This has meant renewed interest in comparing countries that have reformed to date (Great Britain, Sweden and Germany) to extract lessons for countries now considering introducing competitive tendering.

A major study was published by the Centre on Regulation in Europe (CERRE) in 2016, drawing on the lessons from the Great Britain, Germany and Sweden, and offering suggestions for countries, such as France, about to start the tendering process (for summary report, see Nash et al., 2016). Individual country reports for Great Britain, Sweden, Germany and France are also available (Smith, 2016; Nilsson, 2016; Crozet, 2016; Link, 2016).

A key message from these studies is that rail franchising in Europe – in common with other sectors – has reduced costs by 20 to 30%. More precisely, these are subsidy reductions, but because of the general reliance on gross cost contracts, these align closely with cost.

However, Great Britain is an outlier, having instead seen sharp cost increases (Smith, 2016). Cost increases in Great Britain seem to result from very large franchises, and when re-franchising the incoming operator takes over an existing company rather than bringing its own rolling stock and staff. This dynamic, combined with short franchises that are also net cost contracts, has led to a focus on revenue growth rather than cost reduction (Smith, 2016). There is also evidence that Great Britain franchises may be too large, such that they are subject to diseconomies of scale (Wheat and Smith, 2015). Costs and subsidies have risen substantially in France, where there has been no tendering (Nash et al., 2016). Affuso and Newbery (2000) used data from Great Britain to investigate the relationship between contract length and investment and found that short franchise lengths reduce incentives to invest in some assets.

More generally, demand has risen strongly in all countries that have implemented tendering. But part of this demand may be related to 'regionalisation' of responsibility for tendering because France has also seen growth. Nash et al. (2016) listed the following key decisions to be made on future tendering:

> Organisation to be responsible for franchising - regional or national body. Regionalisation appears to have been very effective in countries where it has been adopted, although Great Britain is often seen as the exception;
> Size and length of franchises - evidence from Germany indicates longer franchises may work to reduce costs (Link, 2016) and large franchises may increase unit costs (Wheat and Smith, 2015; Link, 2016);
> Risk Sharing. - evidence from Germany and Sweden suggests that gross cost contracts perform best, although some incentive mechanism is needed for service quality.

A recurring problem with franchising in the UK has been franchise failure during the franchise period. This has been less of a problem in other European countries partly because of the greater use of gross-cost contracts and possibly because their franchises are much smaller (Nash et al., 2016).

Smith and Wheat (2012) discussed various policy responses to franchise failures and the impacts on the performance of Train Operating Companies (TOCs) in Great Britain. Responses have included placing TOCs on management contracts (essentially cost-plus regimes with extra subsidies, and hence weak incentive properties); short-term franchise renegotiations; and placing TOCs temporarily back under public ownership. The authors found that the efficiency of TOCs placed on management contracts deteriorated markedly, but this was not the case with franchise renegotiation.

While in Europe, franchise failure has not been a major problem outside of Great Britain, problems have emerged elsewhere, for example in Melbourne, Australia, in the early years of their reforms and in Latin America (Smith et al., 2010).

Reasons for contract renegotiation in the context of the Portuguese road and rail concessions are provided by Cruz Carlos and Marques Rui (2013). A very high proportion of rail and road contracts were renegotiated during the contract period, and frequently in the early years of the contract. The authors noted that renegotiation itself is a very costly process, and hence should be avoided where possible. They indicated that the main reasons for contract renegotiation were inadequate monitoring of contracts, over-optimistic bids, and inadequate enforcement of contract terms.

5.1.2 Latin America and the Caribbean

Another country to adopt a rail franchising system is Argentina, which is arguably a more relevant case in the context of LICs. Carbajo and Estache (1996) gave an account of early successes of the concession system, such as lower public subsidies and increased passenger numbers. They also set out early problems, such as difficulties in enforcing investment plans and imposing fines. Further, the authors pointed out a dilemma in the design of concessions. By strictly enforcing the terms of a concession agreement, the regulator risks the collapse of companies yet by failing to enforce terms, the regulator sets a precedent and loses credibility.

With reference to the Argentine experience, Crampes and Estache (1998) discussed issues in concession contract design, such as contract length, optimal methods for awarding concessions and recommended a form of menu regulation. Under a menu regulation, companies choose from a menu of contracts offering different trade-offs between rate of return, risk, and profit sharing. In choosing their optimal bundle, a company is forced to reveal information to the regulator, which helps to mitigate the fundamental issue of information asymmetry between company and regulator (the company knows more about its activities than the regulator). Such an approach could also help avoid the need for regular and costly renegotiations, and lessen the risk of failure.

Analysing railway restructuring in Brazil and Mexico, Campos (2001) found that performance indicators generally improved after privatisation, and that concessions may have contributed to reversing railway decline in those countries. Campos (2001) concluded that concessioning can be a viable approach in developing countries, but care is needed in the early stages of concession design.

Analysis of some 1,000 concessions in different industries including road, rail, energy, water and telecommunications in Latin America and the Caribbean concluded that concessions can work well (Gauash, 2004). However, Gauash (2004) found that implementation of contracts was flawed in many cases and opportunistic renegotiations should have been dissuaded. Further, he found that most implementation mistakes could have been avoided by improved design and greater attention to incentives.

Guasch and Straub (2006) discussed reasons for contract renegotiation, and emphasised the importance of a regulator in reducing the probability of either company-led or government-led renegotiations. A study on government-led renegotiations in Latin America and the Caribbean by Guasch et al. (2007) again found that a regulator reduces the probability of renegotiation. The likelihood of renegotiation also reduced when there was an arbitration process but increased with price capping, with contract duration, and following elections and growth shocks.

A subsequent study by Estache et al. (2009) using data on road and rail concessions in Latin America found that when social goals such as employment are considered, auctioneers tend to use a multi-criteria format for concessions. The multi-criteria auctions increased the risk of renegotiation, which can be mitigated by good governance, defined in terms of quality of regulation and anti-corruption policies.

In a case study of several Latin American concessions including road and rail infrastructure, Rodríguez (1999) concluded that concessions are more likely to fail when large-scale capital investments are involved, they are in developing countries, or involve urban transport, or demand uncertainty.

Discussing experience with contracts and regulation in developed and developing countries, Stern (2012) emphasised the complementarity of contracting and regulation, and a role for an independent regulatory agency to build trust between stakeholders, resolve conflicts, and enable ordered renegotiations.

5.1.3 South Asia

Tam (1999) discussed reasons for failure of BOT road concessions based on six case studies - three successful and three failed road infrastructure concessions in Asia. Factors for success included reasonable rates of return, sound mechanisms for adjustment of terms, franchisees that are 'reliable, committed, and strong' and 'technically competent', and equitable and experienced governments and legal systems. The factors for failure included frequent changes in government, government corruption and political interference. All three successful case studies are in a HIC, Hong Kong, while all three failures are in a LIC, specifically Thailand. As the determining factors identified mostly relate to the strength of institutions, this casts doubt on the suitability of concession schemes as a service delivery method for LICs.

Sharipov (2010) analysed perceptions based on a survey of public and senior railway staff in Kazakhstan after reforms in 2005. The reforms separated train operation and infrastructure maintenance, and encouraged competition in the passenger markets by franchising and in freight markets by open access arrangements. The authors stated that usage and safety improved after the reforms, while subsidy levels increased.

5.1.4 Sub-Saharan Africa

Gwilliam (2011, pp. 83-137) in a review of rail delivery methods in Africa stated that 14 of the 30 countries with state-owned railways use concession arrangements, four had begun the concession process, and only one was operating under a management contract. The rest were subject to political influence. Gwilliam also found substantial variation in contract length, ownership of assets, and responsibility for investment in the railway concessions, but noted that productivity improved markedly after establishment of the concession.

Roy and Kieran (2006) discussed the spread of railway concessions in Africa, and subsequent substantial investments in rolling stock and other assets, and found that infrastructure investments tended to remain the preserve of governments and aid agencies. The authors also noted substantial increases in productivity after establishment of concessions. Budin and Mitchell (1997) reported an impressive

increase in freight traffic and substantial improvement in service quality during the first year of the Abidjan-Ouagadougou railway concession.

In reviews of concessions, Bullock (2005; 2009) found that most introduced since 1992 were associated with substantial investments by bilateral and multilateral lending agencies. Labour productivity improved and the concessions initially lived up to their public service obligations, with no indication of an increase in freight rates or passenger fares. However, a road-based system would have been better for passenger services. Few, if any, of the concessions generate much profit and not enough to fund long-term renewals. Of the 14 concessions analysed in 2009, three have been cancelled (and subsequently revived with different operators), one has been badly affected by war, and one has suffered from natural disasters and long procedural delays. Six have operated for five years or more, but only two of them have done so without a considerable dislocation.

Except for the railways immediately adjacent to South Africa (Botswana, Swaziland, and Namibia), railways without concessions have continued to deteriorate over the last decade, and the deterioration in some cases has been so long that their recovery will be a struggle (Bullock, 2009). In a review of railway concessions in Sub-Saharan Africa, Pozzo di Borgo et al. (2006) found no clear evidence of abuse of market power due to competition from road transport, and clauses against excessive pricing in concession contracts.

Railway concessions in Africa face some considerable risks. Roy and Kieran (2006) noted disruptions caused by the civil war in Ivory Coast, and the collapse of a bridge in Malawi. Jones and Murphy (2008) stated the Rift Valley Railways concession was affected by political unrest in Kenya in 2008 together with political pressure from governments. Pozzo di Borgo et al. (2006) noted generally weak financial performance of Sub-Saharan African railway concessions, and private sector reluctance to invest in transport in the region or to take on risk.

Ndonye et al. (2014) evaluated the impact of different public-private partnership (PPP) strategies on the performance of concessions, and focused on the Rift Valley Railways concession in Kenya. A survey of managers indicated that key strategic considerations for concession performance are a strong private consortium as concession holder, a sound financial strategy, a sustainable risk allocation strategy, and finally, investment in technology.

5.2 Integration of operations and infrastructure management

The high costs to build, operate, and maintain railways require high traffic volumes to justify a business case. As opposed to road infrastructure where anyone with a car or truck can operate, railways require operating business to provide freight and passenger services. Railway assets are expensive and their life cycle can span more than 50 years. Until the mid-20th century, railways were mostly operated by the government. More recently, many countries have adopted concessionary models to operate their railways more efficiently. Examples include the UK, Japan, Spain, Argentina and Brazil where lessons can be learned for LICs.

There are many types of business models for railways, ranging from completely state-owned and run to entirely privately owned and run. Business models for railway operation are presented in Figure 13. The UK, for example, adopts a vertically segregated structure, where infrastructure is owned and maintained by the government, and private companies pay for access to operate services on selected routes. On low volume routes where fare collection cannot meet the operating costs, the government provides subsidies to keep services open for the public. Other European countries, such as Germany and France, have adopted a similar model except that a public company also competes in the operating market (SNCF and DB).

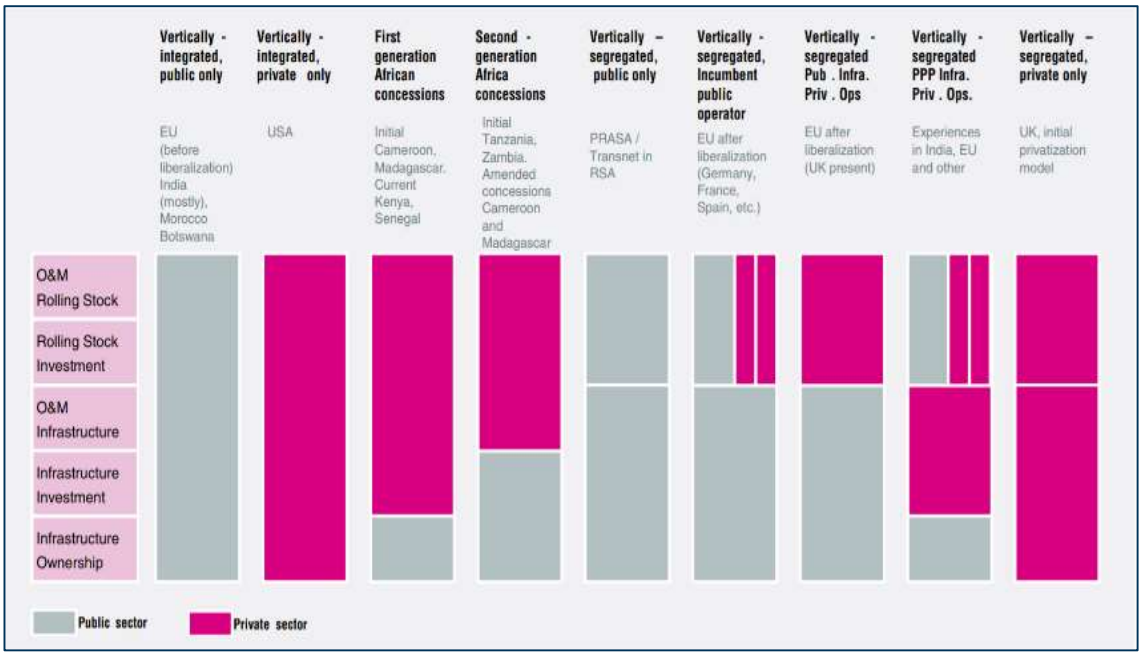

Figure 13: Business models for railways (AfDB, 2015)

In addition, there are vertically integrated structures, such as in the USA, in which private companies own and maintain the entire system. In Sub-Saharan Africa, the first generation of concessions adopted the model of government-owned infrastructure, with concessionaires responsible for maintaining and upgrading infrastructure, and for operating services. As a result, operators found it difficult to compete in the market and only a few dedicated mining lines were breaking even. Furthermore, the model offers little incentive for concessionaires to make long-term investments in infrastructure.

Other structures found in Sub-Saharan Africa make the public sector responsible for investing in infrastructure, while operators are responsible for maintenance. Since the 1990s, many low-income countries (LICs) in the region have opened their railway operations to concessionaires (Figure 14). Three countries (Mozambique, Tanzania, and Zambia) have since cancelled their initial concessions and only Mozambique re-opened the concession at a later date. Two other countries, Guinea and Togo, have completely private mining lines operating, which are commercially viable because of the very high traffic volumes.

Circumstances are different in LICs in South Asia. All lines in Afghanistan, Bangladesh, Myanmar and Pakistan are operated by public companies linked to their national governments.

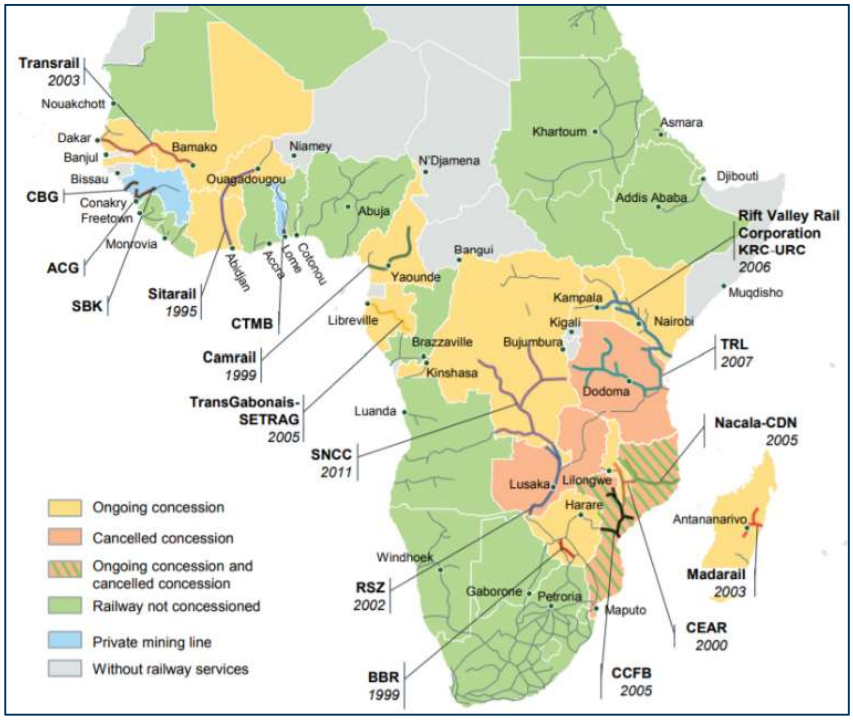

Figure 14: Railway concessions in Sub-Sahara Africa (AfDB, 2015)

However, concessions have not necessarily led to increased traffic density and improved labour productivity (Bullock, 2009; AfDB, 2015). One reason is that is the nature of concessions in Sub-Saharan Africa hinder productivity. The loose regulatory frameworks have resulted in inadequate maintenance and consequently, to asset dilapidation.

In addition, some freight operators have been required to run passenger services as part of their concession scheme. This imposition can impact on their margins because passenger operations usually operate at a loss, especially where fares are decided by the government. Even when operators are eligible for compensation when tariffs do not cover costs, governments have not always honoured their subsidy commitments (Bullock, 2009).

The combination of freight and passenger services on current infrastructure in LICs poses severe constraints on concessions. Firstly, passenger services take slots that could be used for freight services that have better financial returns. Secondly, poor track quality imposes speed limits, which in turn impact on maximum line capacity. Finally, manual signalling systems and single-track routes require very long headways, which considerably affect line capacity.

The impact of vertical separation on railway costs, and to a lesser extent on demand, is well documented. These studies focus mainly on European railways, where EU legislation has required some form of vertical separation and a key question has been how best to do this. Countries, such as Great Britain and Sweden, have full legal separation, whereas other countries, such as Germany, use a holding company structure.

Studies on separation and the best approaches to make separation work include Mizutani et al. (2015) and van de Velde et al. (2012). These two studies included both quantitative and qualitative assessments. A key finding was that in countries with railway capacity constraints, vertical separation does not work well from a cost perspective. Congested networks magnify misalignment of incentives. This suggests that

a holding company or even full vertical integration may work best. Partly as a result of these studies, the European Commission permits both approaches.

Fair access to infrastructure is essential especially if the incumbent operator is also the infrastructure manager. This gives rise to the need for independent oversight of track, station, and terminal access charges, and capacity allocation. Such oversight is needed to ensure that new operators can freely access infrastructure, and the infrastructure manager is compensated for the additional marginal cost in accommodating the additional traffic. This consideration is important for rail liberalisation because without it, new operators are unlikely to emerge and/or the infrastructure manager will have financial difficulties.

In a comprehensive review of best practices, Wheat et al. (2009) synthesised empirical results including means to generalise to other countries. Research could be considered on application of economic and engineering modelling techniques to LIC infrastructure to gain insight into the marginal costs associated with extra traffic. However, the comprehensive results from HICs are a starting point for policy makers and regulators involved in designing track access systems in LICs.

5.2.1 Economic regulation of infrastructure and services

Regulation of infrastructure is considered from the perspective of ensuring funding for infrastructure managers, and their efficiency to ensure that final prices to users are not exploitative (either access charges in rail or tolls for roads or subsidy requirements to funders). Transport services tend to be operated as a service provided directly by the state; competition in-the-market (open access); or competition-for-the market (tendered services). These service delivery mechanisms need to be investigated in terms of the level of protection provided to final users (passenger and freight).

The key issue is the interface between infrastructure manager and transport service operators, because the inherent natural monopoly of the infrastructure manager implies the following:

> A single infrastructure manager is preferred for a specific geographical area to minimise costs;
> Pricing infrastructure at marginal (incremental) cost of usage yields less than full cost recovery for the infrastructure manager even if that leads to efficient (optimal) use of the network;
> Pricing infrastructure at average cost would make socially desirable services unviable;
> The key trade-off is between financial viability of the infrastructure manager and pricing of access for train operators.

A key study in the EU-funded project, NETIRAIL-INFRA examined how cross-industry innovation and cost reduction can be stimulated through a range of regulatory, contractual and structural approaches (Nash et al., 2016). Benedetto et al. (2017) surveyed the status of regulatory reforms in European railways based on a literature review on ideal regulatory characteristics. European rail regulators were found to exhibit many of the features of ideal regulation. However, there is scope for regulatory bodies to be more proactive in shaping track access charges, which are important for funding and in regulating the efficiency and quality of infrastructure managers.

For many years, the powers of the regulator in Great Britain have been the most extensive in Europe. The regulator has conducted or commissioned many studies using econometric techniques to drive up cost efficiency (value for money) (Smith, 2012; Smith and Wheat, 2012; Office of Rail and Road, 2018). These studies have highlighted inefficiencies in Network Rail and have been used to set efficiency targets. Other sectors have adopted these benchmarking approaches and RPI-X regulation is considered successful for utilities, but arguably less so for rail (Smith, 2017; Smith, 2018). An econometric study by Smith et al. (2018) showed how increased powers of economic regulators have contributed to efficiency savings and how these powers interact with other reforms.

5.3 Public authority and skills capacity

Historically, transport infrastructure in developing countries has been of low quality, and investment biased towards 'prestige projects' that may not reflect the most efficient approach to investment (Button, 1992). In a review of the national transport strategies of several HICs and LICs, Lee and Hine (2008) found a tendency to focus on investment rather than institutional and regulatory set ups. They also identified poor financial and environmental sustainability, and no comprehensive approaches to poverty, safety, and environmental issues. There is a clear need for stronger and more effective public bodies – government departments and regulators – in transport in developing countries.

Case studies of transport regulation in Sri Lanka, Pakistan, and Tanzania have highlighted the need for appropriate regulatory frameworks and more effective enforcement. Sohail et al. (2006) concluded that transport regulation must be "open, honest, and effective, but not so detailed or heavy that it incites the potential for corrupt practices" and emphasised the need for communication and coordination between stakeholders, through stakeholder associations and transport forums.

An authority with responsibility for ensuring safety standards and compliance with laws on transport safety needs adequate enforcement powers. The statement of the Office of Rail and Road (ORR, 2016) includes enforcement options. Inspectors are empowered to issue verbal or written advice that standards have been breached or the law not upheld as a first resort. This necessitates a team of qualified inspectors with the power to prosecute in serious cases. The ORR is one of several regulators in Great Britain that are 'prosecuting authorities'. The ORR acts independently of the Crown Prosecution Service (CPS), the main prosecuting agency in Great Britain, and is responsible for preparing case files. Thus, authorities need legal expertise in transport regulation.

An authority responsible for the design of concessions requires both economic expertise and legal expertise on contract law for optimal contract design in terms of contract length, terms, and the economics of enforcement and renegotiation of contracts. In the UK, the Department for Transport (DfT) is responsible for rail franchising. A statement of DfT powers on enforcement of franchising agreements is presented by the Department for Transport (2008).

Organisations responsible for strategic planning of road and rail networks need a range of capabilities to understand the future direction of networks. These include long-term trends in demand and network capacity, future technological developments, future network condition, and long-term investment requirements. Skills are required in engineering, construction, accountancy, planning, economics and forecasting. In the UK, strategic rail planning is led by Network Rail informed by studies on issues affecting specific routes and the entire network. Strategic planning for the road network is done by Highways England, Transport for London, Transport Scotland, and the Welsh Assembly, which have responsibility for strategic road networks, and local authorities have responsibilities for local road networks.

In Mexico, the railway network is oriented to freight transport and freight railways have been run by concession holders since 1995. The Regulatory Agency for Rail Transport (ARTF) was established recently in response to complaints by shippers about tariffs and service levels. A report by the International Transport Forum (2016) described the functions of the new regulator, compared rail regulation in Mexico with the USA and Canada, and outlined priorities for the new Mexican regulator. The report noted it would take ARTF many years to develop a comparable information base. Discussions with the USA and Canadian regulators were recommended, and also with Mexican concession holders to determine the financial and operating data required. It was also suggested that ARTF may wish to develop capabilities in cost modelling, and build a GIS model to analyse traffic flows on the rail network.

Until ARTF capabilities are fully developed, the report recommended a less prescriptive approach to regulation based on negotiation and arbitration, which should also keep regulation costs low. Likewise, development of safety regulations was identified as a long-term priority. Ideally, these regulations should be based on performance criteria rather than prescribing behaviour and design requirements. Existing safety regulations should be continued in the short term. The report identified a need for a "critical mass of human skills and management resources … spread across law, economics, accounting, and engineering". These skills should be similar to those of the USA and Canadian regulators, with a budget and staff proportional to the size and complexity of the Mexican rail industry. The risks of an underfunded or understaffed regulator were noted.

In discussing regulation of railway concessions in Africa, Gwilliam (2011, pp. 112-114) identified inadequate provision for regulators as an impediment to effective regulation. The author stated that "many railway concessions in Africa lack formal regulatory structures with real power and are thus susceptible to abuse". In addition, the author listed factors impacting on concession performance, including conflicts and delays with governments over compensation, concession fees, time frames, staffing, "administratively imposed salary increases, restrictions on access to container facilities, and unfunded public service requirements".

5.4 Road safety regulation

There has been much discussion about road safety in developing countries and specifically Africa, where road crashes and fatality rates have increased along with vehicle ownership. Road safety is the responsibility of many different government agencies and departments as well as traffic police. Driver licensing and vehicle licencing are the responsibility of government agencies. Enforcement of traffic laws and regulations are generally the responsibility of traffic police and the courts, while some government agencies have a role in roadside inspection of freight vehicles.

Assum (1998) appraised road safety initiatives in five African countries - Benin, Côte d'Ivoire, Kenya, Tanzania, and Zimbabwe. The author concluded that each country has the legal framework, organisations, technology, and institutions required for road safety, and is aware of effective road safety measures and the scope of the problem. However, a number of weaknesses were identified:

> inadequate implementation caused by insufficient political concern;
> poor feedback to decision makers, a lower value put on human life and inadequate funding (see Road Funds);
> frustration resulting from inadequate implementation;
> over-reliance on education and information disproportionate to effectiveness;
> weak political position of road safety boards and councils;
> corruption.

Various issues have been identified and discussed including the growth in road traffic injuries in Africa, and the need for governments to improve data collection and analysis, sharing between agencies, and the problem of underreporting (Assum, 1998, pp. 21-22; Khayesi and Peden (2005). Chen (2010) noted a continuing upward trend in road traffic injuries and identified a key obstacle to reducing injury rates is a lack of no leading agencies with regulatory powers and public support.

In a study of road safety in Nigeria, Sumaila (2013) recommended restructuring of Federal Road Safety Corps and strengthening strategic ties with other government departments and agencies to increase effectiveness. The need for driver education on road safety was emphasised.

Abegaz et al. (2014) analysed the effectiveness of new road safety regulations in Ethiopia. These regulations include bans on the use of mobile phones while driving, driving without a seatbelt, riding a

motorcycle without a helmet, and strengthening laws on drink driving, speeding, and unsafe loading. Using data from the period 2002-2011, the authors found considerable reductions in fatalities, injuries and road crash rates from the first year after introduction of the new regulations.

5.5 Regulation of drivers' hours

A key aspect of road safety is the regulation of a driver's hours of work in freight and passenger transport. The links between hours of work and rest time for drivers and the risk of accidents are well established. McDonald (1981) argued that regulation of driver hours reduced the risk of accidents, and highlighted the need for enforcement of and adherence to these regulations. Baas et al. (2000) surveyed truck drivers in New Zealand, and found many drivers exceeded the allowed driving hours, and high levels of fatigue and sleepiness.

In a literature review on fatigue and sleep-related road crashes, Amundsen and Sagberg (2003) emphasised the high proportion of professional drivers reporting incidents of fatigue and falling asleep while driving, and the link between length and quality of sleep and crash risk. The authors attributed low levels of compliance with the regulation to its complexity, and suggested harmonisation of regulations and sanctions across countries may improve compliance and safety. Based on a survey of UK truck drivers, Poulter et al. (2008) found that perceived behavioural control had the largest effect on compliance with regulations than other 'soft factors'.

Hall and Mukherjee (2008) estimated the impact of hours of service regulations on crash and fatality rates using data from the Fatality Analysis Reporting System of the US National Highways Traffic Safety Administration. They estimated that perfect enforcement of the regulation would result in a 3-5% reduction in crashes. Jones et al. (2005) compared working hours' regulations in Australia, Canada, the UK, and the USA. They suggested that a hybrid approach could be effective in which prescriptive measures, such as industry-wide hours of service standards, are combined with a less prescriptive outcomes-based approach.

Enforcement of hours of service and similar regulations relies on the capacity of authorities to inspect records kept in each vehicle and by each company. Technological advances have enabled more reliable record keeping from log books to tachographs that record hours on card or digitally. These technologies are progressively more difficult to tamper with, and the data easier to process. Increasingly, digital tachographs are a requirement for new vehicles, for example, for all new vehicles in the UK since 1 May 2006. The use of digital technology may lead to authorities collecting such data and detecting infractions in real time.

5.6 Corruption and effectiveness of road safety regulation

Nantulya and Reich (2002) discussed global trends in road traffic injury rates, and the reasons for differences in rates and trends in HIC, MIC and LIC countries. Kopits and Cropper (2005) found a non-monotonic relationship between GDP per capita and traffic fatality rates, rising initially as income increases, but falling after a certain income level is reached. The authors noted that, since vehicle ownership rates increase monotonically with income, this turning point reflects a reduction in fatalities per vehicle.

The same inverted-U shaped relationship between income and traffic fatalities was also found by Anbarci et al. (2006). They also found that for any given income level, public sector corruption is associated with increased traffic fatalities. Various ways that corruption can affect traffic fatality rates were discussed. For example, corrupt license examiners may allow drivers to bypass training and testing for a fee. Corrupt vehicle inspectors may sell safety certificates for unsafe vehicles. Corrupt traffic police may abuse their

powers to extort money from innocent drivers, undermining faith in traffic regulations. The traffic police may also be bribed when drivers are at fault.

Tackling corruption by traffic police, vehicle inspectors, license examiners, and other public officials is essential to improving road safety regulation. The usual measures would be to increase monitoring and detection of wrongdoing, and to punish offenders via dismissal, fines or imprisonment. As an alternative, or as a complementary measure, Becker and Stigler (1974) suggested that officials be paid an *efficiency wage (*a wage or salary) above the market-clearing rate, with the mark-up reflecting the magnitude of the potential benefits of corruption, and the risk of being caught. Such a measure would increase the costs of engaging in corrupt practices and could be less costly than increased monitoring. Empirical support for an inverse relationship between wages and corruption has been provided by Van Rijckeghem and Weder (2001).

5.7 High transport tariffs in Africa

Over the last 25 years, a number of comparative studies have been carried out on freight transport costs and tariffs in Africa and Asia. These studies confirm that freight transport tariffs are many times higher in Africa than in Asia and elsewhere. For example, Toll Infrastructure Services (2017) found that transporting goods in Africa often takes three times longer and is 3-5 times more expensive than in Europe, Asia and Latin America. Drawing on data collected in the late 1980s, Rizet and Hine (1993) found that for comparable journeys, freight tariffs in Francophone Africa were 4 to 6 times higher than in Pakistan. While a study in 1995 found that long distance tariffs for a heavy articulated vehicle were about 2.8 times, per ton/km higher than in Indonesia (Hine et al., 1997).

Although most studies relate to long distance transport, short distance rural transport in Africa is also subject to high transport costs and low productivity compared with Asia (Ellis, 1996).

Studies in the 1990s have emphasised a range of reasons for differences in tariffs including higher costs of fuel and parts, poorer vehicle maintenance and lower vehicle productivity, as well as monopolistic practices. Road conditions were not identified. However, a later study of long distance transport (Teravaninthorn and Raballand, 2009) emphasised very high profits in Africa as a reason for high freight tariffs, particularly in West and Central Africa. They suggested that at the time, underlying costs were similar in other regions. Freight tariffs are shown in Figure 15.

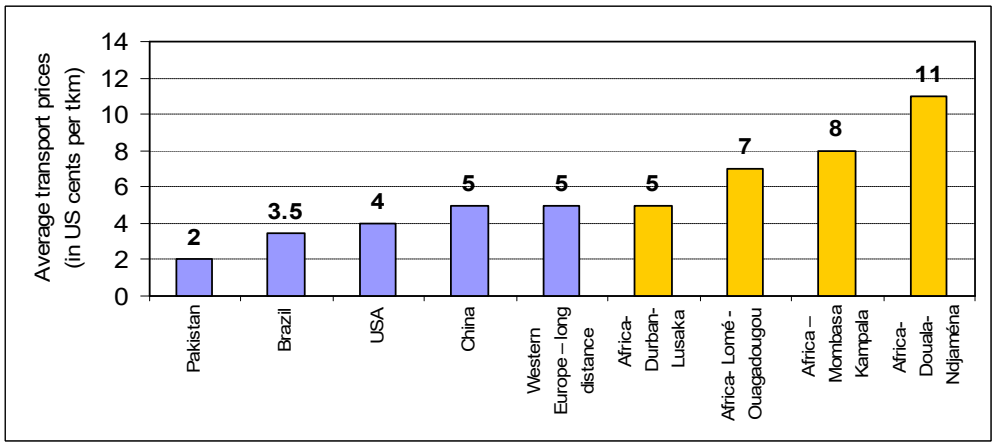

Figure 15: Comparison of long-distance transport tariffs (USD cents per tonne-km) 2007 (Teravaninthorn and Raballand, 2009)

A comparative study has shown that tariffs in Africa were three times those in the USA, taking into account the return journey. In 2010, transport of a 20-ft container from Tema port in Ghana to Ouagadougou in Burkina Faso cost USD 3,200 (of which USD 207 of which was bribes) and took 13 to 22 days. In comparison, a container transported a comparable distance from Newark to Chicago cost USD 654 (one fifth of the price in Africa) and took just 5 days. An export container from Ouagadougou to Tema cost USD 1,755 (USD 66 of which was bribes) and took 6 to 9 days, while an export container from Chicago cost USD 990 and took 2.5 days. The comparison with the USA is more surprising than with Asia, because labour costs are 25 times higher than in West Africa (Annequin and Eshun, 2010).

High charges for long-distance transport in Africa were not related to the quality of road infrastructure. For example, 82% of the Tema to Ouagadougou route, discussed above, is in good to fair condition (Beuran et al., 2015). The issue is the market structure of freight transport operations. Freight operators are able to restrict competition in Africa by operating queuing systems at truck parks, whereby freight consignments are allocated to the first vehicle in the queue. In many countries, the truck and bus parks are organised by transport unions and this is common practice in West Africa. The Ghana Private Road Transport Union (GPRTU) runs the truck, bus and taxi parks. Guards may also be employed to restrict non-members from taking loads (Lyon, 2006). Operators of newer vehicles need to bypass the queuing system to increase vehicle utilisation to recover their capital costs and remain in business. It has been reported that loads acquired outside the parks may be obliged to pay the unions commission (Delaquis, 1993).

Sometimes, a driver can be waiting in a queue for a week or more to find a load. Prices are thus kept high, and utilisation low through the system that encourages over-supply of vehicles. This is also encouragement to keep old vehicles working well beyond their economic life. As a result, vehicle productivity tends to be very low. The annual distance travelled by tractor and semi-trailers is often 50,000 km compared with around 125,000 km in Asia (Rizet and Hine, 1993). With low utilisation, it is uneconomic to use new vehicles, and as a result most commercial vehicles are imported second-hand from Europe. Second-hand vehicles are also widely imported into the Middle East and Central America where similar cartel arrangements operate.

In contrast, transport unions in Asia have far less power. In Pakistan, for example, freight agents who compete with one another consign goods to the first operator willing to accept the load for the given freight tariff (Hine and Chilver, 1991).

No comparable study has been done on passenger transport but differences are likely to exist. For example, in 2008/9 passenger fares for State Road Transport Services in India averaged INR 0.4837 per km (USD 0.01 per km; Economic Times of India, 22 April 2011). In contrast, long-distance passenger fares in Tanzania in 2009 averaged TZS 31.92 per km (USD 0.025 per km; Ministry of Infrastructure Development, Tanzania, 2010).

Ngoundere District in Northern Cameroon provides an example of a local mayor addressing the issue of poor transport services and high fares (Lisinge, 2001). In Cameroon, transport syndicates determine fares and routes, and negotiate with the authorities for access fees, and use of terminals. In Ngoundere, the mayor licenced different transport agencies to operate from different terminals in competition with one another. Within two years, passenger fares dropped by 50%, and service frequency increased, with cleaner and better maintained vehicles. As a result, fares in Ngoundere were dramatically lower than comparable operations in the south of Cameroon where fares were 53% higher for 10 km and 370% higher for 200 km (Lisinge, 2001).

5.8 Road freight overloading

Vehicle overloading, whereby vehicle axle loads exceed pavement design limits is a specific issue on African roads. This occurs because freight operators overload cargo to maximise the payload, operational efficiency and reduce fuel costs (per tonne-km output). However, overloading significantly affects the life of the highway pavement asset. Rys et al. (2015) studied the effect and concluded that if 20% of trucks are overloaded the life of the road pavement reduces by about 50%.

Chan (2008) evaluated economic loss as a result of reduced pavement life caused by vehicle overload in a central province in China, by quantifying the structural damage and road maintenance and rehabilitation costs. The study showed that the weight limit was exceeded by as much as 100%, and some 50 to 70% of heavy trucks were overloaded, compared to 0.5 to 2.0% overloaded in the USA. The study also acknowledged the importance of including social (e.g., safety) and environmental costs, and loss of toll and taxation as a result of truck overloading in future studies. A further study by Bagui et al. (2013) found that 50% of trucks using highways in India were overloaded, and road assets would give the best economic return by limiting the truckloads to the maximum permitted legal loads.

In addition to causing premature failure of road pavement as found by Pais et al. (2013), overweight trucks can induce excessive fatigue damage that could reduce bridge load-carrying capacity and affect durability (Deng and Yan, 2018).

Furthermore, according to Aliakbari and Moridpoure (2016), an overloaded vehicle is difficult to control because it is operated outside the vehicle's design parameters for steering and brakes, and thus becomes a serious threat to road safety. Overloading leads to increased congestion caused by damaged roads and accidents that increase logistics costs in the region. According to Toll Infrastructure Services (2017), transport operators largely welcome overloading control as they value a level playing field that fosters fair competition between modes and operators.

For these reasons, overloading control is a priority and static weighbridges are used to control overloading. Toll Infrastructure Services (2017) estimated there are 260 weighbridges in Africa with plans for another 40 and this undoubtedly has had a strong beneficial effect. Pinard (2010) and Pinard (2011) have documented the steady reduction in overloading due to weighbridge use in South Africa, Namibia, Zimbabwe and Zambia. As well as increasing the availability of weighbridges, the decriminalisation of overloading has also brought benefits (Pinard, 2011).

However, static weighbridges have their limitations. They are inflexible and monitor load at a specified point but do not cover the whole network. An alternative available for several years is the portable weigh-in-motion (WIM) device that allows a road authority to set up temporary checks. Though less accurate than static installations, these portable devices are recommended by, for example, Bagui et al. (2013). According to Hornych (2015), overload control using WIM was tried in Taiwan with a 30% tolerance margin due to potential measurement error. This tolerance margin is rather higher than is desirable. Current research in France (Hornych, 2015; Jacob and Cottineau, 2016) is aiming for a 10% tolerance. This would appear to be an area where progress can be made, potentially leading to better overloading control.

5.8.1 Current situation in South Asia

Indonesia spends IDR 43 trillion (USD 2.4 million) annually to repair roads prematurely damaged by overloaded trucks. Since August 2018, trial operations of three weighbridges in West and East Java have been carried out. Under the Traffic Law No. 22/2009, drivers of the oversized and overloaded trucks can be fined and sentenced to two months in prison. Some Asian countries, such as India, Vietnam and

Thailand, have managed to reduce the problem of overloaded trucks, according to the Jakarta Post (2018).

5.8.2 Current situation in Sub-Saharan Africa

As stated above, over 260 weighbridges are operated in Africa, and a further 40 weighbridges are planned. The installation status, cost and operation of weighbridges in Eastern and Southern Africa were reviewed by Pinard (2010). Most of the 80 operational weighbridges in South Africa are located on national routes (Engineering News, 2015).

Alternative routes without weighbridges and the shortfall in weighbridge necessitates adequate policing of the road network. Overload control strategies should focus on regions and not one stretch of road. According to Chen and Guo (2010), more affordable mobile weighbridges could be used to identify severely overloaded trucks before being escorted to weighbridges, but this solution would place massive demands for a skilled work force.

In 2014, 20% of the two million vehicles weighed in South Africa exceeded the weight limit. Only 2.6% of the 20% were prosecuted according to Dr Paul Nordengen, Council for Scientific and Industrial Research (Engineering News, 2015). Officers accepted bribes and operators paid their way through the weighbridges. Corruption is a major hindrance to compliance. Low fines are imposed and the practice is seen as 'unimportant' by the Department of Justice, according to Engineering News (2015).

Different institutions are responsible for overload control in different countries, and there are differences in institutional capacity and responsibility for overload control. During 2010, several West African countries started implementing standard axle weight rules, but it was not regarded as successful. Currently, there are new initiatives in Ghana and Nigeria, according to Toll Infrastructure Services (2017). Eastern and Southern Africa are in the process of regional harmonisation, standardisation and cooperation. Several initiatives have been developed, including:

> African Strategic Infrastructure Initiative;
> Regional Infrastructure Development Master Plan;
> Tripartite Regional Economic Communities;
> Federation of East and Southern African Road Transport Associations (FESARTA).

5.8.3 Technical challenges and opportunities

Checking truck weight compliance places high demands on resources and the efficiency is generally low. A vehicle is only stopped and guided to the nearest weighing scale when there is a clear indication of substantial overloading.

Technical handicaps that can have negative impacts on overload control efficiency include:

> inconsistent definition of overloading, such as one weighbridge takes account of tyre limit, and another imposes a vehicle limit, which means that a truck could pass at one weighbridge and fail another;
> lightning strikes frequently damage load cells in the weighbridges;
> delay to trucks waiting to be weighed due to dysfunctional weighbridge or inefficient weighing procedures;
> efficient weighbridge infrastructures are very expensive capital investments.

The gain from a weighbridge is savings in road maintenance caused by overloading. Financing and operating weighbridges should be a joint and integrated effort between the public sector and truck operators.

A framework and field studies have recently been developed on truck overloading and novel control and monitoring methods in China and South Africa. The measures proposed by Hu (2011) include:

> weight sensors installed in vehicles;
> wireless device sending data to the GPS installed in the driver's cab;
> remote control terminal to receive and process the information sent by the GPS.

Hoffman and Coning (2014) also devised an ICT system, combined with novel data interpretation to enable sharing of real-time data between overload control centres. The project collected information on the potential for optimising overload control over the entire Eastern and Southern African corridor to meet the often-competing requirements for road protection and logistics efficiency.

Karim et al. (2014) studied the effectiveness of a weigh-in-motion (WIM) system in aiding vehicle weight enforcement in Malaysia. The WIM system is designed to monitor the weight of commercial vehicles as they travel along the road, to identify weight violators while permitting vehicles of legal weight to continue without interruption. They found that the WIM system can be used in conjunction with static weigh stations to detect truck weight violation in developing countries. However, the WIM system has limited accuracy.

A large-scale project was launched in France in 2014 to demonstrate the feasibility of fibre optic WIM sensors, and to develop approval procedures for direct enforcement of overloaded trucks at highway speed. Jacob and Cottineau (2016) found that none of the WIM systems achieved 100% accuracy for the required tolerance (±5% for gross vehicle weight, ±10% for axle loads).

Another way of monitoring truckload is the on-board weigh (OBW) system that is fitted to vehicles rather than to infrastructure. By 2013, OBW systems cost less than EUR 1,000 per truck compared to WIM systems that cost about EUR 100,000 per site, both figures depending on accuracy requirements (Todts, 2013).

According to Strathman (2001), the economic rationale in the USA for truck operators to exceed weight limits in the face of weight enforcement is the prospect of additional revenue after operating costs and potential penalty are deducted. The effects of enforcement intensity and the severity of penalties are similar in deterring overloading, with most enforcement-related deterrence attributable to the use of portable and semi-portable scales.

The World Bank (2005) found that 30 to 40% of trucks in India are overloaded by 25 to 50%. The report contained data on truck operations in India, such as vehicle operating cost, toll rate and journey time that can be used in economic appraisal of overloading and enforcement measures. A case study by Kolo et al. (2014) found that 53% of trucks using a rural road in Nigeria were overloaded. They took a similar approach to Bagui et al. (2013) and analysed the percentage and magnitude of overloading separately based on the number of axles, and positions (e.g., front, rear) of the axles. The study recommended an increase in the legal axle load in Nigeria.

5.9 Cross-border road and rail freight

Land imports take more time than imports by air or sea. The correlation between land distance and import lead-time suggests that in addition to infrastructure, service provision, and logistics issues, geographical hurdles determine a country’s ability to connect with world markets. Furthermore, the

efficiency of border processes affects import lead times. The time for border processes can be reduced at all stages, and especially at clearing goods on arrival.

Although the time taken to clear goods through customs is a small part of the total import time, it rises sharply if goods are inspected physically, even in high-performing countries. Physical inspection is more prevalent in LICs and may mean a shipment is subject to repeated inspections by multiple agencies. The World Bank (2018) showed that the clearance times for the bottom three quintile (20%) performing countries are three times longer and paperwork twice as much as for the top two quintiles. Export supply chains have a much lighter procedural burden than import supply chains. The logistics gap between country income groups appears again in export lead times, which are nearly four times as long for LICs as for HICs, hurting export competitiveness and ability to trade internationally.

Unlike lead times, there is increasing consistency in customs procedures worldwide. However, customs are not the only agency in border management. For many countries, the key to improving border agency performance may lie with reforms to agencies other than customs. Streamlining border procedures to facilitate trade and simplifying documentation for imports and exports have long been high on the trade development agenda, prompting initiatives to bring border agencies together and create a single window for trade.

5.9.1 International legal framework on trade and customs

The General Agreement on Tariffs and Trade (GATT) for international trade in goods came into force in 1948. It was replaced in 1995 by World Trade Organization (WTO), which became the central legal instruments of international trade. Section 3 of the Agreement covered the need to facilitate transit at border crossings, specifically 'freight traffic coming from or going to the territory of other contracting parties shall be exempt from customs transit duties or other charges imposed in respect of transit'.

The World Customs Organization (WCO) develops global standards for the movement of cargo across international borders and is the only intergovernmental organisation that deals with customs procedures governing trade between countries. WCO had 179 members by the end of 2012. Chapters 3 and 6 that deal with clearance and customs control state explicitly that 'Customs control shall be limited to that necessary to ensure compliance with the Customs law'.

The International Convention on the Harmonized Commodity Description and Coding System came into force in 1988. It is used by more than 200 countries and economies as a basis for determining their customs tariffs, and for international trade statistics and economic research.

The International Road Transport (TIR) system is the only regime designed for global international transit. To date, the TIR system is used by some 57 countries in Europe, Central Asia and parts of the Middle East. Its principal advantage is that it is actively used in the well-developed European trucking market.

5.9.2 Current situation in Asia

ASEAN (Association of Southeast Asian Nations) countries form a market of over 500 million people, with a gross domestic product (GDP) of USD 700 billion. In line with the 2015 vision for free flow of goods and services and integrated logistics services, ASEAN member countries endorsed the ASEAN Economic Community (AEC) in 2007. AEC promotes IT in the logistics chain to establish an ASEAN single window and adopts 24/7 customs operation. The provisions in the World Trade Organization (WTO) agreement for customs valuation are considered to facilitate documents processing and other trade-related matters.

De Souza et al. (2018) considered inefficient customs procedures and inspections to be the main barriers to logistics services in ASEAN, followed by barriers in land transport. Gupta et al. (2011) found that cross-

border trade in ASEAN is hampered by unwieldy customs procedures and inspections, lack of coordination, and arbitrary rulings. Tongzon and Cheong (2014) evaluated the extent to which the measures adopted to improve the competitiveness of ASEAN logistics have been implemented and identified the underlying factors hindering implementation. Overall, implementation has been low and characterised by a perception gap between logistics companies and governments. Effective public–private partnership is needed to promote advanced technologies and practices in logistics chains.

5.9.3 Current situation in Sub-Saharan Africa

Adaba and Rusu (2014) examined the effect of an e-government initiative to modernise customs procedures and to facilitate trade in Ghana. E-trade facilitation gives individuals and companies the opportunity to lodge import and exports declarations electronically in a single document. Hinson and Adjasi (2009) found a 1% increase in internet use is associated with a 2.2% increase in exports, through reduction in the entry and search costs for exports from Africa. Hoffman and Bhero (2015) simulated the optimised design of cross-border operations in end-to-end trade corridor management in Africa. The simulation showed that cross-border delays can be reduced by more than 80% by interchange of information to allow dynamic scheduling of customs processing capacity and operational changes. The findings of the simulation are listed as follows:

> the average transit time for all cargo types can be reduced by 35% with change in customs processing capacity but has little further impact once a critical capacity is reached;
> the average transit time for all cargo types can be reduced by a further 28% when all cargo is pre-declared. Combining information interchange in an RFID (radio-frequency identification) enables system and the dynamic changing of customs processing capacity at peak periods can reduce transit times by 82%.

The large discrepancy between the transport cost of service providers and the cost to users (prices) in parts of Africa indicates cartels in the freight market. United Nations (2012) considered transport cartels to be the leading cause of zero or low coordination between customs and private industry users. Some systems in the trucking industry in Sub-Saharan Africa result in large fleets in poor condition, and foster corruption (to bribe the freight agencies to get work). According to Teravaninthorn and Raballand (2009), the negative influences of cartels include:

> Shippers who are forced to use local fleets have to pay a surcharge that reflects higher prices, lower quality, or bribes. These costs are detrimental to landlocked countries. This situation explains why direct contracts (medium or long-term contracts between shippers and truck operators), which are string indicators of good logistics, are almost non-existent in Central Africa and marginal in West Africa;
> The different levels of truck utilisation in Sub-Saharan African result from oversupply of transport capacity;
> To mitigate regulatory burdens, operators use old trucks or utilise newer trucks to very high annual mileages, as illustrated in Figure 16. These trucks are therefore often in poor condition, have high vehicle operating costs and are often overloaded;
> While bilateral freight allocation protects the truck operators in landlocked countries, it creates cartels and slows down market and regional integration. This may result in inadequate capacity to handle freight peaks and low fleet utilisation.

The fleet age and yearly mileage by regions in Africa are shown in Figure 16.

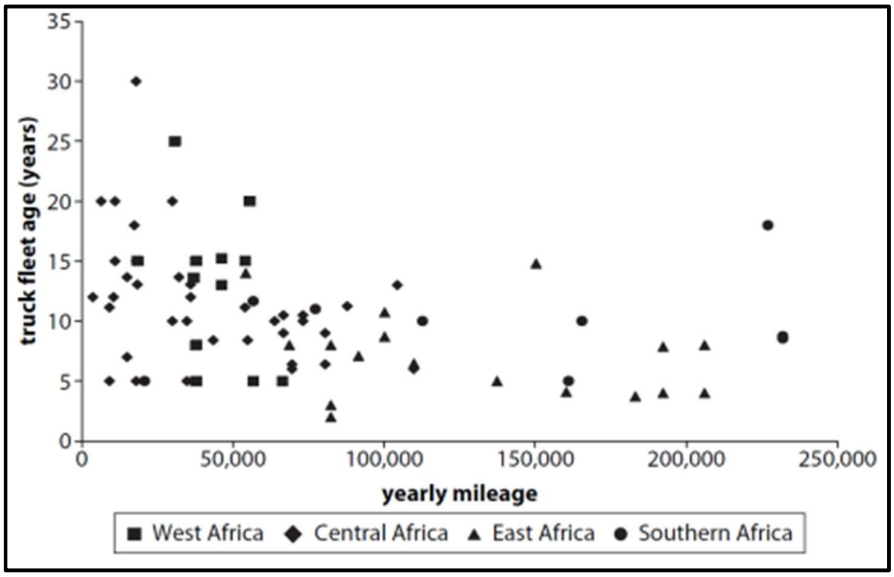

Figure 16: Truck fleet age and yearly mileage (Teravaninthorn and Raballand, 2009)

5.9.4 Current situation in landlocked developing countries

Arvis et al. (2011) highlighted the following issues in border crossings in landlocked developing countries (LLDCs):

> duplication of controls on each side of a border;
> long waiting time and delays;
> inconsistency in procedures;
> fragmentation of brokerage services across borders.

Despite the fact that few traders in LLDCs have access to door-to-door logistics infrastructure developed in advanced economies, the report stated that the transport costs in these countries depends more on operations than on infrastructure capacity. They rely on an extended sequence of operations with many procedures, agencies, and services and all prone to duplicate charges and over-regulation.

LLDCs face multiple clearances, and also when transfer loading from one vehicle or mode of freight to another. In the worst case, all loads must be transferred from a vehicle registered in one county to a vehicle registered in the other. Another system (used in central Asia) allows vehicles to cross a border with a temporary license to import to the transit country. This system requires consistency between the design standards of trucks and the insurance requirements of both countries.

Some transit countries impose quota systems to protect their truck operators. In this system trucks from one country can enter the other by means of a carnet (passport for goods), which only requires demonstration of their registration and insurance certificates. This system is used in 87 countries in Europe, America, Asia, Africa and Oceania. A report by the United Nations (2003) provided case studies of freight and bordering in LLDCs in Asia including Kazakhstan, Uzbekistan, Lao DPR, Mongolia and Nepal.

In response to these challenges, technologies and systems have been developed to facilitate trade via e-border (Arvis et al., 2011). These include:

- Automation of customs documentation is now widespread, with several applications with modules for national transit. For instance, UN Conference on Trade and Development (UNCTAD) have developed transit add-ons to the Automated System for Customs Data (ASYCUDA);
- Interconnection of national customs for a regionally integrated system, such as the NCTS (New Computerised Transit System) in Europe. This allows seamless information exchange to manage documentation and guarantees;
- The carnet barcode in e-TIR helps to validate the carnet at border crossings, and this information is sent into a central database accessible by each participating country. Radio frequency identification (RFID) devices applied to vehicles or trailers also facilitate cargo tracing on a corridor and speed up controls at entry and exit checkpoints;
- Several groups of countries, including some in Africa, have been experimenting with transit data interfaces to transmit information initiated in one country to the next country's border post. Advances in information transfer have immediate benefits in transit facilitation;
- GPS tracking of goods helps rebuild confidence between customs and transit operators, leading to the disuse of unfriendly control solutions, such as convoys. Currently, several suppliers recommend electronic devices to customs authorities.

5.9.5 Current situation in Europe

Road freight transport statistics Eurostat (2017) presents the main trends in road freight transport in the European Union (EU). The analysis is carried out for national, international, cross-trade as well as cabotage transport. Road freight transport by goods type and distance classes are also presented, as well as good movements on countries' territories and country-to-country flows. The new Annex 9 of the UNECE (United Nations Economic Commission for Europe) International Convention on the Harmonization of Frontier Controls of Goods (commonly known as the UNECE Harmonization Convention) came into force in November 2011. This annex is expected to streamline railway border crossing procedures. It deals with rail transport and facilitation of rail border crossings and controls of goods through reduction, harmonisation and coordination of procedures and paperwork. This will be done by:

- introduction of minimum requirements for border (interchange) stations;
- cooperation at these stations;
- moving controls from borders to stations of departure or destination;
- reduction in the time required for controls;
- elimination of paper documents;
- use of uniform rules on Contract for International Carriage Good by Rail (CIM);
- agreement on International Freight Traffic by Rail (SMGS) common consignment note as customs documents.

According to Gregory (2009) in a document published by the London Institute for Public Policy Research, the UK border strategy since 2007 has been to carry out border controls as much as possible in other countries. The strategy also aims to improve the integrity of border control documents using, for example, biometrics, and making better use of data, such as a border management tool by means of the e-Borders programme. The UK border strategy is based on a risk management process. The key risk areas include losses through tax evasion at borders, and organised international crime, such as drug trafficking.

Technology is required to minimise post-Brexit disruption to trade with Europe and to create soft borders with minimal extra infrastructure. This will replace the current IT system, CHIEF (Customs Handling of Import and Export Freight), with a new customs declaration service (Andrews, 2018).

There are two components to well-functioning logistics: committed and effective transport and customs authorities; and competitive logistics services.

According to Ojala et al. (2008), developments in East Asia and other developing countries have been similar to those in Western Europe over the last 20 years. The Organisation for Security and Co-operation in Europe (OSCE) under the United Nations (2012) has published a handbook of the best practices at border crossings.

5.9.6 Alternative modes for freight

Costs of cargo transport are lower by rail than by road. Rail offers stable transport timing and planning, higher speed, volume capacity. Rail cargo does not incur toll road payments, and reduces structural wear to roads, and accidents and bottlenecks on the road network. Compared to road transport, rail cargo has the environmental advantages of reducing energy consumption by 70%, CO_2 emissions by 75% and NOx by 95%.

However, even in the best cargo performing countries, such as Germany, road freight volumes are higher than rail cargo. The volume of road cargo transport increased by 5.4 fold between 1980 and 2010, while rail cargo increased by only 1.6 times during the same period (Cargo Beamer Ltd, 2016).

Ke et al. (2015) applied various regression methods to examine the key factors in the transport mode decision. Results showed that industry characteristics have an impact on the transport modal mix in global supply chains. For instance, manufacturing industries use more airfreight and less sea freight when faced with sales increases, high monthly demand variation, and increased competition.

For low-value bulk products, such as grains and minerals, rail transport is substantially lower in cost than road transport. However, the poor condition of rail infrastructure in many developing countries makes rail unattractive, further reinforcing the decline in railway finance and activity. According to Arvis et al. (2011), rail border crossings trigger complex processes and procedures including:

> changes of locomotive and crew;
> break-of-gauge operations;
> classifying and separating railcars;
> physical inspections of goods;
> transfer and acceptance of documents on rolling stock and freight.

Arvis et al. (2011) also concluded that railways would find it difficult to compete with road freight under the following two thresholds:

> Traffic volume - rail services are unlikely to be maintained when freight volume is less than 250,000 tonnes per year in the short term, and less than 1 million tonnes per year in the long term;
> Transport distance - rail transport has high terminal costs. The minimum distance threshold to offset these terminal costs from their lower costs per km distance is 400 to 500 km.

The availability of rail and water transport connections is summarised in Table 10.

Table 10: Landlocked LICs with rail and water transport connections (Arvis, et al., 2011)

Region	*Rail*	*River, Sea, or Lake*	*Both rail and water*	*Neither rail nor water*
Sub-Saharan Africa	Botswana Burkina Faso Ethiopia Lesotho Malawi Mali Swaziland Zambia Zimbabwe	Central African Republic	Burundi Uganda	Chad Rwanda Niger
South America			Plurinational State of Bolivia Paraguay	
Central Asia	Kyrgyz Rep. Tajikistan Uzbekistan		Azerbaijan Kazakhstan Turkmenistan	
East Asia	Mongolia		Lao PDR	
South Asia	Nepal			Afghanistan Bhutan
Eastern Europe	Armenia			
Totals	**15**	**1**	**8**	**5**

Arvis et al. (2011) reviewed the performance of railways in trade corridors in three world regions: Sub-Saharan Africa; South America; and Central Asia. Teravaninthorn and Raballand (2009) stated that there is competition between rail and road transport, and rail competition plays a role in price setting for heavy bulk commodities in Central and East Africa.

However, absence of rail services on the main international corridors creates opportunities for truck operators to inflate prices.

EU legislation that entered into force in January 2011 requires an entry summary declaration (ENS) to be lodged electronically before the arrival of goods in the customs territory, or before loading containerised cargo in deep-sea traffic. The deadline for lodging the ENS varies according to the mode and is summarised by the United Nations (2012) as follows:

> containerised maritime cargo (except short sea shipping) - at least 24 hours before commencement of loading in each foreign port;
> bulk maritime cargo (except short sea shipping) - at least 4 hours before arrival at the first port in the customs territory;
> short sea shipping - at least 2 hours before arrival at the first port in the customs territory.
> rail and inland waterways - at least 2 hours before arrival at the Customs office of entry in the Customs territory;
> road traffic - at least 1 hour before arrival at the Customs office of entry in the Customs territory.
> combined transport - the deadline for the transport mode that enters the customs territory, for example, a truck on a ferry in short sea traffic, is at least 2 hours before the ferry's arrival at the first port in the customs territory.

In summary, rail is a less costly and more reliable mode than road for freight. In general, the cycle of declining demand, service quality, and financial success has to be broken. Where freight volume or

distance is below the threshold, public financial support for infrastructure costs is needed for rail freight, possibly justified on the basis of providing a viable alternative mode or route. Waterways is another low-cost transport corridor for low-value bulk commodities. Air transport serves a niche market for perishable commodities or high-unit-value products. One of the advantages of air freight is that it eliminates land transit to reach international markets. Intermodal transport, including road, rail, inland water and maritime, can maximise infrastructure use, and make best use of each mode efficiently and sustainably.

In a well-organised and well-managed logistics environment, with functional cross-border ICT systems and interconnections between agencies, a shipment can be followed physically and administratively from point of origin to destination. The location of the clearance point is irrelevant because clearing would be done on the data available before departure and duty paid at some point in the transport chain. This approach is recommended by the World Customs Organization (WCO). Under such arrangements, stops at the border and the point of destination can be minimised for most shipments.

The United Nations (2003; 2012), GIZ (2010), Whiteing (2017) and Hanaoka et al. (2018) have identified the following measures for efficient border control of freight:

> Reduce time required for import and export procedures, notably customs procedures where fully paperless systems (e-border) can be implemented, thus reducing complicated, non-standard documentations;
> Formulate a coherent integrated intermodal transport strategy to enhance freight movements between ports and hinterlands, particularly for SMEs and others requiring effective freight consolidation services. This involves coordination between multiple transport modes, together with a strategy for dry ports (inland freight depots), free industrial zones, inland customs clearance arrangements and bonded facilities;
> Invest in transport infrastructure and consider alternative funding opportunities, such as developer contributions and public-private partnership arrangements. Give priority to development of coastal and river transport for domestic freight and as feeders to longer distance international maritime services. Ensure consistent technical standards for transport infrastructure along the main corridor;
> Develop ICT infrastructure and smart border control measures, such as non-intrusive inspection with enabling software packages and systems. Computerised data for border procedures (preferably captured automatically) require consistent procedures and better controlled inland clearance;
> Remove restrictive regulations (such as, on road transport of containers), and accelerate changes to the inconsistent regime of arrangements for liability for freight on different transport modes;
> Introduce requirements for employment of competent, professionally certified personnel in all freight transport operations as part of a reformed, more quality-based freight regulatory regime. Reduce skills shortage and unofficial payment;
> Simulate stakeholder interactions corresponding to corridor choice for transit cargo transport in landlocked countries under the competitive circumstances. Understand stakeholder interests and roles (literature review and survey), and how transport network changes corresponding to stakeholder decisions (modelling). This also applies to sustainable urban freight;
> Promote competition in transit transport services, empower transport service providers to offer services in the territory of their transit neighbours, especially for carriage of goods in transit to or from their own countries. Limited competition between operators, transport modes and routes may result in inefficient pricing policies and services.

5.10 Cross-border road and rail freight

Reducing time and time uncertainty at borders for road and rail freight will facilitate international trade for LICs. This can in turn increase investment, open new commercial opportunities and access to new materials, reduce the cost of inputs, and improve the competitiveness of domestic companies.

As well as the macroeconomic outlook, the extent to which these potential benefits can be realised depends largely on how freight operators respond to reductions in time and time uncertainty at borders. This also depends on the extent to which such improvements reduce costs for freight operators.

5.10.1 Value of time and other journey attributes

The value of time reduction at a border can be calculated by multiplying the time reduction by the rate which freight operator value that time. The value of time (VOT) and value of reliability (VOR) from the perspective of freight operators needs to be known. While many studies have estimated road user VOT/VOR, few studies have focused on VOT/VOR for freight, particularly in LICs.

In an overview of methods used, de Jong (2007) distinguished factor cost methods and modelling approaches. Factor cost methods add up the monetary costs of factors used, such as labour and fuel costs. Modelling approaches employ revealed preference (RP) based largely on analysis of the impact of mode characteristics on mode choices, or stated preference (SP) that uses survey methods to estimate VOT/VOR.

Based on a SP study, using survey data on Australian road freight shippers, Wigan et al. (2000) found that the road freight value of time is substantial. Another analysis of mode choice based on a SP survey of Australian freight shippers also suggested substantial VOR (Brooks et al., 2012). Kurri et al. (2000) in a SP survey of transport managers in Finnish manufacturing companies found reliability was considered to be more important than transport time. The authors derived per-ton-per-km VOT estimates for road and rail freight. Similarly, Bergantino and Bolis (2004; 2008) have suggested that service frequency and reliability are more important than journey time in the choice between land and ro-ro freight.

A SP study of Belgian freight shippers using various transport modes found the determining factors of mode choice were time, reliability, and flexibility (Beuthe and Bouffioux, 2008). Feo et al. (2011) used a SP survey to analyse modal choice of Spanish forwarders and found a substantial effect of increasing service frequency on willingness to switch to maritime multimodal freight from road freight. Interviews with freight stakeholders in the USA identified reliability as a key factor in determining model choice, and in some cases, more important than speed (Hillestad et al., 2009).

Two studies using SP surveys of freight shippers in the Netherlands also estimated VOT and VOR (de Jong, 2009; 2014). The transport mode choice was analysed of 27 firms in the Ticino region of Switzerland by Masiero and Hensher (2010). They looked at the impact of accounting for asymmetric preferences, i.e. loss aversion. This is the idea that willingness to accept (WTA) values – relating to compensation for late delivery) is higher than willingness-to-pay (WTP) for shorter journey times. The authors found that allowing for such asymmetry improves model fit.

Similarly, Danielis and Marcucci (2007) in their analysis of a SP survey of Italian manufacturers proposed introducing non-linearities at 'cut-off' points suggested by respondents. Jin and Shams (2016) provided VOT and VOR estimates based on a SP survey of different groups – shippers, carriers, and forwarders - in Florida. They found evidence of heterogeneity of these groups, and of higher VOT and VOR estimates for perishable than non-perishable goods. Bergkvist (2001) analysed SP data from Swedish companies and emphasised the need to account for heterogeneity across regions and industries. A SP study of Californian truck operators likewise indicated heterogeneity in VOT across firm types, shipment sizes, and methods of driver compensation (Kawamura, 2000).

A recurring finding is that reliability in journey time is important to freight shippers, and possibly more important than journey time itself. Fowkes et al. (2004) presented further evidence from a SP survey of UK freight users. They discussed possible reasons from the demand and supply sides. Reasons on the demand side include the use of just-in-time manufacturing methods that require reliable delivery times,

strict deadlines for port arrivals, and narrow windows for delivery in hub-and-spoke networks. Reasons on the supply side concern efficiency, such as use of drivers' working hours, efficiency in warehousing, and in capacity utilisation. Summaries of VOT and VOR findings for rail and road freight, and overviews of methods used are provided by Feo-Valero et al. (2011), de Jong (2014), and Zamparini and Reggiani (2007; 2010; 2016).

5.10.2 Value of travel time in LICs

Results regarding freight operators in HICs are relevant to the extent that reductions in border time and reliability may help to increase trade in LICs with HICs, which may be beneficial for development. Nevertheless, VOT and VOR may be different in developing countries where needs and priorities differ. As previously mentioned, less research has been done on freight VOT and VOR in LICs. A study of VOT in developing countries for the Department for International Development (DFID) covered Bangladesh, and focused on passenger transport rather than freight (IT Transport Ltd, 2002).

Shinghal and Fowkes (2002) used a SP survey of companies in different industries in India sending freight via the Delhi-Bombay corridor. They found frequency of service and journey time were important, and reliability of transit times particularly important for exporters. This latter point highlights the potential benefits of time reductions at borders for international trade. Similarly, Larranaga et al. (2017) found that reliability and cost were the key factors in freight mode choice in Rio Grande do Sul, Brazil.

Norojono and Young (2003) used a SP survey to analyse mode choice of freight shippers in Indonesia, and concluded that safety and reliability are more important than travel time in the choice between rail and road freight. Similar findings were presented by Arunotayanun and Polak (2011), who used the same data to explore the use of latent class specifications, and found a substantial degree of heterogeneity in preferences.

However, a SP survey by Zamparini et al. (2011) found reliability and flexibility were the least important service attributes for logistics managers in 24 companies in Tanzania. Transit time and the monetary value of damage and losses are more important in terms of WTP and willingness to accept (WTA). The authors pointed out that this may reflect the challenges facing freight transport in Tanzania, where transport infrastructure is of low quality compared to other Sub-Saharan African countries, leading to slow freight movement and high rates of damage and losses.

A RP study using freight transport data in Nigeria found that VOT and VOR – reliability captured by the standard deviation of journey times – varied between shippers of consumer goods and shippers of capital goods (Ogwude, 1993). An analysis of road, rail, and pipeline freight traffic in Kenya derived RP VOT estimates and found modal choice to be sensitive to cost and delivery speed (Cundill, 1986). Analysing commercial vehicle operations in Malaysia, Thomas (1983) found that journey time savings due to road improvements resulted in relatively small increases in vehicle utilisation because of other constraints. Thomas (1983) also found that the VOT benefits consisted of an increase in driver non-working time.

In contrast, an analysis of freight operations in Pakistan by Hine (1991) found elasticities ranging between -0.84 and -1.00 with a mean value of -0.94, between trips made per day and working time per trip (including travelling time, and loading and unloading). The analysis suggested that with the wide spread of journey distances, time savings after road improvements are likely to translate into extra trips and that total working time per day (including travel time, and loading and unloading) remains broadly constant.

Easing border issues for freight transport is a particular concern for LLDCs. As of 2019, the United Nations Conference on Trade and Development (UNCTAD) identified 32 LLDCs - 16 in Africa, 12 in Asia, two in Latin America, and two in Central and Eastern Europe. For these countries, maritime transport of

international freight is not an option. This has been a major impediment to development for LLDCs, which face bottlenecks not only at the seaport, but at each transit country (Faye et al., 2004).

Of particular relevance is a SP study by Zhang et al. (2011) on VOT for rail freight from Tianjin Port in China to Ulan Bator, the capital of Mongolia. The results of a preliminary survey of freight forwarding companies highlight the scale of the problem for Mongolia. Compared to an average passenger journey time of 32 hours, the average rail freight journey time was 13.1 days including 4.3 days waiting at Tianjin Port, 3.8 days travelling from Tianjin to the Mongolian border, 1.2 days waiting at the border, and 3.8 days from the border to Ulan Bator. The authors described the route of great importance to landlocked Mongolia because it is the shortest and most commonly used route to the nearest seaport. Border issues derive from the need for transhipment from either road to rail (rail is the only transport mode from the border to Ulan Bator), or from the standard gauge railway in China to the broad gauge railways in Mongolia.

Banomyong and Beresford (2001) compared the time, distance, and estimated costs of various routes available to garment exporters from Laos PDR, another landlocked country. They found that the preferred route (based on estimated cost and time) via Malaysia was not the same as the most frequently used route via Thailand.

5.10.3 Border impacts on freight flows and trade

Studies have examined the impact on USA-Canada and USA-Mexico road freight of tighter border security measures after the 11 September attacks in 2001. Anderson (2012) documented downturns in USA-Ontario truck crossings – already suffering bottlenecks because of the small number of road links – in the years after 2001. The author attributed these downturns partly to enhanced security measures. Truck inspection times at the border increased by about 25% from mid-2001 to mid-2003 (Taylor et al., 2004). A similar conclusion was reached in the USA-Mexico road freight analysis by Walke and Fullerton (2014). Using a computable general equilibrium (CGE) model, Roberts et al. (2014) estimated the macroeconomic impacts of waiting times at USA points of entry. The authors found that reduced waiting times would improve USA gross domestic product (GDP), employment, and balance of trade. Hummels and Schaur (2013) used data on import revenues, prices, shipping costs, and shipping times broken down by country of origin, mode (air or sea freight), and destination port to model exporter choices between air and sea freight. They estimated that the impact of a day in transit is equivalent to that of an ad-valorem tariff of 0.6 to 2.1%.

In a similar application using data on landlocked Sub-Saharan African countries, Christ and Ferrantino (2011) concluded implied time costs generally exceed the monetary costs of trucking. They suggested this contributed to explaining why the comparative advantages of these countries lie mainly in primary commodities, such as metals and high-value agricultural products, while hindering the export of time-sensitive goods.

These studies looked directly at the impact of increased wait times on cross-border freight, rather than estimated VOT/VOR and related measures to estimate the impact of changes in time or reliability on freight transport choices. Similar studies on LICs were not identified, but the USA case is of interest for lessons applicable to LICs.

5.11 Conclusions

The literature has been reviewed on a wide range of topics relating to road and rail transport services in LICs has covered topics, from franchising and concessioning, to various aspects of safety and economic regulation, to waiting times for border transit. The review makes clear that LICs face considerable

challenges in these areas, and that resolving these challenges is important to their development. Based on this review, we have identified a need for further research into the following:

- feasibility and suitability of concessioning and franchising as service delivery methods for road and rail infrastructure, and the optimal design of such contracts, for LICs;
- specific needs of economic and safety regulators in LICs, and the appropriateness of certain forms of regulation;
- best approaches to improving to road safety in LICs, through increasing penalties, improving enforcement, anti-corruption drives, education, and other measures;
- driver hours in road freight in LICs, including laws, technology, and enforcement in various countries, enforcement, the prevalence of exceeding limits, and the effects of this on infrastructure and road safety;
- cost-effectiveness of different technologies for monitoring truck overloading in the LIC context – fixed versus mobile weighbridges, weigh in motion, on board weighing systems, and the effect of overloading on safety and infrastructure in LICs;
- possible technologies, agreements, and other measures to reduce waiting times at borders, and their appropriateness to LICs;
- empirical research on the impacts of border waiting times and uncertainty on LIC economies.

6 Literature Review: HVT Corridors and Networks

HVT corridors and networks comprise arterial and main roads and railways that form the national transport backbone that connects the smaller feeder road and rail links. HVT networks carry the major share of passenger and freight traffic and play a major role in economic and social development. Thus, investments in HVT corridors and networks must also have a substantial impact on economic and social development.

To meet growing demand for transport infrastructure and services, governments in developing countries undertake major road, rail and port projects to build and upgrade transport networks to improve domestic and cross-border connectivity. Infrastructure investments need to be planned in conjunction with trade and economic development, and are often manifest in corridor-based development.

Transport corridors enable spatial organisation of economic activities because they bring together infrastructure, facilities, institutions, and investments to generate economic growth (ADB, 2014; Brunner, 2013). Corridor-based developments are estimated to bring substantial benefits (Hahm and Raihan, 2018; Edmonds and Fujimura, 2006), and are gaining traction as many governments try to boost productivity and local economic activities.

6.1 Development impacts

This review discusses the impacts of HVT projects and networks - road and rail - have on economic and social development. Studies reviewed have been carried out in South Asia and Sub-Saharan Africa and include several studies in the neighbouring regions of South-east Asia and Central Asia.

Numerous empirical studies have shown that HVT corridors and networks bring substantial economic and social benefits to the local and surrounding areas (for example, Blankespoor et al., 2018; Gachassin et al., 2015; Ghani et al., 2016; Hlotywa and Ndaguba, 2017). Transport networks and corridors contribute to reducing trade costs and interregional price gaps, and stimulate interregional trade, investment and land value. Evidence from empirical studies suggests that investment in regional transport infrastructure holds great promise for developing countries of Asia and Sub-Saharan Africa (Zhai, 2012; Bosker and Garretsen, 2012).

HVT networks and especially roads, benefit rural areas by increasing incomes and agricultural productivity, reducing poverty and providing better access to facilities and services (AITD, 2011). HVT networks can stimulate structural transformation from traditional subsistence farming to commercial agriculture and to non-farm activities (ADB et al., 2018; Mahmud and Sawada, 2018).

6.2 Evaluation methods and techniques

Methods used to assess economic impacts of transport projects are evolving. Traditionally, methods focused on the economic benefits in terms of time and cost savings for passengers and transport service providers, and on direct or intermediate outcomes, for instance, the framework of conventional cost benefit analysis (CBA).

Analytical tools and models have been developed to gain insights into the development impacts of transport networks on different groups and locations, labour market expansion, global trade growth, and economic development.

This broader view is essential in considering transport projects that contribute to network connectivity, and activities of supply and distribution centres, intermodal terminals and international gateway facilities.

A wide range of econometric and other models and techniques have been used to study the development impacts of transport impacts including:

> gravity models;
> Multi-regional Input Output (MRIO) Analysis;
> simulations based on Computable General Equilibrium (CGE) models;
> other econometric/statistical techniques.

Some studies (e.g., Roberts, et al., 2018) have considered the direct (intermediate outcomes) and long-term indirect (economic benefit outcomes) effects. Direct effects are observed in terms of increased mobility, reduced travel time, and asset value, and long-term indirect effects in terms of changes due to economy-wide dynamic processes activated by the direct effects.

6.3 Socio economic benefits

A number of studies have provided evidence of the substantial economic and social benefits of transport projects (for example, ADB et al., 2018; Ghani et al., 2016). Estimates from multiple studies have suggested cumulative gains ranging from less than 1% to more than 10% of GDP (ADB, 2007; Anas et al., 2015; Gilbert and Banik, 2010; UNESCAP, 2012). The variation in estimates and other findings in different studies are thought to be due mainly to differences in characteristics of individual studies, difference in context and, different phenomena measured (Deng, 2013).

A review of 78 studies including 18 studies in Africa (from six countries, namely Cameroon, DRC Congo, Egypt, Ethiopia, Nigeria, Tanzania, and Uganda); and six regional studies) provides evidence of the substantial economic and social benefits of transport projects (Roberts et al., 2018). Meta-analysis of the results has revealed statistically significant benefits of transport networks to real and nominal income, consumption, gender, education and job creation. However, Roberts et al. (2018) did not provide the actual values reported in the studies reviewed. HVT corridor development projects may bring very high rate of GDP growth near the corridor. A study by ADB et al. (2018) found that inclusion of complementary reforms in a corridor intervention package could increase the GDP of the host country by 9.3 to 12.4 percentage points near a new or upgraded corridor.

Simulation-based estimates have demonstrated transport infrastructure and services make a substantial contribution to GDP in the long term (Hahm and Raihan, 2018; UNESCAP, 2012; Zhai, 2012; Stone and Strutt, 2009; Gilbert and Banik, 2010; Francois and Wignaraja, 2008). In general, the contribution well exceeds the cost of service provision. However, direct comparison of the estimates is not possible because the same units of measurement were not used in all studies. The models used and contexts also varied.

Hahm and Raihan (2018) used a Computable General Equilibrium (CGE) model to estimate the potential economic benefits of the six Belt and Road Initiative (BRI) economic corridors. Using China as the analytical base for the comparison, the study found economic benefits for China and all countries along the six BRI economic corridors, which include countries in South Asia - Bangladesh, India and Pakistan.

The estimated percentage increase in real GDP for three BRI countries in South Asia were 7% in Bangladesh, 4% in Pakistan, about 3% in India, and about 6% in Myanmar, a South Asia neighbour. For landlocked countries' (Kazakhstan, Kyrgyzstan, Lao PDR, Mongolia, Tajikistan, Turkmenistan, and

Uzbekistan) estimates vary between 5 and 10% of GDP. However, some other low-income countries, such as Cambodia, may also experience growth in GDP of more than 10%.

A UNESCAP (2012) study used a CGE model to assess the development impacts of three Asian Highway routes from Kunming, China through Southeast Asia to South Asia. The results showed that, although most country regions would remain unaffected, some regions would have substantial gains in GDP of about 2.2 to 2.8 %. For other regions, the average losses would be small at about 0.3 to 0.4% in GDP.

Zhai (2012) investigated the social impacts of regional transport infrastructure in developing countries in Asia. The quantitative analysis has suggested that with the required annual investment, the estimated total social benefits would be about 10% of projected GDP in 2020.

Gilbert and Banik (2010) estimated the impacts of South Asia Sub-regional Economic Cooperation (SASEC) and of SASEC transport infrastructure to connect Bangladesh, Bhutan, north-eastern India, and Nepal. The simulation study indicated that the cumulative impacts as percentage of GDP would vary between 0.7% and 14% (India 0.7%, Pakistan 2.7%, Bangladesh, Sri Lanka 4.6% and Nepal 14.8%). In absolute value, the gain to India was highest (USD 4,330.3m) followed by Pakistan (USD 2,600.8 million), Bangladesh (USD 2,295.1 million) Sri Lanka (USD 933.8 million); and Nepal (USD 2,057.1 million).

Similar potential gains from increased sub-regional infrastructure investments were found in other studies. Stone and Strutt (2009) valued social impacts at USD 8.1 billion, resulting from moderate improvements to road infrastructure and trade facilitation in the Greater Mekong Subregion (GMS).

A major transport infrastructure project can have similar impacts on regional GDP. Anas et al. (2015) used an Input-Output model to examine the impacts of a major toll way in West Java, Indonesia. Freight costs were found to decrease by 17% and GDP in Bandung District to increase by 1.2%.

Pradhan and Bagchi (2013) examined the effect of road and rail infrastructure investment on economic growth in India in the period 1970-2010. Using a Vector Error Correction Model (VECM), they found bidirectional causality between road transport investment and economic growth, and unidirectional causality between rail investment and economic growth. Causality was found to be bidirectional between road transport and net increase in physical assets, and unidirectional between rail transport and net increase in physical assets. Considering the findings, they suggested that expansion of transport infrastructure (road and rail) along with net increase in physical assets can lead to substantial economic growth.

Hlotywa and Ndaguba (2017) assessed the impact of road infrastructure investment on economic development in South Africa. The study used time series, econometric models cointegration and vector error correction model (VECM). The results demonstrate that road transport investment variables account for approximately 86.7% of variation in economic development in South Africa. The study also examined the macroeconomic impact of labour-based road construction in undeveloped rural areas. Input-output analysis of 11 projects found that the GDP multiplier ranges between 1.34 and 1.53 (average 1.45).

Hong et al. (2011) examined the link between transport infrastructure investment and regional economic growth, using a panel data model with data for 31 Chinese provinces for the period 1998-2007. Transport infrastructure was shown to play an important role in economic growth, and road infrastructure contributed more to economic growth in locations with poor roads. Investment in water transport infrastructure was found to contribute only after the investment exceeded a threshold level. A retrospective analysis showed that uneven distribution of transport infrastructure is an important reason for disparities between regions.

Using cross-country analysis of 60 countries for the period 1980-2010, Ng et al. (2017) compared improvement in road mobility and accessibility and economic growth. Road mobility is to do with the interruption of travel on a road due to junctions. Higher order roads, such as motorways and freeways, have a limited number of junctions enabling relatively uninterrupted travel and thus have high mobility. Accessible roads such as local roads have many junctions but provide a direct route to a destination. Their study found that in countries of medium and high level development, improved road mobility facilitated export-led growth. This indicates that promotion of exports needs to be implemented in conjunction with expansion of high-mobility road networks to enhance economic growth. The researchers also suggested that improved road mobility is required to meet demand for long-distance travel, and more investment is required to build roads of higher accessibility in countries of low-level development.

6.4 Trade and investment

Several studies provide evidence that HVT network development and/or improvement can reduce transport costs which in turn increases trade along the improved network (ADB et al., 2018; Edmonds and Fujimura, 2006; Hahm and Raihan, 2018; Papriev and Sodikov, 2008; Warr et al., 2010).

Intercountry transport corridors can increase cross-country trade volumes. Hahm and Raihan (2018) showed that all countries in BRI would increase exports. For example, the increase for Bangladesh, India, and Myanmar would be 3 to 7% and for Pakistan 14%. Several other countries would also experience high increase in exports. Exports of agricultural commodities would increase more than manufactured products. The export increase of agricultural commodities from poorer countries, such as Bangladesh, Cambodia, Lao PDR and Myanmar, could contribute to poverty reduction.

Hahm and Raihan (2018) also suggested that increase in imports would be higher than exports. For example, the import increase in Bangladesh, India, and Myanmar would be about 8 to 14% (compared to 3 to 7% export increase) and for Pakistan 14% (same as imports), and for some countries well above 15%. The researchers noted that this would lead to deterioration in the trade balance in most countries and would pose a risk for the overall balance of payments, which in turn could adversely affect economic growth.

As demonstrated by increase in road and rail traffic volumes, rehabilitation and improvement of the Maputo corridor in Southern Africa has boosted transit trade flows and bilateral trade between South Africa and Mozambique. The Maputo corridor has led to more than USD 5 billion in investment, and 15,000 jobs in the construction and operation of transport, logistics, energy, and industrial ventures along the corridor (ADB et al., 2018).

The NH-5 corridor in Vietnam has attracted investment and created jobs (ADB et al., 2018). In 2006, 83,453 and 134,846 jobs were generated along the corridor in the provinces Hung Yen and Hai Duong, respectively.

Freund and Rocha (2011) investigated the effects of different components of trade time on export in Sub-Saharan Africa. They found that the total effect of inland transit was nearly four times as large as the effect of the other components of time. The results imply that a one day increase in transit time leads to a nearly 7% decline in exports. Another study (Buys et al, 2010) investigated the economics of upgrading a primary road network that connects the major urban areas in Sub-Saharan Africa. Simulation results of the study indicated that upgrading has the potential to increase overland trade between countries in Sub-Saharan Africa by about USD 250 billion over 15 years. The upgrading programme would require an estimated USD 20 billion for initial upgrading and USD 1 billion annually for maintenance.

Another empirical study by Bosker and Garretsen (2012) also suggested that market access matters for economic development. The study showed improving market access for Sub-Saharan Africa (e.g., by

investing in intra-continent infrastructure or through increased continental integration) will have substantial positive effects on future economic development.

Papriev and Sodikov (2008) used the gravity model to evaluate overland trade expansion in 28 countries resulting from improvement to the Asian highway network. The study has indicated that the highway network offers major potential for overland trade expansion. A regression-based cost model estimated that USD 6.5 billion investment would be required to upgrade and improve the road surface condition. One scenario of improving road quality indices up to 50 suggests that total intra-regional trade would increase by about 20 % or USD 48.7 billion annually. In the second scenario of improving road quality indices up to 75, a predicted increase of about 35% or USD 89.5 billion annually.

A gravity model-based study of the Greater Mekong Sub-region by Edmonds and Fujimura (2006) suggested that cross-border road infrastructure has had a positive impact on intraregional trade in major commodities, with elasticity in the range of 0.6 to 1.4.

Warr et al. (2010) used a general equilibrium model to estimate the regional economic impacts of the Second Mekong International Bridge over the Mekong River between Thailand and Lao PDR. The bridge was completed in 2006. The study found interregional transport costs reduced from 6.52 to 2.36% of final sales, representing an absolute reduction of 4.16% of total sales. These results suggest that in the short term, transport cost reductions consistent with improvement in interregional transport infrastructure produce a modest increase in trade volumes in both directions and some reduction in poverty. However, over a longer period, the economic benefits, including poverty reduction, are larger and are substantial in the border regions of both countries.

Similar effects on growth in trade has also been observed in a study in Eastern Europe. To assess externalities related to regional transport infrastructure, Shepherd and Wilson (2007) used detailed data from the original road network database. Their gravity model simulations for countries in Eastern Europe suggested that an ambitious but feasible road upgrade could increase trade by 50% above baseline, which exceeded expected gains from tariff reductions or trade facilitation programmes of comparable scope. The study also found that large cross-country spill overs due to overland transit. Total intraregional trade could be increased by 30% by upgrading roads in three countries - Albania, Hungary and Romania.

6.5 Rural economy, poverty reduction and social impacts

Roberts et al. (2018) found that substantial impacts on poverty reduction. Similar development outcomes from a simulation study of corridor transport in Bangladesh were reported by ADB et al. (2018). Some studies also found that people in rural areas benefit from major roads, and strategic transport infrastructure, such as a major bridge (AITD, 2011; Blankespoor et al., 2018).

Four studies provide evidence of transport networks having positive social impacts on rural people through poverty reduction and increased employment in non-farm activities (ADB et al., 2018; Blankespoor, et al., 2018a; Neupane and Calkins, 2012; AITD, 2011). Two of these studies (AITD, 2011; ADB et al., 2018) found a structural shift in the rural economy in terms of increase in non-farm activities and more employment.

The NH-5 Highway corridor in Vietnam has had positive impacts in the corridor region and the whole country (ADB et al., 2018). In the period 1995-2000, GDP per capita grew by 6.1% in the region compared to the national average of 5.7%. The number of households in poverty dropped by 35%. Cities closer to and further away from NH-5 experienced higher income growth per capita and more rapid poverty reduction than the rest of the country. The poverty rate in Vietnam as a whole reduced by 27% during this period as a result of broader spill overs from NH-5 to other regions (ADB et al., 2018).

An empirical study by Blankespoor, et al. (2018a) investigated the impact of the Jamuna Bridge in Bangladesh, strategic infrastructure on the national highway network. They found that cropping intensity increased by 3%, and in the area using chemical fertilizer by 7%. The large reduction in transport costs (about 50%) due to the bridge has led to agricultural development in the newly connected hinterland as a result of technology adoption and better match of land to crops. The long-term estimate (2005-2013) was positive and statistically significant, with increase in rice yield of 5.2%.

A study in Ethiopia found the spatial limitations of impacts increased with increasing distance from the road (Minten et al., 2013). The study found that increasing transaction and transport costs over a 35 km distance, along a route mainly accessible to foot only, led to a 50% increase in fertilizer price and to a 75% reduction in its use. Farmers who live about 10 km from the distribution centre face per unit, transaction and transport costs as high as the cost to bring the fertilizer from the international port to the input distribution centre (about 1,000 km). The study concluded that "tackling the last mile(s) costs should be a priority."

A study by Omamo (1998) in Kenya showed that improved rural road networks that reduce transport costs could decrease motivation of small farmers to meet food needs through domestic production and promote specialisation that raises farm incomes.

Neupane and Calkins (2012) examined poverty and income inequality in Southern Thailand along the Asia highway network route (AH18) in Songkhla province. They used descriptive statistics and a one-way ANOVA method that included poverty and income inequality indices to analyse the household survey data. The analysis showed the average household income varied with location. Poverty was lower along the Asia Highway route.

The impacts of a major National Highway (NH2) of 995 km across three states in India were analysed (AITD, 2011). Compared with the baseline survey, literacy increased by 6%, female literacy by 12%, school enrolment by 7%, female school children by 12%, and population using medical facilities by 7%. Improvements were observed in women's participation in the labour force (9% increase), employment in non-agricultural activities (7% increase), and increase in annual (deflated) per capita income by INR 243.

6.6 Equity and inclusive development

Roberts et al. (2018) found transport networks had a beneficial effect on social inclusion in terms of education and gender in most of the studies reviewed. About 75% of studies showed benefits of spatial distribution in terms of equity.

A major empirical study using archival data investigated the impact of India's vast colonial railway network (Donaldson, 2018). He found "Railroads reduced the cost of trading, reduced interregional price gaps, and increased trade volumes". He also found that "When the railroad network was extended to the average district, real agricultural income in that district rose by approximately 16 percent".

The findings of Chen and Haynes (2017) have confirmed that the high-speed railway network in China has contributed to decreasing regional economic disparity and promoted regional economic convergence.

6.7 Employment

The review by Roberts et al. (2018) found that roads have a beneficial effect on social inclusion in terms of job creation. More jobs especially in non-farm activities and greater participation of women in the labour force were also observed in the AITD study (2011).

An ILO study of two states of India (Gujarat and West Bengal) found that infrastructure investment created a substantial number of jobs (Sinha et al., 2015). The study found a 10% increase in the investment in highways and urban roads construction led to 83,401 more workers hired in Gujarat and 178,181 more workers hired in West Bengal. This also led to BDT 13.52 billion growth in Gujarat and BDT 14.05 billion in West Bengal.

Two studies on the Jamuna Bridge in Bangladesh have provided evidence of its impacts on rural employment and job transition patterns (Blankespoor, et al., 2018b; Mahmud and Sawda, 2018), even though these studies used different methodologies.

Blankespoor et al. (2018b) found that besides increasing employment, the bridge construction facilitated a farm to non-farm shift in employment. About 40% of the employment increase in services came from reduction of employment in manufacturing and agriculture sectors. These results suggest a long-term structural change in employment pattern.

The analysis of Mahmud and Sawada (2018) also found that the bridge led to an increase in local employment and facilitated a shift from farm to non-farm in both districts: non-farm employment increased from 6.7 to 14% in one district, and from 8.6 to 16% in the other district.

A shift of production and labour from agriculture was also found in a study in Cameroon (Gachassin et al, 2015). The study found that better road access led to diversification of the economic activities in the most isolated households.

6.8 Location and spatial effects

While the estimated economic and social impacts of HVT corridors and networks are beneficial, there are often negative impacts in some country regions and for some groups.

Dzumbira et al. (2017) found regional differences in development impacts of the Maputo Development Corridor. Economic impacts, access to services, employment opportunities, income levels and access to formal housing in nodes along and near the N4 spine were better than those further away from the corridor.

In China, the National Express Network (NEN) has increased real incomes in nearby prefectures by nearly 4% on average but decreased real wages in many prefectures in the urban and rural sector (Roberts et al., 2018).

Other studies also provide evidence of uneven distribution of the benefits of transport networks (ADB et al., 2018; Chen and Haynes, 2017). This finding has implications for the planning and design of transport projects.

HVT networks can motivate businesses to relocate to areas better served by the network. An empirical study in Uganda found that businesses gain more from being located in areas that offer agglomeration economies, availability of skilled workforce and better infrastructure conditions (Lall et al., 2014). Public infrastructure investments in other locations are likely to attract fewer private investors.

6.9 Negative socio-economic impacts

The road traffic death rate is highest in Africa (26.6/million people) followed by South and South-East Asian countries (20.7/million people). In both regions, the fatality rate has increased compared with 2013. The burden of road traffic injuries and fatalities is disproportionately borne by vulnerable road users and those living in low- and middle-income countries (WHO, 2019). In addition to a public health

problem, road traffic injuries are a development issue. Low- and middle-income countries lose approximately 3% of GDP as a result of road traffic crashes (WHO, 2015).

Roberts et al. (2018) found that transport networks and corridors have a detrimental impact on the environment in terms of deforestation and CO_2 emissions. Laurance et al., (2009) provided evidence effects of road clearings on tropical forests in central Africa and other regions. A highway across the north-western Congo Basin has promoted massive logging, poaching and forest loss.

However, the environmental impacts in some studies should be considered from another perspective, for example, the Delhi-Mumbai dedicated freight corridor (DFC). The alternative to the DFC would have had far more detrimental environment impacts. Pangotra and Shukla (2012) analysed trends in CO_2 emissions and found that annual CO_2 emissions under the business as usual scenario with DFC in 2046 (2.33 million tons) are less than one-fifth of those under the same scenario without DFC (12.32 million tons). Similarly, annual CO_2 emissions under the low carbon scenario with DFC (0.28 million tons) are less than one-eighth than under the same scenario with DFC and less than one-fortieth without DFC.

Hanaoka and Regmi (2011) estimated CO_2 emissions in multimodal freight operation and a total road freight operation. They estimated that multimodal transport reduced CO_2 emissions for 2008-2009 by 57,687 MT.

6.10 Negative impacts of cross-border transport

Cross-border transport infrastructure is also accompanied by a wide range of negative externalities, including:

> negative impacts on local farmers and businesses (Lin and Grundy-Warr, 2012);
> spread of HIV/AIDS and sexually transmitted disease (Günther Slesak et al., 2012; Regondi et al., 2013);
> erosion of social values and cultural identities (Lin and Grundy-Warr, 2012);
> trafficking of vulnerable groups, particularly women and girls (Deane, 2010; Molland, 2010).

As a result, the perceptions of local people in border areas may not always be favourable to cross-border infrastructure (Lin and Grundy-Warr, 2012; Warr, 2010).

Trafficking of women and girls is a serious problem in border areas of countries in South and South-East Asia. Tameshnie Deane (2010) examined cross-border trafficking of women and girls from Nepal to India. This study cited different sources to estimate that 7,000 to 10,000 girls, between the ages of 9 to 16 years are trafficked each month from Nepal to India.

Cross-border transport infrastructure can also have other adverse social impacts on the local people. Günther Slesak et al. (2012) reported alarming HIV rates in ethnic minorities to sexually transmitted diseases (STDs) and HIV/AIDS along a new major intercountry road in south-east Asia. A review by Regondi et al. (2013) found evidence of the spread of HIV/AIDS along the road network in Southern Africa.

Lin and Grundy-Warr (2012) examined the opinions and perceptions of local people about a proposed bridge between Thailand and Lao PDR on a highway connecting Bangkok to Kunming, China. The researchers found local people considered that farmers and businesses would be negatively affected by increasing Chinese presence in the area. This represented a complex mix of problems and opportunities that would play out differently in different sectors, in different countries, and between actors. The researchers concluded that potential ill feelings among the local people could risk future cross-border geopolitical ties and trade.

6.11 Cross-border facilitation

In South Asia, most trade between neighbouring countries takes place along land routes, particularly the road corridors. De (2011) analysed the effects of inefficient facilitation of trade flow and concluded that transaction costs and delays at borders affect trade flows in the same way as tariffs. The econometric evidence strengthens the link between trade costs and trade flows. The higher the transaction costs, the less trade between partners in neighbouring countries. A 10% drop in transaction costs at borders increases exports by about 2%.

Intercountry trade in goods and services can be greatly improved with efficient facilitation at border points and improved transit procedures (De, 2011; Freund and Rocha, 2011). These improvements would boost trade between landlocked countries (Arvis et al., 2011). However, the gains to countries may not be equal in either relative or absolute terms (Gilbert and Banik, 2010; UNESCAP, 2012).

Stone and Strutt (2009) have suggested that welfare gains of USD 8.1 billion could be attained from moderate improvements in road infrastructure and trade facilitation in the Greater Mekong Subregion (GMS).

UNESCAP has developed a corridor performance method that provides information on the relative importance and variability of time and cost of each interface point within the corridor (UNESCAP and KOTI, 2006). The method was used to analyse the performance of trade corridors in East and Central Asia. A study by UNESCAP and KOTI (2006) showed cost details for available transport modes and transit time at each interface or border post along the trade corridors.

Arvis et al. (2011) did case studies on cost, time and reliability of exports on corridors in South and East Asia, focusing on transit traffic for landlocked countries. The researchers showed that the transit procedures regulating goods were poorly designed and implemented, which has discouraged competition and high-quality logistics services.

6.12 Transport corridor management

Most national and transnational traffic moves along a few high-density transport routes and corridors. The Program for Infrastructure Development in Africa has identified 42 transport corridors that form a core network in Africa for regional integration and global connectivity (Sequiera et al., 2014). The Spatial Development Initiative (SDI) is the dominant approach to corridor planning in Africa. The SDI approach considered broader objectives of corridor development from the beginning and was first applied to the Maputo Development Corridor (EPS-PEAKS, 2015).

Developing countries in Asia are also following the corridor approach to development. Under different national and sub-regional development initiatives many transport corridor development projects are being implemented or are under consideration. These include the Golden Quadrilateral (GQ) domestic corridors in India (Ghani et al., 2016); South Asian Economic Corridors (SASEC; Gilbert and Banik, 2010); Greater Mekong Subregion (GMS) corridors (Srivastava, 2011; Stone and Strutt, 2009); and Central Asian Regional Economic Corridors (CAREC; ADB, 2014).

Corridor development and operation are complex because of their wide reach and scope, and involvement of a large range of stakeholders. It is also complex because corridors evolve over time, and evolution takes place in several stages. While there is no consensus about the number of stages, three basic stages can be identified. Initially the corridor is simply a transport corridor; then it becomes a logistics/trade corridor; and finally, an economic corridor. Some researchers have also considered one or two additional stages of development, for example, Gálves-Nogales, 2014; and AfDB, 2013. However, there are no clear boundaries between some stages (Dzumbira, 2017).

The appropriate interventions for corridor development depend on the type of corridor, and the stage of evolution and range of stakeholders involved. Sequira et al. (2014) considered two cycles for a development corridor:

(i) development cycle, characterised by a concentration of investment in economic or transport infrastructure;
(ii) operational cycle, characterised by a focus on logistics efficiency;
(iii) In each cycle, the focus, the stakeholders and the types of challenges vary and thus require different management approaches.

Multiple government departments from different sectors and different tiers of government, institutions and agencies as well as private and civil society entities play a role along corridors and at border-crossings. Because of the international nature of corridors and the relative weakness of the private sector in working across borders, the governments have taken the lead in corridor management (Arvis et. al., 2011). Corridor management can be idiosyncratic for various reasons including historical development of the corridor, initial conditions, and political objectives and institutions in countries along the corridor (Arvis et al., 2011). As a result, several management structures have emerged.

There are two broad types of corridors: transnational and national. Governments have considered management structures for coordinated development and operation of corridors. The transnational corridor management structures can be grouped into four broad categories (Arnold, 2006):

> public-private partnership management model, for example, Maputo Corridor Logistics Initiative (MCLI) for MDC (Adzigbey et al., 2007; Grosdidier de Matons, 2014; Sequeira et al., 2014.);
> legislative management model based on treaties between countries, for example, Northern Corridor Transit and Transport Coordination Authority, NCTTCA (Adzigbey et al., 2007; Grosdidier de Matons, 2014);
> consensus-building model, for example, Dar es Salaam Corridor Committee for Dar es Salaam corridor (Grosdidier de Matons, 2014; Adzigbey et al., 2007);
> project coordination model, for example the CAREC corridors in Central Asia (ADB, 2014).

National corridors may also benefit from a formal management structure for coordination, especially large, multi-sectoral or multi-modal corridors. Corridors under the project coordination model include the current national corridor management structures in India (Bhalaki, 2013), Malaysia (Athukorala and Narayanan, 2017) and Thailand (NESDB, 2017).

These management structures were established under respective national laws but their legal status and management structure differ. Legal instruments govern corridor management and operations, such as treaties, conventions, agreements, or as protocols, covenants, compacts, exchange of notes, memoranda of understanding (Grosdidier de Matons, 2014). These instruments may be bilateral covering two countries or multilateral covering many countries along a corridor, a sub-region, region or global.

Grosdidier de Matons (2014) reviewed legal instruments on trade and transport facilitation including corridors governance instruments in African countries. In addition to regional and global instruments, Asia has some 42 subregional agreements on transport facilitation (UNESCAP, 2014). However, only some of these agreements are in force. More than 100 bilateral agreements have been signed in the region (UNESCAP, 2014).

As mentioned above, corridor management ranges from private sector-led operating as lobby groups (such as, MCLI) to intergovernmental body or state-run authorities (such as, NCTTCA). Each structure has its strengths and weaknesses but no study could be found that assessed current management structures.

Most national and regional corridors have a three-layer management structure comprising: an apex/umbrella body; an executive/coordination committee; and a secretariat. While the composition including power sharing varies per corridor, the apex body is composed of a council of ministers from member states, and the chairmanship is generally rotated by the member states. The apex is the highest policy making body and gives direction to the executive committee and secretariat.

Policy and institutional reforms and other complementary interventions may be required to support specific needs in a particular stage of development. The appropriate interventions for corridor development depend on the type of corridor, and the stage of evolution and range of stakeholders involved at any particular stage of evolution (EPS-PEAKS, 2015).

An efficient corridor secretariat is necessary to sustain the corridor development and operational processes but its configuration should adapt to the corridor development cycles (Sequeira et al., 2014).

National stakeholders must be involved in transit corridor management. The stakeholders from public and private sectors directly responsible for transit matters are expected to discharge their duties. However, a national level coordination or facilitation committee ensures effective national support of corridor activities as well as liaison with the corridor secretariat. In recognition of this need, some corridor management structures, such as the Dar es Salaam Committee, has established national coordination committees (Adzigbey et al., 2007).

As transport and logistics services are mostly provided by the private sector, their involvement in corridor development and operation is important. The corridor management structures reviewed showed uneven participation of the private sector. While involving the private sector is important, involving the correct partner is paramount (Sequeira et al., 2014).

6.13 Discussion and conclusions

The discussion considers the lessons learned from the literature review for policy and future research perspectives.

6.13.1 Trade-offs/complementary interventions

Transport infrastructure development generally positive impacts on the economy, income, poverty reduction, employment, equity, and social development. However, there are trade-offs between economic and social development, and adverse impacts on the environment and on some groups in society. In some situations, there can be trade-off between growth and poverty (Fan and Chan-Kang, 2008). Thus, the potential gains to economy and welfare must be balanced against the potential adverse impacts in other areas.

Such trade-offs indicate the need for complementary interventions to address the negative impacts of transport infrastructure development. Further research needed on these trade-offs so that appropriate interventions and institutions can be part of the planning and design of major transport projects. For example, road safety, which is major issue in South Asian and African countries (WHO, 2019) should not be an afterthought in road infrastructure projects. Similarly, further research is needed to guide the planning of transport infrastructure in environmentally sensitive areas, and measures to reduce the negative impacts.

Transport infrastructure may be necessary but not sufficient for economic development (Gachassin et al., 2015). To ensure the benefits of large transport infrastructure investment, additional complementary policies and institutions may be required (Melecky et al., 2018). Such complementary interventions depend on the specific situation, and need to be based on better understanding of the underlying

mechanisms and the initial conditions that corridor development may have. Furthermore, transport policies need to be combined with non-transport policies, such as agricultural extension and rural logistics centres.

6.13.2 Assessment of multiple economic and social impacts

The review showed that transport development can have diverse effects on local areas and population groups as well as further afield. Thus, the spatial distribution of economic impacts must be considered in transport planning and development, and contribute to the choice of complementary interventions. Thus, research is needed to improve and adapt analytical tools for ex-ante assessment of the multiple impacts of transport infrastructure projects. A closely related issue to develop local capacity in LICs in the use of advanced assessment tools, including capacity building in local institutions.

6.13.3 Isolated communities

Studies indicate that investment in transnational transport networks holds great promise for economic development in land-locked countries in South Asia and Sub-Saharan Africa. However, the impacts on rural communities, especially in sparsely populated countries in Africa and Asia is limited without feeder rural road networks. This can be a major barrier to agricultural input distribution and technology adoption (Minten et al., 2013). Often, the economic return on investment in rural feeder roads can be much higher than on major roads (Fan and Chan-Kang, 2008). Research is also required on interventions that could improve linkages with the rural areas, which could lead to structural transformation of the rural economy and, in turn, increase social development and reduce poverty.

The negative externalities of cross-border transport must be addressed. The major challenges include human trafficking, illegal trade in narcotics and other items, and spread of diseases. However, some of these problems are deeply rooted in endemic poverty. Therefore, in tackling these challenges with direct intervention measures, measures to reduce poverty are also necessary.

6.13.4 Transport corridor management

The success of a transport corridor depends on its management structure (ADB et al., 2018). The management structure should allow for effective participation of all stakeholders including the private sector. Several management structures have emerged, and domestic corridors are also being developed with formal management structures. While corridor performance measurement and monitoring tools have been developed (such as, Kunaka and Carruthers, 2014; ADB, 2014; UNESCAP and KOTI, 2006), no study was found on their assessment. Such a study would contribute to designing and improving management models.

Currently, there is no general framework for designing governance structures for transport corridors. Research could be considered on how a transport corridor governance structure could be organised, structurally and procedurally, so that multiple stakeholders in corridor development, management and operation can play their roles and interact effectively. Allied to this, the research could also consider how governments can nurture institutions to forge partnerships and collaboration with such actors and facilitate their action.

7 Priority Research Areas

Priority research areas have been identified from extensive literature reviews (see Chapters 3 to 6) of the four key areas in long distance road and rail transport in low-income countries (LICs) in Sub-Saharan Africa and South Asia. These priority research areas were discussed in depth with key stakeholders in both regions during workshops held in November 2018 in Dhaka, Bangladesh, Nairobi, Kenya, and Dar es Salaam, Tanzania. The workshop outcomes were also substantiated in the responses of 51 stakeholders in the two regions to a detailed online questionnaire (Appendix 2).

Eight priority research areas together with key research questions are proposed for the four areas on long distance transport of:

> road Infrastructure;
> rail Infrastructure;
> road and Rail Transport Services;
> HVT Corridors and Networks.

The eight priority research areas identified together with the key research questions related to each of the research areas are listed in Table 11. Each research priority is closely aligned with the development goals for LICs in the two regions, and specifically with the approaches advocated by UK Aid Direct in support of DFID strategic objectives, as shown in Table 11. The potential contribution of the research priorities in achieving the UN Sustainable Development Goals (SDGs) and the goals of the World Bank initiative of Sustainable Mobility for All (SuM4All) are also given in Table 11. A full statements of these goals are given in Section 1.2.

Table 11: Priority research areas identified in long distance road and rail transport and alignment with development goals

	Priority Research Areas	UK AID supportive approaches[1]	Transport Relevant SDGs[2]	SUM4ALL Ambition[3]
ROAD INFRASTRUCTURE				
1	**Affordable high-volume roads that are low maintenance and resilient to climate change** *What new standards and designs are required for the construction and maintenance of roads that are climate resilient, low maintenance, using low-cost marginal materials?*	4. Improve access, supply and quality of basic services 6. Increased economic empowerment - job creation, income generation, and market access. 7. Strengthen the response to conflict and local-level crisis to improve resilience in fragile and conflict-affected states.	**Target 9.1** **Target 11.2** Targets 9.4, 9.5 Targets 12.1, 12.4, 12.7 Targets 13.1, 13.2, 13.A	Universal access Efficiency Green mobility
2	**More effective expenditure on roads by maximising local participation** *How can local stakeholders participate effectively to ensure more value for money in planning, design and construction of long distance roads?*	1. Partnerships to promote greater accountability 3. Strengthen advocacy actors to hold decision makers to account. 4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access.	**Target 11.2** Target 9.5 Target 10.2 Targets 16.5, 16.6, 16.7	Universal access

	Priority Research Areas	UK AID supportive approaches[1]	Transport Relevant SDGs[2]	SUM4ALL Ambition[3]
RAIL INFRASTRUCTURE				
3	**New affordable and sustainable approaches to increase railway network capacity** *How can novel cost-effective design, build and maintenance approaches be adopted to improve railway network condition, connectivity, affordably and sustainably?*	4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access. 7. Strengthen response to conflict and local-level crisis to improve resilience in fragile and conflict-affected states.	**Targets 3.6, 3.9** **Target 9.A** **Target 11.2** Targets 9.5 Target 12.1 Target 13.A	Universal access Efficiency Green mobility
4	**New approaches to improve the commercial viability of railway networks** *What e-technologies and construction and maintenance practices will deliver the efficient and sustainable operation and expansion of railway infrastructure?*	4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access. 7. Strengthen the response to conflict and local-level crisis to improve resilience in fragile and conflict-affected states.	**Targets 3.6, 3.9** **Target 9.A** **Target 11.2** Target 9.5 Targets 12.1, 12.4 Target 13.A	Universal access Efficiency Green mobility
ROAD AND RAIL SERVICES				
5	**Improving rail network performance to deliver competitive services** *How can current rail policies and regulations incorporate new approaches to deliver safe rail operations and sustainable railway concessions to be competitive with road transport?*	4. Improve access, supply and quality of basic services. 6. Increased economic empowerment - job creation, income generation, market access.	**Targets 3.6, 3.9** **Target 11.2** Target 9.5 Target 12.1 Target 13.A	Universal access Efficiency Green mobility
6	**Improving transit transport along corridors and across borders** *What affordable and appropriate technologies can be implemented to speed up goods flow along transport corridors and to increase the efficiency of border procedures?*	4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access. 7. Strengthen response to conflict and local-level crisis to improve resilience in fragile and conflict-affected states.	**Targets 9.1, 9A** **Target 11.2** Target 9.5 Target 12.1	Universal access Efficiency Green mobility
HVT CORRIDORS AND NETWORKS				
7	**Stakeholder governance structures for smart transport corridors** *What enhanced governance structures would improve stakeholder performance and the efficiency of corridor operations?*	1. Partnerships to promote greater accountability 3. Strengthen advocacy actors to hold decision makers to account. 4. Improve access, supply and quality of basic services. 6. Increase economic empowerment - job creation, income generation, market access.	**Targets 9.1, 9A** **Target 11.2** Target 9.5 Target 10.2 Targets 16.5, 16.6, 16.7	Universal access Efficiency Green mobility
8	**More equitable distribution of the economic and social benefits of transport corridor development**	4. improve access, supply and quality of basic services.	**Targets 9.1, 9A** **Target 11.2** Target 9.5	Universal access Efficiency Green mobility

	Priority Research Areas	UK AID supportive approaches[1]	Transport Relevant SDGs[2]	SUM4ALL Ambition[3]
	What technology improvements are required to strengthen project appraisal methods to quantify costs and benefits for planning equitable and sustainable development?	6. increase economic empowerment - job creation, income generation, market access.	Target 10.2	

[1] UK AID Supportive Approaches. For complete statement, see Chapter 1.
https://www.ukaiddirect.org/about/fund-priorities-2/

[2] SDG targets in abbreviated statement. For complete statements, see Chapter 1.

The targets emboldened are those most specifically relevant to long distance strategic road and rail. Improvements in road and rail transport will contribute to achieving the targets. These are:
3.6: Halve global road traffic deaths and injuries by 2020.
3.9: Reduce deaths and illnesses from hazardous chemicals, pollution and contamination.
9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure to support economic development and human wellbeing for all.
9.A: Facilitate sustainable and resilient infrastructure development in developing countries.
11.2: Access to safe, affordable, accessible and sustainable transport systems for all.
For details of all SDGs Targets, see Chapter 1 and https://sustainabledevelopment.un.org/

[3] SuM4All - Sustainable Mobility for All. For complete goal statement, see Chapter 1.

7.1 Road infrastructure

Regional and strategic national roads carry more than 80% of freight and passenger traffic in Sub-Saharan Africa and South Asia. However, current practices in road construction and maintenance do not deliver resilient roads required for long-term economic and social development.

Research indicates that new approaches and methods could reduce road construction and maintenance costs, make roads more resilient and contribute to reducing greenhouse gas (GHG) emissions from the transport sector in these regions. Thus contributing directly to the SDG of taking urgent action to combat climate change and its impacts (in particular targets 13.1, 13.2 and 13.A). Improved road construction and maintenance would in turn contribute directly to the SDGs of industry, innovation and infrastructure (SDG 9: targets 9.1 and 9.4), sustainable cities and communities, (SDG 11: target 11.2) and responsible construction and consumption (SDG 12: targets 12.1, 12.4 and 12.7).

Financing construction and maintenance of long-distance road corridors and strategic national roads presents difficult choices for indebted and resource-limited LICs. With population growth forecast to continue in both regions, LIC governments face ever greater challenges in balancing expenditure on road infrastructure and other services including education, health and welfare safeguards. Scarce domestic resources will have to be used more effectively and efficiently, and new ways explored to attracting funding from private investors, and from traditional and new development partners.

In light of these issues, two principal research areas are proposed for road infrastructure, and supported by two additional research priorities.

Priority research area 1. Affordable high-volume roads that are low maintenance and resilient to climate change

There are numerous challenges in improving the long-term sustainability of road infrastructure in LICs in Sub-Saharan Africa and South Asia. A key challenge is to make road infrastructure resilient to the effects of climate change including more frequent and sever extreme weather events. Another key challenge is to reduce costs and delays in construction and maintenance by making optimum use of less expensive, marginal materials, such as by-products, stabilised natural soils and locally aggregates. A further challenge in making road infrastructure sustainable is to ensure proper and timely maintenance which has often not been given the financial priority and political profile required.

Thus, the research priority is to develop design procedures and concepts to ensure the long-term sustainability of road infrastructure in LICs in Sub-Saharan Africa and South Asia.

The research objectives are:

> To improve the sustainability of road construction and maintenance by investigating the suitability of marginal materials, such as by-products, stabilised natural soils and locally available aggregates (directly addressing SDG targets 9.1, 9.4, 12.1, 12.4 and 12.7);
> To enable roads to recover their level of service (or a very large proportion of it) rapidly and with little intervention after an extreme weather event (addressing SDG targets 9.1 and 9.4). This will be substantially assisted by developing design procedures and concepts for road drainage structures to cope with more severe extreme weather events occurring as a result of climate change;
> To deliver low (or easy) maintenance resilient roads (thereby addressing SDG targets 9.1, 9.4, 12.1, 12.4 and 12.7). The research will quantify the economic effects of inadequate maintenance for all the major road elements in order to provide design guidance and standards.

The following approaches are proposed:

> review distressed road infrastructure caused by excessive water due to extreme weather events, and/or inadequate maintenance in order to establish design improvements;
> review and analyse standards to establish the requirements and design standards for road infrastructure resilient to extreme weather events to ensure service level;
> develop pilot-scale designs;
> engage stakeholders in identifying issues and reviewing research findings.

Key research question 1: What new standards and designs are required for the construction and maintenance of roads that are climate resilient, low maintenance, and use low-cost marginal materials?

Priority research area 2: More effective expenditure on roads by maximising local participation

High-volume roads are not only of international and national strategic importance but also have a role in supporting local communities. Increased local ownership of these roads will inhibit corruption and provide impetus for best practice in planning, design and prioritisation of road maintenance.

The proposed research is directed to establishing local ownership of road infrastructure in the broadest sense. This involves using local contractors, labour and materials, and mechanisms for local oversight of procurement, design, construction and maintenance. The research directly addresses SDG 10 (reduced inequalities: target 10.2) and SDG 16 (peace, justice and strong institutions: targets 16.5, 16.6 and 16.7).

The research objectives are:

- to involve local road engineers, contractors and suppliers in strategic road contracts, for instance, in procurement mechanisms that encourage local bidders;
- to enable local ownership of strategic road infrastructure by evaluating local rural ownership schemes, such as those in Afghanistan;
- to enable local involvement in scrutinising road planning, tendering and contract award, construction and subsequent management.

The following approaches are proposed:

- consult potential partners in road authorities;
- design alternatives to provide incentives to local contractors and suppliers;
- trial small-scale options and liaise with participating local companies and procurement organisations;
- conduct a political-economy analysis of the ownership concept for the road infrastructure;
- analyse mechanisms to harness local stakeholders to increase efficiency, reduce wastage, and combat corruption;
- investigate the feasibility of intelligent GPS cloud based data management systems, aspects of which can be accessed by the public (e.g., road condition);
- supplement road condition data by local observation, such as via smartphone apps;
- design and trial a regulatory framework to enable local scrutiny of public road infrastructure.

Key research question 2: How can local stakeholders participate effectively to ensure more value for money in planning, design and construction of long distance roads?

Additional research priorities:

E-tendering methodologies

E-tendering will contribute to combating corruption in client organisations and to preventing employment of inappropriate contractors. This research would contribute to addressing SDG 9 (Industries, innovation and infrastructure, target 9A, in particular) and SDG 16 (Peace, justice and strong institutions; targets 16.5, 16.6 and 16.7). The objective is to establish which e-tendering methods would reduce opportunities for corruption. Trials would be conducted in tender appraisal methods, such as a 'second lowest bid' approach and appropriate safeguarding algorithms to identify cartel operation. A desk study would be conducted that includes evaluation of organisations using e-tendering. This research would be carried out in consultation with national, state and local government.

Weigh-in-motion in overload control

The effect of overloading on accelerating pavement damage is well documented and further research would contribute to reducing the incidence of overloading and the economic damage caused. This research would contribute to addressing SDG 9 (Industry, innovation and infrastructure) by evaluating available technologies and identifying recent developments including the efficacy of the technology. In addition, calibration trials would be conducted to establish a realistic post-calibration error margin and to determine appropriate advice on calibration methods. Transparent and equitable formulae would be investigated to determine charges based on the degree of overloading. The most appropriate methods of charge collection would be assessed in conjunction with the relevant authorities.

7.2 Rail infrastructure

The viability of railways in LICs is improving as a result of a combination of factors including economic growth, rapid urbanisation, densification of economic corridors, an emerging middle class, expanding mobile communication and untapped mineral resources. There has been considerable recent Chinese

investment in railways in both Sub-Saharan Africa and South Asia, although there is scepticism about the long-term affordability and technical interoperability of many of these projects.

The environmental advantages of railways provide opportunities to contribute to SDG targets 3.9: reducing deaths and illness related to environmental pollution, and SDG target 13.A: addressing the needs of developing countries in meaningful climate mitigation actions. Railways offer opportunities for optimising energy use and thus to address SDG targets 12.1 and 12.4, which are associated with efficient use of resources. In addition, railways are a safer transport mode with fewer fatalities and injuries, thereby contributing to SDG Target 3.6 and reducing global deaths and injuries. Improving the viability of railways as a means of public transport will contribute to SDG Target 11.2 in the provision of safe, affordable and accessible transport system for all.

Priority Research Area 3: New affordable and sustainable approaches to increase railway network capacity

The research focuses on improving railway networks in LICs. Previously, the railway was the backbone of regional transport around which communities have developed. However, many older routes have fallen into disrepair, while new routes have been constructed without full consideration to creating joined up networks.

Most routes, including the new Chinese-funded, standard gauge railways, are single track, which limits capacity and potential for expansion for new services provided by open access providers. The key issue is how to make better use of existing infrastructure so that the rail network supports regional and continental economic plans. The focus has been on constructing new rail infrastructure with little attention to rehabilitating older infrastructure that could be potentially more cost-effective in developing a joined up network to support the local economy appropriately.

The research objectives are:

> to increase the capacity of railway infrastructure and to enable extension of freight and passenger services without the need to construct new routes;
> to enable cost-effective rehabilitation and upgrading of infrastructure and expansion of railway networks through cost-effective construction and operation approaches;
> to improve interoperability between countries.

The following approaches are proposed:

> collect data on railway network configuration (location and type of asset) and asset condition to assess current network condition;
> perform benchmarking to identify operational specifications for future speeds and traffic volumes;
> undertake stakeholder workshops and short-term mobility research visits between the UK and the selected countries;
> use simulation models with data obtained from the benchmarking to identify the physical and operational requirements to achieve the highest capacity in the short-, medium-, and long-term.

Key research question 3: How can novel cost-effective design, build and maintenance approaches and methods be adopted to improve railway network condition, connectivity, affordably and sustainably?

Priority Research Area 4: New approaches to improve commercial viability of railway networks

The research addresses the challenges of funding and implementing financial viability railway construction and operation for freight and passenger services. International standards may prove too costly and may not be fit for purpose in terms of regional requirements. A major concern is that recent Sino-African projects are not sufficiently focused on long-term sustainability, which can lead to poor maintenance and degrade operability. Differentiated railways to meet different volumes and service types can bring greater return on investment. Furthermore, adequate local and regional skills capacity is required for appropriate operation and maintenance.

The research is directed to identifying the technical requirements and technologies to support railway network expansion affordably and sustainably (addressing SDG 9 (target 9A) and SDG 11 (target 11.2).

The research objectives are:

> To develop local and regional economic standards for rail infrastructure taking account of safety and reliability based on specific national and regional requirements for railway traffic speed, tonnage and volumes;
> To support railway network operation and efficient and sustainable expansion by adopting technological solutions such as:
  - new materials and construction methods for track infrastructure
  - digital communication systems for in-cab signalling
  - modular architecture for cost-effective maintenance
  - new traction technologies for cleaner, more reliable operation and which reduce infrastructure deterioration and allows for reduced headway and therefore improve network capacity
  - control systems and condition monitoring for improved safety and to enable preventative infrastructure maintenance.

The following approaches are proposed:

> collect data from operators and infrastructure managers, following previously defined methods for verification and validation;
> engage with researchers and local authorities to identify, classify and prioritise renewal requirements;
> review emerging technologies to meet the LIC requirements without resorting to costly pre-packaged solutions from high-income countries;
> focus on technologies that require lower maintenance, and systems that increase safety and interoperability in complex operations;
> collaborate with local universities to promote capacity building and to ensure the long-term sustainability of the research.

Key research question 4: What e-technologies and construction and maintenance practices will deliver efficient and sustainable operation and expansion of railway infrastructure?

7.3 Road and rail transport services

Priority Research Area 5: Improving rail network performance to deliver competitive services

Failure of railway concessions can lead to escalating costs, low-quality service provision and, in the extreme, to termination of services, with substantial societal and economic disruptions. Essential requirements for sustainable rail services in LICs is the design of concessions and optimal regulatory and contracting model and solutions. In addition, improving the mode share of passenger transport cuts across many SDGs. Railways are inherently safer and lead to fewer fatalities and accidents (SDG Target 3.6) and cause less environmental damage (SDG Target 3.9). Providing a viable passenger service as an alternative to road transport will increase the reliability of the transport system (SDG Target 9.1).

The research objectives are:

> To determine when separate management of railway services and infrastructure in LICs would be appropriate, and the most appropriate separation models, including the impact of different institutional and organisational structures, and specifically vertical separation versus vertical integration, and intermediate structures;
> To improve the efficiency and societal welfare of railways by investigating different forms of competition (e.g., concessions, open access) and franchising models;
> To ensure funding and fair prices, while ensuring safety standards meet the required levels by assessing the most suitable economic regulation, contractual and structural approaches for rail infrastructure, for example, setting access charges and efficiency analysis, and more widely, economic regulation;
> To improve railway regulation by enabling governmental and regulatory bodies to have the appropriate types of regulatory frameworks for railway operation and the appropriate powers, capacity and legal status, and to assess the capabilities and funding of government, strategic planners and regulators;
> To reduce contract failure by investigating contract design issues and identifying the appropriate institutional skills to monitor and enforce contracts.

The following approaches are proposed:

> case study-based analysis to draw together experience from EU countries and access the applicability of the experience of EC to LICs;
> extend to the LIC context, qualitative studies carried out to determine an appropriate regulatory set-up for EU railways;
> statistical analyses of the impact of key reform parameters, such as regulation, vertical separation, and competition on costs and efficiency and demand;
> review the type and extent of competition and the impact of number of competitors or particular aspects of regulatory activity on costs and demand;
> engage LIC stakeholders to provide data and shape the design of appropriate solutions.

Key research question 5: How can current rail policies and regulations incorporate new approaches to deliver safe rail operations, and sustainable railway concessions to be competitive with road transport?

Priority Research Area 6: Improving transport transit along corridors and across borders

Transporting goods in Africa often takes three times longer and is 3 to 5 times more expensive than in Europe, Asia and Latin America. The World Bank (2018) has shown that the clearance times at borders for the bottom three quintile performing countries (of which these are LICs) are three times as long and paperwork twice as much as for the top two quintiles. The literature review has indicated that transit time and reliability affect freight transport choices. This is the case in LICs as well as in HICs with evidence of border waiting times for cross-border freight having negative economic impacts on LICs.

Cross-border freight is a major concern for LICs, and is stifling trade and economic development, particularly in landlocked countries. Furthermore, improving cross-border freight is directly related to SDG target 9.1: development of reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development.

Research is needed to establish how new technologies and border process alignments can speed up and improve reliability at border crossings. The economic and social benefits arising from improved transit

times would be assessed and, where possible, quantified. This research would provide a holistic appraisal of the benefits to improving freight transit across national borders.

Research would draw on the key recommendations of the United Nations (2003; 2012), GIZ (2010), Whiteing (2017) and Hanaoka et al. (2018) to develop measures to make border control of freight more efficient.

The research objectives are:

> To reduce cross border transit times and uncertainty (and import and export procedures) by developing ICT infrastructure and smart border control measures, such as non-intrusive inspection, fully paperless systems (e-border) with enabling software packages and systems;
> To enhance freight movements between ports and hinterlands particularly for SMEs and others requiring effective freight consolidation services through formulating a coherent and integrated intermodal strategy. This involves coordination between transport modes and a strategy for the development of 'dry ports' (inland freight depots), free industrial zones, inland customs clearance arrangements and bonded facilities;
> To remove restrictive regulations (such as, restrictions on container transport by road), and accelerate changes to the inconsistent arrangements for liability for freight on different transport modes.
> To enable quality-based freight transport regulatory regime by introducing requirements for employment of competent, trained personnel, and reducing skills shortage and unofficial payment.

The following approaches are proposed:

> Engage in workshops, border technology experts, policy and regulatory stakeholders, economists and social scientists from HICs and LICs. Stakeholder representation is essential for landlocked countries and successful corridors, such as the Northern (from Kenya) and Central (from Tanzania) corridors of East Africa;
> Assess smart border control technology approaches and best practices worldwide. This would include available technologies and promising new technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI) and block-chains;
> Assess current bilateral and multilateral facilitation and transit arrangements between countries in the regions;
> Identify issues in improving current practices and analysis the options for improvement;
> Develop a framework for consideration and adaptation to the local situation in individual countries.

Key research question 6: What affordable and appropriate technologies can be implemented to speed up goods flows along transport corridors and to increase efficiency of border procedures?

Additional research priorities:

Funding mechanisms to support the operation of transport services

There is tension in LICs between balancing an affordable user price and funding transport services, contributing to infrastructure maintenance and covering the capital costs of the original investment. High passenger user charges and freight rates discourage trips that could yield net benefit to passengers and freight receivers and as well as broader society. This is because the incremental resource cost on the infrastructure is below the price charged to recover the full cost of the infrastructure. Too high prices could lead to inequity and low social mobility. However, such marginal cost-based charges would not cover the cost of provision. This is known in economics as the problem of 'natural monopoly'. Ultimately, the difference has to be recovered to make transport services sustainable. This desk study and consultations would synthesise best practice solutions in LICs. Experience in HICs, such as least distorting

pricing (e.g., Ramsey pricing), and the feasibility for LICs would be assessed. The study would include the feasibility of direct government support and the extent to which ticket pricing can be differentiated flexibly for users who can and cannot afford to pay.

7.4 HVT corridors and networks

A well-managed smart transport corridor can reduce transport costs, increase efficiency in the supply and distribution chain, and reduce the carbon footprint of freight transport.

Transport corridors contribute to regional and local development because they encompass infrastructure facilities, policies and institutions and investments that generate economic growth. Such multi-sectoral development initiatives are a new concept in most countries in Sub-Saharan Africa. A range of issues need to be addressed to ensure the national and transnational transport corridors operate efficiently and contribute to economic development in their immediate vicinity and further in the surrounding region. Thus, transport corridors and the associated economic and social development contribute to SDG Targets and specifically in providing regional and trans-border infrastructure, which can in turn support economic development and human wellbeing (SDG Target 9.1).

However, transport corridors and their multiple economic and social impacts inevitably involve trade-offs. Thus, the potential impacts must be taken into account in planning and designing major transport infrastructure investments. The proposed research will provide insights that will contribute to transport infrastructure planning and development and support more balanced, sustainable and inclusive development from transport infrastructure investment. The research addresses directly the SDG of Industry, innovation and infrastructure (SDG 9: Target 9.1).

Priority Research Area 7: Stakeholder governance structures for smart transport corridors

Currently, there is no general framework for governance structures for transport corridors and governance structures vary according to corridor initiatives. Often multiple government departments from different sectors (and from different tiers of government), institutions and agencies as well as private and civil society entities are involved in some form of governance. This can lead to inefficient and ineffective corridor operation.

The research objectives are:

> To improve the efficiency and productivity of corridor operation by developing effective institutional frameworks that contribute to monitoring and dealing with negative externalities from corridor operation, and streamline procedures that encourage greater private sector participation;
> To enable stakeholders to interact effectively in corridor development, management and operation by addressing how a governance structure can be organised, structurally and procedurally;
> To forge partnerships and collaboration between stakeholders by assessing the role of governments in facilitating these activities.

The following approaches are proposed:

> identify the major issues in corridor development, management and operation;
> identify the stakeholders and their potential roles;
> assess the effectiveness of available governance models and their limitations;
> examine the use of technology in streamlining administrative and smart corridor operations, and develop a generic institutional framework for corridor governance structure;

> develop a framework for a governance structure in close collaboration with stakeholders and national implementing agencies;
> engage national and local research institutions in LICs with national and transnational corridors in operation or being implemented.

Key research question 7: What enhanced governance structures would improve stakeholder performance and the efficiency of corridor operations?

Priority Research Area 8: More equitable distribution of the economic and social benefits of transport corridor development

Better *ex-ante* assessment of the impacts of transport and corridor development at regional level is required as well as better understanding of the impacts on local areas, population groups, and other aspects of the economy. These insights would contribute to planning and design of major transport projects and corridors to ensure they are more responsive to policy objectives. The research addresses SDG 9: Industry, innovation and infrastructure (specifically, Target 9.1) and SDG 10: Reduced inequalities (particularly, Target 10.2).

The research objectives are:

> to assess the potential benefits of improved transport infrastructure and services in transport networks and corridors;
> to identify more balanced, sustainable and equitable development by identifying assessment methods to quantify costs and benefits.

The following approaches are proposed:

> Assess analytical methods to assess economic impacts of major transport projects and corridors for adaptation and extension to assess the impacts and intermediate outcomes, and their policy implications;
> Assess analytical methods for policy analysis and formulation for spatial planning including intervention measures to compensate for the negative effects and to address the multiple effects on local communities and population groups;
> Identify the intermediate outcomes to be considered in planning and developing infrastructure projects;
> Develop a methodology for impact assessment and pilot the developed methodology and models;
> Engage national research institutions in collaboration with research institutes.

Key research question 8: What technology improvements are required to strengthen project appraisal methods to quantify all costs and benefits for planning equitable and sustainable development?

Additional research priorities

Monetisation of the social benefits of HVT corridors

HVT corridors and networks bring substantial social benefits, but these benefits are often overlooked in assessments. Appraisal methods for road investment currently include social benefits in a subjective multi-criteria analysis approach, but this tends to reduce the value of the appraisal and the relative contribution of social benefits. To address this, research on building social accounting approaches aims to identify appropriate methodologies to monetise social benefits for inclusion in appraisal analyses of

economic investment. Although a standalone project, this research would contribute to appraisal methods to quantify all costs and benefits for planning equitable and sustainable development.

Addressing the negative externalities of cross-border transport corridors

A study is proposed on the extent to which HVT corridors and networks have negative externalities, such as negative effects on the environment and land use, trafficking of vulnerable groups especially women and girls, and spread of HIV/AIDS and STDs. This research would support SDG Targets 9.a and 11.2: provision of safe, affordable, accessible and sustainable transport for all.

The proposed approach is as follows:

> assess the nature and extent of these externalities;
> analyse current mitigation practices and options to redress them;
> recommend ways to incorporate mitigation measures in corridor design and legal and regulatory arrangements, and to compensate those negatively affected and put in place other arrangements as required;
> develop a framework to monitor the progress in alleviating the negative effects.

Linking HVT corridors and networks for more inclusive rural development

Without appropriate functional and physical connectivity with rural road networks, HVT corridors and networks may have little impact on their surrounding rural areas. Thus, the major challenge is to establish functional transport linkages between local and rural communities, and the urban and national economy. This research would focus on measures to establish functional linkages between rural communities and the wider regional economy using HVT corridors and networks. Best practices would be identified, options for functional and physical linkages evaluated, and measures to support development in rural areas assessed. This would consider the advantage of improved transport and logistics services along a transport network or corridor. Closer linkages would contribute to achieving the full potential benefits from investments in HVT corridors and networks and support SDG Targets 9.1 and 11.2.

8 Proposed State of Knowledge Papers

A workshop at the University of Nottingham on 17 December 2018 agreed to provide seven abstracts of potential State of Knowledge (SoK) papers. The purpose of the abstracts is to meet the Terms of Reference (ToR) requirements to provide a basis for selecting the topics for at least two full SoK papers to be published in a peer-reviewed scientific journal. This decision potentially increases the number of papers specified in the ToR because it was considered that the additional papers were needed to cover the research priority areas identified in the literature reviews. It is proposed to present the review papers for publication in a special issue of Sustainability, an online, open access, peer reviewed journal. This will provide a single source of information, thus meeting a requirement of the ToR for a concise information source.

SoK papers are proposed on key issues in making long distance road and rail transport more cost effective and sustainable in low-income countries (LICs) in Sub-Saharan Africa and South Asia. Short abstracts are presented for the SoK papers on the following topics:

> overcoming institutional barriers to cost-efficient highways in LICs;
> feasibility of using recycled materials to reduce road construction and maintenance costs;
> priority for upgrading existing railways to interconnect rail networks to deliver more regional growth;
> adapting and adopting state-of-the-art technology for safer and reliable train operations;
> reducing transport costs by strengthening competition, regulatory and institutional reforms;
> unlocking the potential of transport corridors to generate wider socio-economic development;
> more effective transport corridors by involving stakeholders in corridor management.

Topic: ***Overcoming institutional barriers to cost-efficient highways in Low-Income Countries***

Abstract:

There are wide discrepancies in the unit prices and quality of road construction and maintenance in low-income countries. These discrepancies can be attributed to engineering reasons, such as ground condition and variation in intrinsic material and inefficiencies associated with ineffective governance. This paper explores the evidence for the discrepancies in road construction and maintenance associated with the latter issue.

The paper will present the structure and culture of local or national government (the client organisation) as keys to dealing with these inefficiencies. Transparency and close stakeholder involvement with the client lead to greater effectiveness, more robust decision-making and less corruption, and therefore more sustainable practice. Corruption appears to be less in the private sector and effective public-private partnerships can lead to increased cost-efficiency. However, this is only possible where the client organisation is prepared to evaluate and manage the risks involved in these partnerships and to provide close oversight but without obstructive interference. Without this platform of trust, cost over-runs, sub-standard performance and financial collapse of the private sector partner are likely.

Topic: ***Designing pavements sustainably: how to include non-standard or recycled materials without compromising whole-life performance***

Abstract:

This paper considers the technical opportunities for achieving value for money by road pavement recycling and the associated challenges. Steady advances have been made in recent decades, for example in the effectiveness of cold-mix asphalt binders. Nevertheless, the opportunities for recycling are not being realised in many LICs due in part to a lack of road pavement design and maintenance guidance on the use of recycling.

This paper reviews the different design and maintenance methods available for incorporating recycled road pavement materials in both temperate and tropical climates. The increased uncertainty that occurs when using recycled materials is addressed with respect to required design reliability for different classes of road and the likely impact on future maintenance.

Recent research carried out in the UK is evaluated in the light of experience from South Africa in order to make recommendations for highway pavement structural design and maintenance. Consideration is also given to the whole-life economics of using recycled materials to maintain primary road networks. The capabilities required of the public and private sector in order to allow uptake by national or regional highway authorities are also explored.

Topic: ***Priority for upgrading existing railways to interconnect rail networks to deliver more regional growth***

Abstract:

Increasing concern about the sustainability of road transport has led to a revival in railways in LICs of Sub-Saharan Africa and South Asia. There is wide consensus on the need to expand rail networks. However, new routes have been planned without due consideration to the requirements for joined up networks and provision for expansion to meet future regional economic and social development needs. In addition, the focus has been on new rail infrastructure routes at the expense of upgrading older infrastructure around which communities and economic corridors have developed. Financial constraints in LICs require careful assessment to ensure funding is used to achieve greater return on investment. The implication for railways is that priority should be given when possible to upgrading infrastructure rather than constructing new lines.

The paper assesses operational strategies that make better use of existing infrastructure to increase the performance of rail networks for passenger and freight operations. Improving infrastructure on existing routes can potentially be more cost-effective than large-scale new infrastructure projects that are more appropriate to connect new areas to a regional network. Thus, the paper investigates the potential of upgrading existing railway lines to achieve capacity improvements. Data on current conditions and performance are used to identify the key areas for upgrade as well as the level of intervention required on different sections of networks. Areas for improvement are identified by benchmarking against railways networks in high-income countries. Improved operational strategies for better track utilisation are discussed as means of addressing lower standards in infrastructure quality.

Title: ***Adapting and adopting state-of-the-art technology for safer, more reliable train operations***

Abstract:

LICs in Sub-Saharan Africa and South Asia are now investing heavily in new railway infrastructure to replace their dilapidated networks. These investments in developing continental railway networks will reduce the carbon footprint of transport and help to provide affordable, accessible and sustainable transport for all. To overcome funding shortages, some countries are taking substantial resource-for-infrastructure loans to build new standard gauge lines.

As well as questions about the social, economic, and political feasibility of these loans, it is questionable whether adopting international standards may be too costly. As a result, such new infrastructure projects may not be fit for purpose in terms of the specific regional demands. A further concern is that these rail infrastructure investments are not sufficiently focused on long-term sustainability, which can lead to poor maintenance and consequential degrading operability. In addition, there is evidence that new infrastructure cannot support long-term requirements for capacity and interoperability to support sustainable economic growth.

In order to reduce the considerable initial construction and on-going maintenance costs of these railway network, research is needed to find cost-effective solutions in infrastructure and rolling stock at a system level. Differentiated railway networks, in which standards and configurations are adapted across the network, can prove a greater return on investment by promoting productivity and economies of scale. Potential technologies that could be used to facilitate differentiated railway networks are evaluated in the paper using a simple modelling approach. The technologies evaluated include new materials and construction methods; digital communication systems and in-cab signalling; modular architecture for cost-effective maintenance; and new technologies for traction for cleaner and reliable operation; and condition monitoring for safety. The results of the modelling are compared with high-income countries to estimate the potential gains in capacity and reliability from different technologies.

Topic: ***Reducing transport costs by strengthening competition, regulatory and institutional reforms***

Abstract:

Road and rail transport corridors are essential for economic growth and social development, but transport services require appropriate funding. While these services must be offered at affordable prices to facilitate the free flow of goods and passengers, there are financial challenges in costs, subsidies and pricing.

Furthermore, effective oversight of road transit regulations and rail concessions by public authorities is essential for regulatory compliance, including road safety.

Mode-specific issues are addressed, such as road versus rail, as well as issues common to both modes. These issues include reform of regulations on driver hours, structuring rail concessions, increasing competition, and tackling corruption. These reforms are required to deliver efficiency gains, and service quality improvements at lower costs for users.

The long and costly clearance times at border crossings highlighted in a World Bank report (2018) are discussed. This report showed costs for the bottom three quintile LICs is three times higher and paperwork twice as much as for the top two quintiles LICs. The literature review also indicates that transit

time and reliability impact on the mode choice for freight and that cross-border delays substantially increase freight tariffs.

Finally, a range of regulatory, competition and wider institutional reforms are considered to improve transport services, and to reduce operator costs and user prices.

In many LICs, the opportunities presented by strategic road and rail are not being fully realised for a variety of reasons. Studies and examples of successful and unsuccessful delivery of transport services worldwide will be reviewed, including evidence on the extent to which border transit time and unreliability impacts on trade and alternative technologies to improve cross border crossing. Lessons are drawn for best practice. Experience in LICs is used to identify opportunities to enhance transport service delivery, and reduce costs and pricing in LICs. Finally, a research agenda is proposed that builds on best practices worldwide to be applied to the specific circumstances in LICs. The agenda will contribute to achieving economic growth and social benefits from improving transport services and transit flows.

Topic: ***Unlocking the potential of transport corridors to generate socio-economic development***

Abstract:

Often, corridor development is limited to transport and logistics efficiency in transnational corridors. However, complementary interventions by public authorities and other stakeholders can generate wider socioeconomic development in the corridor region by capitalising on improved connectivity and transport. Such corridors enable spatial organisation of economic activities, bring together infrastructure facilities, policies and institutions and investments to generate wider socioeconomic development. Developing efficient national or transnational transport corridors is difficult but evidence from the literature suggests that this approach can contribute to more sustainable economic and social development.

The review includes issues in corridor development, and specifically best practices and how to address major development issues, such as investment, coordination, and negative externalities. The lessons learned are reviewed with regard to the development of transformative corridors; complementary interventions by public authorities (infrastructure, institutions and policy reforms); and capacity of public authorities for project development, design and implementation). Finally, conclusions are drawn about the major factors to be considered in developing transport corridors to generate more sustainable and inclusive socioeconomic development.

Topic: ***More effective transport corridors by involving stakeholders in corridor management***

Abstract:

A wide range of actors are involved in transport corridors and border crossings. These include government departments in different sectors and tiers of government, institutions and agencies as well as private and civil society entities. Their actions and inputs need to be coordinated to ensure corridor development and operation are efficient and productive. For various reasons, corridor management can be idiosyncratic and as a result, different transport corridor management frameworks have emerged, ranging from a simple partnership of stakeholders to structured institutional arrangements for corridor management and operation. The paper considers the effectiveness of commonly used corridor management frameworks in dealing with major issues in corridor development and management.

Corridor management includes the role of various stakeholders and their interaction, building trust between stakeholders, corridor performance measurement and legal instruments. The lessons learned identified in the literature review are analysed in terms of improving corridor management and sustainability of the management organisations. Finally, essential features of effective corridor management framework and their usefulness and sustainability are discussed.

9 Capacity Building Strategy

9.1 Approach

A range of institutions in the countries to be selected for Part 2 of the HVT programme will be responsible for the practical uptake and implementation of the HVT research findings. The institutions are likely to be research organisations, transport authorities and government ministries. These organisations may need to build the necessary capacity to enable them to take up the research findings.

Our strategy for capacity building assessment is as follows:

> identify in the selected countries the major institutions responsible for, or best suited to, the uptake and implementation of research findings;
> carry out a gap analysis of the capacity of these organisations to uptake and implementation the research;
> identify generic capacity building programmes suitable for the institutions according to their needs identified in the gap analysis.

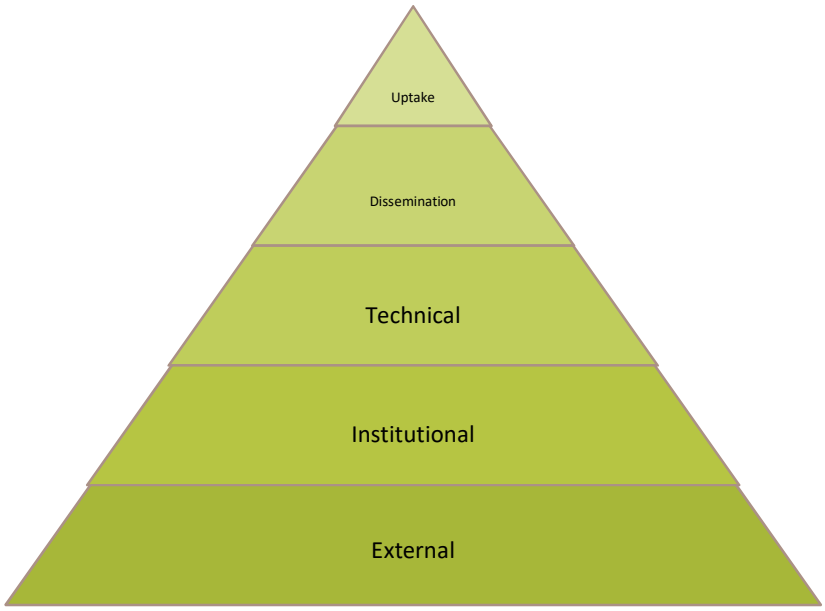

Figure 17: Building blocks for research uptake and capacity building

9.2 Self-assessment

For the gap analysis, we will use a self-assessment method to assess research capacity on five interrelated building blocks, namely external environment, institutional issues, technical capability, research dissemination, and research uptake, see Figure 17.

Typically, capacity needs focus narrowly on technical aspects, for example, the knowledge, skills and aptitudes to access, use, create and communicate research information. However, as the pyramid in Figure 17 shows, research uptake by an organisation, research group, or an individual is influenced by a number of interrelated building blocks. These are external (supporting) environment, institutional capabilities and organisational arrangements, technical aspects related to good quality research, and the ability to disseminate research to stakeholders.

We have developed a self-assessment questionnaire for distribution to organisations to determine, score and prioritise their capacity building needs. The questionnaire was discussed with four road authorities from Ethiopia, Sierra Leone, Pakistan and Zambia and refined accordingly. The building blocks of the research uptake pyramid (Figure 17) encompass many issues that influence the extent of research uptake. These issues are:

> External: aspects, such as whether there is an enabling/willing environment to consider research findings and embed research in policy and practice;
> Institutional: concerns the organisation in which the research entity presides and whether this organisation provides sufficient support. Issues to consider include the research policy, dedicated research funding, research laboratory, exposure to international research, research training programmes for staff, and adequate salaries;
> Technical: aspects include information literacy (skills in finding and appraising academic literature), thematic topic knowledge, knowledge application and justification of research methodologies, critical analysis skills, and the ability to develop research proposals;
> Dissemination: features include academic writing skills, knowledge management, use of e-communication tools and skills in communicating with end users and non-specialists;
> Uptake: aspects, such as if and how the products of research are embraced by the local and national transport industry.

A self-assessment questionnaire based on these building blocks will enable an organisation to score its research capacity against the optimal score for each of the five building blocks. The sum of the scores will indicate the organisation's overall research capacity. Scrutiny of the low scores will indicate capacity-building requirements.

The overall capacity building score, CBS_m for an organisation, m, is determined in Equation 1.

$$\boldsymbol{CBS_m} = \sum_{i=1}^{I} \boldsymbol{w_{bbi}} \frac{1}{4} \sum_{j=1}^{J} \left[\boldsymbol{w_{qij}} \times \boldsymbol{S_{qij}} \right] \qquad \textbf{Equation 1}$$

Where w_{bbi} is the weight of building block, i. $\sum_{i=1}^{I} w_{bbi} = 1$, $I = 5$

W_{qij} is the weight of a question j associated with building block i. $\sum_{j=1}^{J} w_{qij} = 1$

S_{qij} is the (unweighted) score for question ij for an organisation in country m; $1 \leq S_{qij} \leq 4$

The capacity-building questionnaire is presented in Appendix 3.

To explain the equation, there are five sets of questions addressing each of the five building blocks. The number of questions is not the same for each building block and does not affect scoring because each question is weighted. A question has four parts (a, b, c and d), each designed to assess the competence of the organisation, and are listed in a ranking order. The score is one if Qa is TRUE, two if Qa AND Qb are TRUE, three if Qa, Qb and Qc are TRUE and four if Qa, Qb, Qc and Qd are TRUE. A TRUE response is not possible unless a TRUE response has been given to the preceding part.

For example, in assessing a person's height: if Q1a is: 1.7m < height; Q1b: 1.75m < height; Q1c: 1.8m < height; and Q1d: 1.85mm < height. Then if the person's height is 1.78 m; Q1a TRUE; Q1b TRUE; Q1c FALSE; Q1d FALSE (and would score 2). However, it is not possible to score: Q1a TRUE, Q1b FALSE, Q1c TRUE.

10 Country Partner Selection

10.1 Methodology

The country selection process uses a multi-criteria approach consisting of four tier two (multi-criteria) indicators and tier three indicators as detailed below. For a country to be considered, three pre-selection criteria have to be met. These criteria are:

> a DFID priority country in Sub-Saharan Africa or South Asia;
> willingness of the relevant road authorities to engage in the HVT Programme;
> sufficient research capacity.

Willingness to engage in the programme will be assessed qualitatively from the responses of road authorities to the stakeholder questionnaire (see Appendix 3). The research capacity of those countries to meet the first two pre-selection criteria will be screened in a desk-based exercise and a discussion with the Programme Management Unit (PMU) of the High-Volume Transport programme. Detailed self-self-assessment of the research capacity of the organisations in the selected countries is presented in Chapter 9.

Countries meeting the pre-selection criteria will be ranked using a weighted score associated with the tier two and tier three indicators. Scores are given for road and rail separately. The weights for each criteria and sub-criteria have been determined using a pairwise comparison process carried out by the project team.

The selection of countries will be made in consultation with the PMU, and in consultation with local counterparts and other stakeholders.

The selection criteria are as follows:

Pre-selection (countries must satisfy all these criteria)

> DFID priority countries in Africa and South Asia
> willingness to engage in the research programme
> sufficient capacity to engage in the research programme.

Multi-criteria (tier two and tier thee indicators)

1. Road or Railway network size (tier two)
    a. For HVT road countries connected by the Trans-African highways or the Great Asian Highway, ranked by (tier three):
        1. Total highway length (paved)
        2. Annual average daily traffic
        3. Annual average tonne-km carried
    b. For HVT rail (tier 3)
        i. Those connected by the Trans-Asian Railway in Asia, ranked by:
            1. Total railway network length
            2. Tonne-km and passenger-km
        ii. In Africa
            1. Total railway network length
            2. Tonne-km and passenger-km

2. Countries that are actively investing in long-distance road and rail transport (tier two), ranked by (tier three):
   a. Five-year annual average value of road or rail expenditure by GDP
   b. Percentage of high volume road network (only) in good or fair condition
3. Countries that have a remit for improving transport links as part of a wider poverty reduction strategy (tier two), ranked by (tier three):
   a. Five-year annual average donor investment in HVT road or rail infrastructure by GDP (tier three)
4. Countries in which demographics, climate change and extreme weather events, and rates of urbanisation mean that the potential benefits of HVT research would be maximised (tier two), ranked by (tier three):
   a. Percentage of population in urban areas (2018)
   b. Urbanisation rate for the period 2015-2020 (estimated)

The score, S_m for country, m, passing the pre-selection criteria is determined using Equation 2.

$$\boldsymbol{S_m = \sum_{i=1}^{I} w_{t2i} \sum_{j=1}^{J} \left[w_{t3ij} \times \frac{S_{t3ij}}{\bar{S}_{t3ij}} \right]} \qquad \textbf{Equation 2}$$

Where w_{t2i} is the weight of tier 2 indicator, i. $\sum_{i=1}^{I} w_{t2i} = 1$, and

w_{t3ij} is the weight of tier 3 indicator, ij. $\sum_{j=1}^{I} w_{t3ij} = 1$

S_{t3j} is the unweighted score for country m according to tier three indicator ij;

$\bar{S}_{t3ij}$ is the unweighted maximum score for all countries according to tier 3 indicator ij.

10.2 Preliminary recommendations

The results of the above analysis produced the ranking shown in Table 12. Of the top seven countries ranked according to Equation 2 in Sub-Saharan African four countries, Nigeria, Tanzania, Kenya and Zambia, are common to both the road and rail rankings. For the analysis of countries in south Asia, Bangladesh, Nepal, Afghanistan and Indonesia are in the top seven on both the road and rail rankings. Albeit, the data for Pakistan railways were not available. We would advocate assessing country buy-in and capacity before selecting the countries.

Table 12: Provisional country ranking

	Sub-Saharan Africa		South Asia	
Rank	Road	Rail	Road	Rail[1]
1	Nigeria	Tanzania	Indonesia	Bangladesh
2	Tanzania	Mozambique	Pakistan	Nepal
3	Uganda	Kenya	Afghanistan	Afghanistan
4	Ghana	Sudan	Bangladesh	Indonesia
5	Kenya	Nigeria	Nepal	
6	Zambia	DRC	Myanmar	
7	Ethiopia	Zambia		

[1] Note data for Pakistan was unavailable.

11 Conclusions and Recommendations

11.1 Conclusions

Our detailed SoK reviews provide an evidence base to identify pressing transport related issues in LICs and the applied research required to support sustainable provision of HVT long distance road and rail. This research is required so that transport can most effectively contribute to meeting the SDGs that apply especially to LICs in Sub-Saharan Africa and South Asia. These research priorities are closely aligned with the approaches advocated by UK Aid Direct in support of DFID strategic objectives.

The priority research areas were discussed in depth with key stakeholders in regional workshops in Dhaka, Bangladesh, Nairobi, Kenya, and Dar es Salaam, Tanzania. The workshop outcomes were also substantiated in the responses of 51 stakeholders in the two regions to a detailed online questionnaire.

11.1.1 Road infrastructure

The road infrastructure review focused on sustainable high-volume road networks, specifically on reducing whole-life costs, securing financing and improving governance. The conclusions from the review are presented below.

Reducing whole-life costs

> There is a need for new road structural designs to allow for the use of non-standard and recycled materials;
> Improved tools are required for the design and construction of roads on tropical soils, including the prediction of soil behaviour under traffic, and the use and specification of stabilisation techniques.
> Mechanisms are needed to encourage uptake of road geometric and structural designs based on whole life-cycle analysis that are appropriate to each location;
> Improved whole life-cycle analysis approaches are required to consider road constructability, maintainability and the wider socio-economic benefit of labour intensive methods;
> To cater for the implications of climate change, research must target novel drainage systems that are easy to maintain and do not readily fail when overloaded;
> With ever-increasing pressure on drinking water resources, it is necessary to investigate materials for road construction that will reduce or prevent pollution of aquifers;
> Technology driven solutions are required to enable LIC road authorities to collect and analyse road data at low cost and acceptable accuracy.

Road financing

> Means of limiting government interference need to be identified to ensure road funds are used to maximum effect;
> Appropriate means of ensuring accountability of foreign investment in road infrastructure need to be identified, including stronger public sector control and improved transparency;
> A multi-country project evaluation is needed to investigate the cost effectiveness of public-private partnerships (PPPs) and their role in combating corruption.

Governance

> Methods are required to increase competition and transparency, and to reduce collusion to lower the price of road construction in LICs;

> To encourage openness in tendering and contract award, use of e-procurement and stakeholder representation in these processes need to be investigated;
> Research is needed on how shared ownership of road assets contributes to efficient management and also social development, thereby increasing transparency and accountability;
> Research is required to better understand and deal with optimism bias whereby planned construction costs are underestimated and traffic forecasts are overestimated.

11.1.2 Rail infrastructure

The review centred on fundamental aspects of rail infrastructure provision in Sub-Saharan Africa and South Asia, namely interoperability, connectivity, the permanent way infrastructure, operational capacity and Chinese involvement. The major conclusions are presented below.

Data collection

> To underpin future research, data collection is required to address the general paucity of up-to-date information on railway infrastructure and operations.

Technical standards and technologies

> Strategic methods need to be developed and implemented, including investment appraisal and technical planning methods for new railway lines;
> Research is required to identify rehabilitation approaches for disused lines, and innovative solutions in design and operational strategies to make network performance more cost effective;
> To address constraints to operation capacity, traffic management strategies have to be developed for the large numbers of sections of single-track railway lines.

11.1.3 Road and rail transport services

The literature review was wide ranging and, covered franchising and concessioning, safety and economic regulation, and border transit. The review makes clear that LICs face considerable challenges in these areas, and that resolving these challenges is important to their development. Based on this review, the following conclusions may be drawn:

> The feasibility and suitability of concessioning and franchising need to be assessed as service delivery methods for road and rail infrastructure, and the optimal design of such contracts needs to be investigated;
> Research is required to identify the specific needs of economic and safety regulators in LICs, and the appropriateness of different forms of regulation;
> New approaches to improve road safety are urgently required and should consider increasing penalties, improving enforcement, anti-corruption drives and education;
> Methods of improving road freight driver behaviour are required, including legislation, technology, new enforcement approaches and the design of road infrastructure;
> Assessment is required of the cost-effectiveness of different technologies for monitoring truck overloading;
> Research is required to identify appropriate cost-effective measures to reduce waiting times at borders, including the use of technology, reducing bureaucracy and improving cross border agreements;
> Empirical research is required to assess the impacts of border waiting times and uncertainty on LIC economies.

11.1.4 HVT corridors and networks

The review of HVT corridors and networks considered their socio-economic impacts and means of assessing these and, corridor management. The conclusions drawn from the review are presented below.

Economic and social impacts

> Research is required to understand better the positive and negative impacts of the development of corridors and networks so that appropriate interventions and institutions can be part of the planning and design process;
> Research needs to guide the planning of transport infrastructure in environmentally sensitive areas, and measures to reduce the negative impacts;
> To ensure the maximum benefits of large transport infrastructure investment, research is required to identify the appropriate and necessary complementary (non-transport) policies and institutions for a given context;
> There is a need to improve and adapt analytical tools for ex-ante assessment of the multiple impacts of transport infrastructure projects to improve the quantification of spatial distribution of economic impacts;
> Research to identify equitable investment appraisal approaches which consider socio-economic benefits to gauge the returns on improving connectivity to rural road networks;
> New approaches are required to address the negative externalities of cross-border transport including human trafficking, illegal trade, and the spread of diseases.

Transport corridor management

> Research is required into effective management structures to allow for the meaningful participation of all stakeholders;
> Studies must assess corridor performance measurement and monitoring tools to contribute to designing and improving management models;
> There is a need for research to identify appropriate transport corridor governance structures, including the level of government involvement, so that multiple stakeholders in corridor development, management and operation can interact effectively.

11.2 Recommendations

Research

The Research Framework for Theme 1 must support the long-term vision of high volume transport in LICs and use technologies and technical research approaches to respond to key challenges. The research must address the development goals for LICs in the two regions, and specifically the approaches advocated by UK Aid Direct in support of DFID strategic objectives. The research must also contribute to achieving the UN Sustainable Development Goals (SDGs) and to the goals of the World Bank initiative of Sustainable Mobility for All (SuM4All). By responding to these goals explicitly, the HVT Long Distance Applied Road and Rail research programme will also explicitly demonstrate the role of transport research in advancing economic and social development in LICs.

Based on these requirements and drawing on the conclusions of the literature review, it is recommended that a research programme be carried out in eight priority research areas as follows.

1. Road 1: Affordable high volume roads resilient to climate change and traffic demands
2. Road 2: Spending scarce funds better by maximising local involvement
3. Rail 1: New approaches to improve network capacity that are affordable and sustainable

4. Rail 2: New approaches for improving commercial viability of railway networks
5. Services 1: Improving rail network performance to deliver competitive services
6. Services 2: Reforming transit transport along corridors and across borders
7. Networks & Corridors 1: Stakeholder governance structures for smart transport corridors
8. Networks & Corridors 2: Spatial distribution impacts of corridor projects on income, society and the economy.

SoK papers

Based on the seven abstracts in Chapter 8, the research priority areas identified and the need for academic rigour, four articles are proposed for publication on the topics as follows:

1. designing pavements sustainably: how to include non-standard or recycled materials without compromising whole-life performance;
2. adapting and adopting state-of-the-art technology for safer and reliable train operations;
3. reducing transport costs by strengthening competition, regulatory and institutional reforms;
4. Unlocking the potential of transport corridors to generate wider socio-economic development.

The papers are to be presented for publication in a special issue of Sustainability, an online peer-reviewed journal. This single, open-access source will facilitate discussion of key long distance road and rail research areas that are required to address UN SDGs and affordable, safe and environmentally friendly transport to support mobility for all.

Capacity building

A method has been proposed in Chapter 9 for assessing the capacity building requirements of the local organisations selected to participate in Part 2 of the HVT programme. It is recommended that this approach be used early in the Part 2 of the HVT programme to enable capacity building programmes to be developed and implemented to meet requirements, preferably timed early in the second part of the HVT programme.

Country ranking

Based on the country ranking exercise presented in Chapter 10, following countries are recommended for consideration as partners for Part 2 of the HVT Programme: Nigeria, Kenya, Tanzania and Zambia in Sub-Saharan Africa, and Indonesia, Bangladesh, Afghanistan and Pakistan in South Asia.

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Appendix 1: Stakeholder Engagement

Four stakeholder workshops were held as part of our engagement activities. Two workshops were in Sub-Saharan Africa (Kenya and Tanzania respectively), one in South Asia (Bangladesh) and one in the UK (London). The aims of the first three workshops were to promote widely the HVT programme, to elicit stakeholder opinion on the preliminary research areas, identified for Part 2 of the programme and to engage meaningfully with local stakeholders. The aim of the London workshop was to present the findings of the programme to date and to discuss and debate the proposed SoK papers. The workshops are described in the following sections.

A1.1: Dhaka (Bangladesh) workshop

A one-day stakeholder consultation workshop, hosted by the Centre for Development Research Studies (CDRS) at the Bangladesh University of Engineering and Technology (BUET), was organised in Dhaka on 6 November 2018.

The aim of the workshop was to inform participants of the HVT research programme and elicit stakeholder opinion on priority research areas on the four sub-themes for Theme 1.

The objectives of the workshop therefore included:

i) To learn more about the current issues related to HVT road and rail transport provision in South Asia (with a focus on Bangladesh)
ii) To debate the current research needs in South Asia in the following areas:
   a. Road infrastructure
   b. Rail infrastructure
   c. Road and rail transport services
   d. HVT corridors and networks
iii) To suggest areas in which some future research may be undertaken, and
iv) To consider how local capacity in the identified areas of research may be increased.

Attendees

Invitations were sent to target stakeholders in South Asia. Due to geographical and visa issues participation was limited to 19 participants from Bangladesh. The participants represented the Planning Commission, Ministry of Transport, Roads and Highways Department, Bangladesh Railway, the Local Government and Engineering Department (LGED), research organisations and universities, as well as representatives from Donor Partners. A full list of attendees is provided in the relevant workshop report.

Workshop programme

The meeting was organised into a morning and afternoon session. A summary of the workshop is given below.

> Dr. Shakil Akhter, Director of CDRS gave a welcome address and explained the purpose of the meeting and its expected outcomes;
> Mr. James Evans (Cardno IT Transport) presented the first presentation on the overall HVT applied research programme on long distance strategic road and rail;
> Dr Sarwar Jahan from the Policy Research Institute delivered a presentation highlighting the present focus of transport development in Bangladesh, future scenarios of development and transport demand over the next twenty years, and major issues related to road and rail;

> Subsequently, Mr. Shishir Kanti Routh, Superintending Engineer from the Roads and Highways Division, provided a presentation on highway development in Bangladesh, highlighting the current issues in development, specification and design standards for access-controlled highways;
> Mr Md. Saidur Rahman, Project Director from the Bangladesh Railways, provided details regarding current initiatives being implemented to improve the railway service and augment the capacity of Bangladesh Railways. The details included new railway lines under construction and railway freight transportation;
> Dr Abdul Quium made a presentation on the emerging research areas related to road infrastructure development identified by the HVT Theme 1 Team.

Deliberations took place after the presentations and the participants took part in the ensuing discussions. Views were expressed on the initial research areas considered important for Bangladesh. The responses were generally supportive of the research areas across all the four sub-themes. The attendees agreed affirmatively that the list of emerging research areas were highly relevant to Bangladesh.

Additional research areas were not recommended / introduced. However, the following suggestions were made.

> Additional revenue generation for railways from non-core business opportunities including leasing of assets (e.g. excess railway land and other properties);
> Studies on impacts of railway projects and development of appropriate appraisal methodologies for railway projects in developing countries;
> Multi-modal transport development comprising of inland waterways, roads and railways;
> Considering the prospect of the "blue economy" in Bangladesh, research in climate resilient infrastructure and studies on transport infrastructure development in environmentally sensitive coastal areas of Bangladesh (this is addressed implicitly in the sub-theme 1 research area: Affordable high volume roads resilient to climate change and traffic demand).

AI.2 Dar es Salaam (Tanzania) workshop

The HVT Theme 1 Rail infrastructure sub-theme group, ran a workshop in Nairobi, Kenya on 23 November 2018. The workshop was arranged on a date to capitalise on the attendance of the East Africa Rail conference, which was held between 21-22nd November 2018 at the Intercontinental Hotel in Nairobi. In order to facilitate access and increase potential attendance, the HVT workshop was held at the same venue.

Aim and objectives

The aim of the workshop was to inform participants of the forthcoming HVT research programme and elicit stakeholder opinion on rail infrastructure and associated transport services.

The objectives of the workshop therefore included:

i) To learn more about the current railway projects in Africa
ii) To identify current knowledge gaps in rail infrastructure and transport services
iii) To suggest areas in which some future research may be undertaken, with a focus on the following general areas:
    a. Strategic needs
    b. Regulation and operation
    c. Infrastructure
iv) To consider how local capacity in the identified areas of research may be increased.

Attendees

Fourteen participants representing government bodies, railway operating companies, private consultants and academics attended the workshop. The participants represented organisations based in Kenya (7), Namibia (2), Nigeria (1), Rwanda (1) and Uganda (3). A full list of attendees is provided in the Nairobi workshop report.

Workshop programme

The workshop programme included a presentation of the HVT programme and detailed presentations on the Rail Infrastructure and Rail Transport services. The HVT research needs were discussed and the questionnaire was introduced to the participants and time provided for them to complete them on site.

In addition to discussing the proposed areas of research, much was proffered about the need for capacity building in terms of skills, standards, and policies. The constraints, that require specific technologies to be developed, rather than the mirroring of European or Chinese solutions, were also aired.

A1.3 Nairobi (Kenya) workshop

A one-day stakeholder consultation workshop, hosted by STET International (Tanzania) Limited), was organized in Dar es Salaam on 6 November 2018.

Aim and objectives

The aim of the workshop was to inform participants of the forthcoming HVT research programme and elicit stakeholder opinion on priority research areas of the four sub-themes for Theme 1.

The objectives of the workshop included:

i) To learn more about the current issues related to the development of major HVT network and corridors in East Africa
ii) To identify some current knowledge gaps in the areas of development impact, transport services and technology (related to road and rail infrastructure)
iii) To suggest areas in which some future research may be undertaken, and
iv) To consider how local capacity in the identified areas of research may be increased.

Attendees

Invitations were sent to target stakeholders in East Africa, namely, Rwanda, Uganda, Kenya, Ethiopia and Tanzania. Twenty-one participants attended the workshop however there were no participants from Rwanda or Ethiopia. A full list of attendees is provided in the associated workshop report.

Workshop programme

The workshop included a presentation of the HVT programme and detailed presentations on the Road Infrastructure and HVT corridors and network sub-themes. The HVT questionnaire was discussed broadly and the participants were split into three groups to discuss, complete the questionnaire and present group ideas.

Research areas

Table AI.I summarises the research topics discussed and agreed at the three international workshops. All of the Theme 1 research areas were discussed and approved in broad terms during at least two of the workshops. Three additional areas were also a recurring theme at the workshops, namely road safety, multimodal issues and capacity building. The former topic is an agreed research area for Theme 4. Although multimodal issues are not addressed directly by a research sub-topic they are implicit within sub-theme 3 (particularly within the sub-topic of Improvement of trade and transport procedures and pricing of regional transport infrastructure services).

Table AI.I: Research areas and sub topics discussed and verified

Research Area	Sub topic	Workshop		
		Dhaka	Dar es Salaam	Nairobi
(Road 1) Affordable high volume roads resilient to climate change and traffic demand	Road geometry, pavement design and drainage design standards	x	x	
	Construction and maintenance practices and materials	x	x	
	Overloading	x	x	
	Asset management	x	x	
(Road 2) Spending scarce funds better by maximising local involvement	Road financing and PPP	x	x	
	Governance	x	x	
(Rail 1) New approaches for improved network capacity that are affordable and sustainable	Regional and international benchmarking	x		x
	Network development	x		x
	Interoperability	x		x
(Rail 2) New approaches for improving commercial viability of railway networks	Safety improvement	x	x	x
	Technical capability and new technologies	x		x
(Services 1) Improving rail network performance to deliver competitive services	Railway concession design and delivery procurement mechanisms	x	x	x
	Railway concessions and infrastructure	x	x	x
	Regulation of infrastructure	x	x	x
(Services 2) Reforming transit transport along corridors and across borders	Cross border road and rail freight	x	x	x
	Improvement of trade and transport procedures and pricing of regional transport infrastructure services	x	x	
(Corridors and Networks 1) Stakeholder governance structures for smart transport corridors	Management of transport networks and corridors	x	x	
	Public authority and skills	x	x	
(Corridors and Networks 2) Spatial distribution impacts of corridor projects on income, society and the economy	HVT transport networks/corridors to support more inclusive development in rural areas	x		x
	Development impacts of railway projects	x	x	x
	Spatial distribution of income and other aspects of economy	x	x	
Other research areas identified	Road safety		x	
	Multimodal studies	x	x	

Research Area	Sub topic	Workshop		
		Dhaka	Dar es Salaam	Nairobi
	Skills and capacity building		x	x

A1.4 Final Part 1 workshop

A Final Theme 1 project workshop was held in London on 8th February 2019, at which DFID, the HVT Team Leader and Theme 1 Lead attended. Also present at the meeting was the Chair of the HVT Steering Committee and members of the HVT Technical Advisory Panel and the project sub-theme leads.

Aim and objectives

The aim of the workshop was to present the work achieved to date and to elicit advice from, DFID, the HVT Team and its Technical Advisory Panel for the remaining aspects of the project.

The associated objectives were to:

> Present final conclusions and outcomes of the Part 1 study;
> Agree on titles and abstracts for SoK journal papers;
> Describe the methodology proposed to select possible partner countries and to identify these countries;
> Present the methodology for assessing the capacity building requirements of selected countries.

Workshop programme

The workshop began with presentations by the sub-theme leads on the outcomes and conclusions of the Part 1 research study. This was followed by discussion with DFID about achieving a balance between application of good practice informed by the current state of knowledge, and undertaking foresight and future scenario analysis to anticipate the future requirements for high volume transport in LICs.

The sub-theme leads then discussed the title and abstracts of the proposed state of knowledge journal papers. The HVT PMU indicated which abstracts required attention to provide more clarity on the expected contents of the paper.

The project team presented the findings from the stakeholder engagement survey, and also the country selection methodology, as well as the approach for capacity building analysis.

Lastly, final dates for completion of concluding project activities and delivery of the State of Knowledge journal papers was agreed between the project team and the HVT PMU.

Appendix 2: Stakeholder Engagement Questionnaire

Questionnaire

The UK Department for International Development (DFID) has commissioned a £14 million, five year, research programme to address research and associated capacity building, in High Volume Transport for low-income countries. Four themes are addressed within the programme, namely (i) long distance strategic road and rail, (ii) Urban Transport, (iii) Low Carbon Transport and, (iv) Gender, Vulnerable Groups and Inclusion in High Volume Transport. The programme comprises two parts. Part 1 will establish the state of knowledge associated with the four theme areas and will suggest a programme of relevant research activities to be carried out in Part 2 as well as identifying potential partnering low-income countries (LICs) and associated organisations.

A consortium led by Cardno IT Transport was awarded the contract in Part 1 to conduct a 'State of Knowledge' (SoK) study to formulate the Applied Research Programme and Implementation Strategies' for **Theme 1, long distance strategic road and rail.**

Your institution has been identified as a key stakeholder in the HVT Programme. We would be grateful if you could participate in the stakeholder consultation by completing this short questionnaire and letting us know your opinions regarding potential research areas for Theme 1.

Please be aware that all responses will be treated as confidential and all data will be reported in an anonymous format.

RESPONDENT BACKGROUND

1.1 Job Title / Position……

1.2 Institution……

1.3 Country……

1.4 Gender……

Theme 1 has been split into the following four sub-themes:

1. Long Distance Road Infrastructure
2. Long Distance Rail Infrastructure
3. Road and Rail Transport Services
4. HVT Corridors and Networks

We would be grateful if you could give us your opinion of the priority research areas in the above four sub-themes:

Road infrastructure

Road infrastructure is the physical structure of the road pavement as well as earthworks, structures, and ancillary furniture. The research aims to address the sustainability of infrastructure in low income countries by addressing two main themes: (i) *Lower whole life-cycle costs (Road geometric, pavement and drainage design standards; Construction and maintenance practices and materials; Overloading; Asset Management)*, and; (ii) *Securing finance and governance (Road funds and public-private partnerships (PPP); Governance)*. These areas are elaborated below.

Lower whole life-cycle costs:

i. *Road geometry, pavement and drainage design standards* – the research will update the knowledge and understanding to ultimately help optimise the cost of building roads, and improve road safety through the consideration and use of appropriate geometric, pavement and drainage design standards. Amongst other things, the research will investigate relationship between design speed controlled by highway geometry; and practical utilisation (speed and travel times); whole life-cycle cost pavement design, and; drainage design for climate resilience.
ii. *Construction and maintenance practices and materials*– the research will update the knowledge and understanding to ultimately help reduce the cost and improve the quality of the provision and maintenance of roads, via innovative construction and maintenance approaches and via consideration of marginal / recycled materials. Research will compare using socio-economic means alternative construction and maintenance approaches (e.g., heavy plant vs labour based), technologies (e.g. surface dressing vs in-situ recycling) and the use of marginal materials. Research will also consider the effectiveness and durability of maintenance types (e.g. crack sealing).
iii. *Overloading* – the research will update the knowledge and understanding to ultimately help reduce overloading and therefore the premature failure of roads. Research will investigate how to encourage, incentivise and enforce overloading control. The use of associated technology will also be considered.
iv. *Asset management* – the research will investigate processes and technologies to reduce the life cycle costs of maintaining existing and new road infrastructure through the use of risk informed approaches. Research will focus on (i) investigating on introducing risk informed approaches within life cycle cost decision making to road management and (ii) using big data, technology and computational approaches (e.g. machine learning, deep learning) to support asset management decision making.

Securing finance and governance:

i. *Road Financing* – the research will update the knowledge and understanding to ultimately help secure existing funding sources and develop new ones. Research will focus on innovations associated with road use charging and public-private partnerships (PPPs). Reasons for the declining success of road reforms introduced in the last 40 years.
ii. *Governance* – the research will update the knowledge and understanding to ultimately help develop the national construction industry and improve build quality, encourage competitiveness and transparency. Research will therefore focus on the most appropriate contracting regimes and practices in low-income countries. The impact and negation of corruption practices will also be considered.

Based on the above, please rank the relevance of the identified research areas for our country and / or institution.

Research areas	Relevance to your country / institution					
	Very High	High	Medium	Low	Very Low	Don't know
Road geometry, pavement and drainage design standards						
Construction and maintenance practices and materials						
Overloading						
Asset management						
Road Financing and PPP						
Governance						

Please let us know of any <u>additional</u> research areas in road infrastructure that you think are of high or very high relevance:

1.

2.

3.

4.

Rail infrastructure

The rail infrastructure is the physical infrastructure that guides a railway vehicle. It consists of the railway track, earthworks, structures, catenary, switches and crossings and signalling. The research will initially understand, via international benchmarking, the relative current performance of railways in developing countries. This will enable later research to identify appropriate technologies which can be used to introduce step changes in the design, maintenance and operation of railway systems. Two themes will be addressed (i) *Data collection, benchmarking and capacity development* and (ii) *Technical and operational standards and new technologies*. These themes are elaborated below.

Data collection, benchmarking and capacity development:

i. *Data collection*– the research will enable the current performance of railways in Sub-Saharan Africa and South Asia to be better known as currently much of the existing data is outdated. The research will consist of collecting performance data from railway organisations in both regions.
ii. *Regional and international benchmarking* - Research will benchmark railways worldwide enabling the identification of high-level railway investment requirements
iii. *Potential for network development* – Research will investigate the potential for railways in countries which do not currently have them. The research will carry out economic analyses of corridors and regional trade to identify the potential benefits that can be achieved by building railway lines in these countries.

Technical and operational standards and new technologies:

i. *Regional inter-operability* – the research will update the knowledge and understanding to ultimately help facilitate cross border train movements as currently many countries do not have the same standards (e.g. track gauge). Research will gather infrastructure and operational standards for track equipment, signalling systems, and rolling stock, in order to provide cost estimates of improving interoperability.
ii. *Safety improvement* – the research will update the knowledge and understanding to ultimately help improve railway safety in Sub-Saharan Africa and South Asia, where it is significantly lower than in other countries. This research will conduct RAMS (reliability, availability, maintainability, and safety) analyses on selected networks to identify critical points in interfaces between infrastructure and operations that need addressing.
iii. *Technical capability and new technologies* – the research will update the knowledge and understanding to ultimately allow appropriate technology to be incorporated within the railway system. The research will investigate new technologies which are fit for purpose and that have a high impact to investment ratio.

Based on the above, please let us know the relevance of the identified research areas for your country and/or institution.

Research areas	Relevance to your country / institution					
	Very High	High	Medium	Low	Very Low	Don't know
Data collection						
Regional and international benchmarking						
Potential for network development						

Research areas	Relevance to your country / institution					
	Very High	High	Medium	Low	Very Low	Don't know
Regional interoperability						
Safety improvement						
Technical capability and new technologies						

Please let us know of any additional research areas in rail infrastructure that you think are of high or very high relevance:

1.

2.

3.

4.

Road and rail transport services

Road and rail transport services are an important part of the chain that enables value to be maximised from investments, and require state involvement to ensure safe and effective provision. The programme will address two broad themes: (i) *Regulation, concessions and institutional restructuring*, and (ii) *Road and rail freight services*. These themes are elaborated below.

Regulation, concessions and institutional restructuring:

i. *Railway concession design and delivery procurement mechanism* - research will update the knowledge and understanding to ultimately help improve the delivery and efficiency of railway services. The research will investigate best practices, including different forms of competition and franchising, to induce efficiency in the rail sector in Low Income Countries (LICs).
ii. *Railway concessions and infrastructure* – research will update the knowledge and understanding to ultimately help improve the integration between operations and infrastructure management. The research will consider the circumstances under which it is appropriate to separate the management of railway services and the management of the infrastructure in Low Income Countries (LICs), and the most appropriate models for so doing.
iii. *Regulation of infrastructure and services* – research will update the knowledge and understanding to ultimately help ensure certainty of funding and fair prices, whilst ensuring safety. Research will identify the most suitable regulation, contractual and structural approaches.
iv. *Public authority and skills* – research will update the knowledge and understanding to ultimately help improve regulation and strategic planning of railways. Research will investigate the types of regulatory frameworks that are appropriate for railway operation and the required powers, capacity and legal status governmental and regulatory bodies require for railways in Low Income Countries (LICs).

Road and rail freight services:

i. *Cross border road and rail freight* - Research will investigate the potential trade and economic benefits of reducing wait times and uncertainty at borders, and the scale of increase in cross-border freight that might be achieved. Research will also investigate the mechanisms available for reducing waiting time, including e-border technology.

Based on the above, please let us know the relevance of the identified research areas for your country and/or institution.

Research areas	Relevance to your country / institution					
	Very High	High	Medium	Low	Very Low	Don't know
Railway concession design and delivery procurement mechanism						
Railway concessions and infrastructure						
Regulation of infrastructure and						
Public authority and skills						
Cross border road and rail freight						

Please let us know of any additional research areas in road rail services that you think are of high or very high relevance:

1.

2.

3.

4.

HVT corridors / networks

An HVT network/corridor is the network of arterial and main linear inland surface transport routes of a country. HVT networks connect the main production, consumption and distribution centres with manufacturing hubs, gateway ports and airports and establishes linkages with the transport networks of neighbouring countries. Research will focus on (i) *Provision and management of corridors and networks* and (ii) *Effects and impacts of corridors and networks*.

Provision and management of corridors and networks:

i. *Role of government in developing and managing transport networks/corridors* – research will update the knowledge and understanding to ultimately help improve public sector engagement in the management of transport networks and corridors. Research to identify the stakeholders and their potential roles at various stages of network/corridor planning, development and operation, and how governments may nurture institutions to forge partnership/collaboration with such actors.
ii. *Management of transport networks and corridors* – research will update the knowledge and understanding to ultimately help improve the quality of transport and logistics services and optimize the use of alternative routes and transport modes in the corridor. Research will identify the current issues, best practices and options to address various issues in corridor management (domestic and transnational).
iii. *Improvement of trade and transport facilitation/transit procedures and pricing of regional transport infrastructure services* – research will update the knowledge and understanding to ultimately help reduce the cost of trading and thereby increase the volume of inter-country trade and economic growth on both sides of a border. Research on current issues, best practices and options available including ICT applications in border clearance procedures and implementation of intelligent transport systems to increase the level of transport security and border crossing efficiency.
iv. *HVT transport networks/corridors to support more inclusive development in rural areas* - research will update the knowledge and understanding to ultimately help improve functional linkages between local rural communities and the national economy. Research on how and what type of intervention measures may be necessary to support development in rural areas and take the advantage of improved transport and logistics services along a transport network/corridor.

Effects and impacts of corridors and networks:

i. *Development impacts of railway projects* - the research will update the knowledge and understanding to ultimately help enable an increase in efficiency in the overall supply and distribution chain, and reduce the carbon footprint of freight transport. Research will evaluate recent rail projects, including both passenger and railway freight corridors and also the research will assess the impacts of multi-modal transport projects/operations with rail as a component.
ii. *Effects on spatial distribution of income and other aspects of economy* – the research will update the knowledge and understanding to ultimately help realise the potential benefits of improved transport infrastructure and services in a transport network/corridor. Research to assess current analytical models used to understand the economic impacts of transport projects and examine how such models may be adapted to help in policy analysis and policy formulation for spatial planning.

Based on the above, please let us know the relevance of the identified research areas for your country and/or institution.

Research areas	Relevance to your country / institution					
	Very High	High	Medium	Low	Very Low	Don't know
Management of transport networks and corridors						
Improvement of trade and transport facilitation/transit procedures and pricing of regional transport infrastructure services						
HVT transport networks/corridors to support more inclusive development in rural areas						
Development impacts of railway projects						
Effects on spatial distribution of income and other aspects of economy						

Please let us know of any additional research areas in transport networks/corridors that you think are of high or very high relevance:

1.

2.

3.

4.

Return to itt@cardno.com by Friday 7th December at the latest.

Thank you for taking part in this Survey.

2.2 Questionnaire results and analysis

The stakeholder engagement questionnaire was distributed to 70 academic and government institutions from DfID priority LICs in Sub-Saharan Africa and South Asia. Twenty-nine of these are in East Africa, six in West Africa, 10 in Southern Africa and 17 in South Asia. An electronic copy was made available through Survey Monkey (see https://www.surveymonkey.co.uk/r/2ZX69J8), an online survey distribution and analysis system.

A total of 38 responses were received via Survey Monkey and an additional 17 responses received in hard copy format via our workshops.

Analysis of 55 responses was undertaken, and Figure 2.1 presents the responses received by region. Approximately 40 respondents were from Sub-Saharan Africa and 10 from Asia. In addition, three respondents were from the United Kingdom (and one is unknown). Furthermore, an employee of the Zambia Road Development Agency sent an email on 20 December 2018, copied to 418 (four hundred and eighteen) of his colleagues, indicating that the Agency had completed the questionnaire on 20 December 2018.

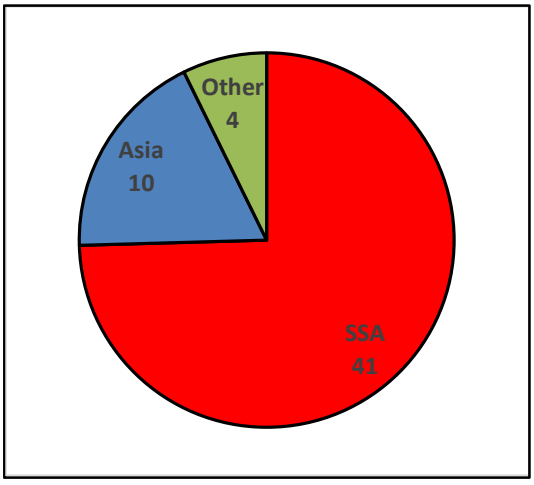

Figure AII.I: Questionnaire responses by region

For the reasons given above, the country responses can be regarded as a proxy for engagement with the HVT programme (Phase 1). Though not a perfect indicator, Phase 1 engagement can be a possible predictor of the likely engagement for Phase 2 of the HVT programme. Figure AII.II: presents responses by country. In Sub-Saharan Africa, the two countries that provided the greatest number of questionnaire responses were Kenya and Tanzania (in part because a workshop was held there) and Ethiopia. Out of these three countries, Tanzania scored highest in our country selection ranking in Africa. As indicated above with the Zambia Road Development Agency, the number of responses may not be a true indicator of country buy-in. Including Zambia, all five countries that scored the highest in our country selection process have provided at least one response. In South Asia, Bangladesh provided the greatest number of questionnaire responses followed by Pakistan and Afghanistan. These three countries were considered priority countries (along with Indonesia).

Taking the above into account would suggest that this consultation exercise confirms (with the caveats stated above) the partial buy-in of those countries we identified in the Interim Report, as partner countries for Part 2 of the HVT Programme, namely:

> Sub-Saharan Africa: Nigeria, Kenya, Tanzania, Zambia and Mozambique
> South Asia: Indonesia, Bangladesh, Afghanistan and Pakistan.

However, the participation in the questionnaire of organisations from Nigeria and Mozambique on the surface however might be regarded as weak (one response each), particularly as both countries are engaging meaningfully in ReCAP. Further, Nigeria is populous and has a strong research capacity in comparison to other countries in the region. However, there may be extenuating circumstances and as mentioned above with the example of Zambia, the number of responses do not in themselves reflect buy-in. Ethiopia was ranked highest by the Theme 2 ranking process, was in the top seven countries according to our (Theme 1) road ranking.

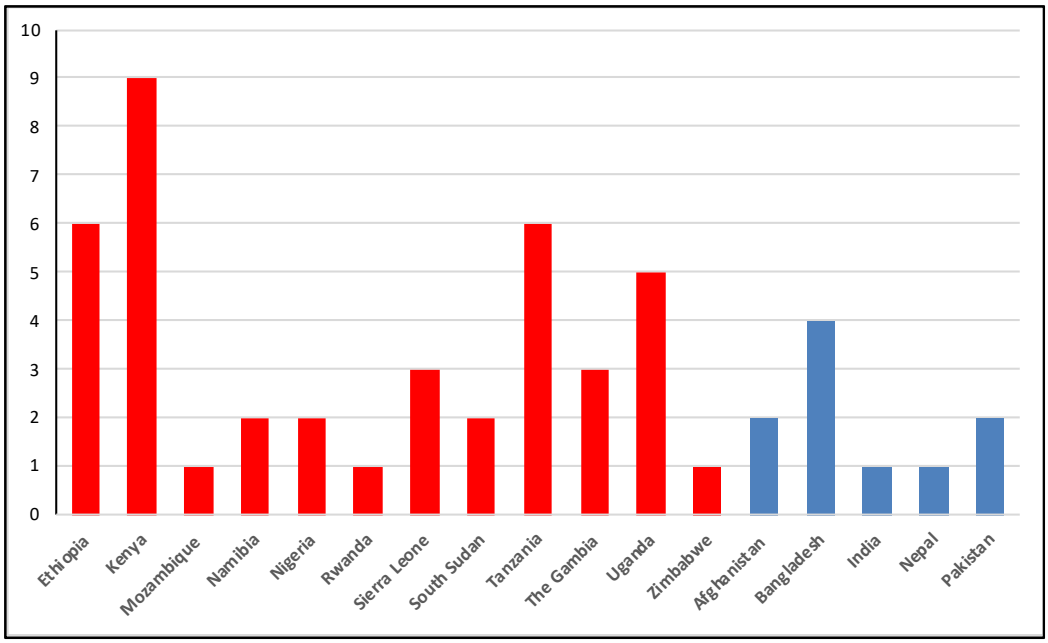

Figure AII.II: Questionnaire responses by country

The questionnaire solicited responses regarding 18 sub-topics across the four sub-themes. These have been aggregated into the eight research questions. Respondents rated the relevance of each sub-topic to their country and institution (very high, high, medium, low, very low). A scoring system was adopted whereby 4 was given to a response rating of very high, 3 for high, 2 for medium and 1 for low and 0 for very low. Noting that each sub-theme has two broad research areas and a number of associated sub-topics the average scores by sub-theme, research area and sub-topic are presented in Table AII.1. A second rating system was used to rate these average scores. Accordingly, an average score S of $4 \geq S > 3$ was rated as "very highly relevant", an average score of $3 \geq S > 2$ as "highly relevant", a score of $2 \geq S > 1$ as "relevant" and $1 \geq S > 0$ as "low relevance". A score of zero was considered to indicate that the research topic was "irrelevant".

Each single research topic was regarded on average as at least "highly relevant", strongly endorsing the identified research areas (and indeed the findings of the workshops). For example, the sub-topic for railway regional and international benchmarking (which was regarded as least relevant) obtained a

relevance score of 2.78 (i.e. "highly relevant"). Secondly, it is probable that there is some bias in the results obtained due to a possible bias in the total number of respondents with expertise in the research topics suggested.

Table AII.I: Summary of respondents' relevance scores

Research Area		Questionnaire sub topic	Average sub- topic score	Average research area score
Road Infrastructure 1 and 2	1. Affordable high volume roads resilient to climate change and traffic demand	Road geometry, pavement design and drainage design standards	3.18	3.27
		Construction and maintenance practices and materials	3.37	
		Overloading	3.12	
		Asset management	3.40	
	2. Spending scarce funds better by maximising local involvement	Road financing and PPP	3.26	3.16
		Governance	3.06	
Rail Infrastructure 1 and 2	3. New approaches for improved network capacity that are affordable and sustainable	Regional and international benchmarking	2.88	3.03
		Network development	3.06	
		Interoperability	3.17	
	4. New approaches for improving commercial viability of railway networks	Safety improvement	3.16	3.19
		Technical capability and new technologies	3.22	
Road and Rail Services 1 and 2	5. Improving rail network performance to deliver competitive services	Railway concession design and delivery procurement mechanisms	3.20	3.10
		Railway concessions and infrastructure	2.93	
		Regulation of infrastructure	3.17	
	6. Reforming transit transport along corridors and across borders	Cross border road and rail freight	3.22	3.26
		Improvement of trade and transport procedures and pricing of regional transport infrastructure services	3.30	
Corridors and Networks 1 and 2	7. Stakeholder governance structures for smart transport corridors	Management of transport networks and corridors	3.50	3.34
		Public authority and skills	3.19	
	8. Spatial distribution impacts of corridor projects on income, society and the economy	HVT transport networks/corridors to support more inclusive development in rural areas	3.21	3.11
		Development impacts of railway projects	2.91	
		Spatial distribution of income and other aspects of economy	3.20	

The respondents' score by each Research Area is presented in Figure AII.III. Note the darker shade of blue represents the highest ranking within each sub-theme.

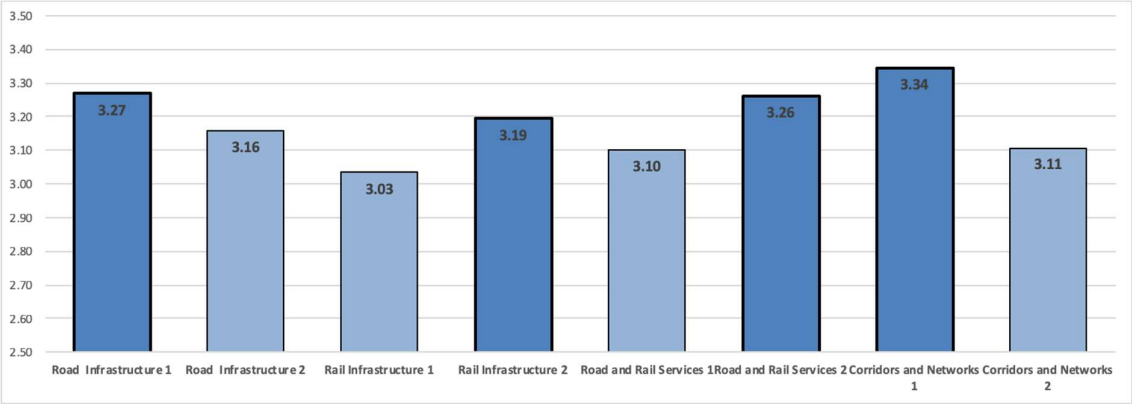

Figure AII.III: Respondents' scores by research area

It is likely that a respondent with expertise in a particular field would rate research in their field as more relevant than perhaps research related to another field. To address this, the average scores determined for each sub-theme would need to be weighted in some way according to the stated expertise of the respondents. However, such detailed analysis of the results has not been possible. For this reason we believe that it would not be appropriate at this stage to rank the research projects across the eight research areas. Rather, it is perhaps most suitable to rank the projects within each sub–theme. Therefore Table AII.II presents the revealed preference for each research area within each sub-theme. Statistical tests have been conducted to assess significance.

Table AII.II: Respondents' preferences for research

Sub-Theme	Research Area (% Revealed Higher Preference)		P value	Significant at 95% CL
Road Infrastructure	Affordable high volume roads resilient to climate change and traffic demand (52%)	Spending scarce funds better by maximising local involvement 48%	0.33	No
Rail Infrastructure	New approaches for improved network capacity that are affordable and sustainable 41%	New approaches for improving commercial viability of railway networks 59%	0.13	No
Services	Improving rail network performance to deliver competitive services 48%	Reforming transit transport along corridors and across borders 52%	0.19	No
Corridors and Networks	Stakeholder governance structures for smart transport corridors 69%	Spatial distribution impacts of corridor projects on income, society and the economy 31%	0.03	Yes

Note: pairwise t-test conducted.

Accordingly, based on the results presented above, the following research areas can be prioritised within each sub-theme:

> Road Infrastructure – No priority can be assigned.
> Rail Infrastructure – 59 % of respondents expressed a preference for **new approaches for improving commercial viability of railway networks**. (Note however this is not significant at the 95% confidence level)
> Road and Rail Transport Services – No priority can be assigned.
> Corridors and Networks – 69% of respondents expressed a preference for **stakeholder governance structures for smart transport corridors**. (This is significant at the 95% confidence level)

In addition, we received qualitative responses from the questionnaires, which have been analysed in order to identify any patterns. These can be summarised as follows:

> Road Infrastructure - The issue of road safety featured with some (four) respondents citing the need to conduct research into safety audit methodologies. This mirrors the workshops. Road safety was a theme it was agreed would be addressed in Theme 4 of the HVT programme. Some (three) respondents also highlighted the need for investigations into public involvement and participation in road infrastructure planning. It could be argued that this would be addressed by the questions related to road infrastructure research area 2. Two respondents highlighted the need to consider IT and emerging technology in the road sector, perhaps as a reminder that this is also pertinent to the road sector (one might argue that this aspect has been addressed by the asset management sub topic). An interesting recommendation included research into vehicles (in contrast to infrastructure). One respondent stated the need for predicting traffic loading (presumably in contrast to the more established methodologies in predicting average annualised daily traffic). One respondent provided the suggestion that bridges should be incorporated within the road infrastructure research;
> Rail Infrastructure – Four respondents recommended research into freight railways including a focus regarding the advocacy / influencing decision makers to consider allocation of investment. The need for conducting research into developing low cost railways (presumably as a trade-off with respect to level of service) was cited by one respondent. One respondent highlighted the need for conducting research into the environmental impacts of railways. Interestingly (psychological) research into the interaction between human and machines in the rail sector was recommended (by on respondent). Several respondents made suggestions that links rail infrastructure research with some of the research areas also covered in Corridors and Networks (sub-theme 4). Interestingly a respondent recommended research in public vandalism and theft of railway property;
> Road and Rail Transport Services – Three respondents highlighted the need to consider inter-modality within road and rail and passenger and freight services - this is a reminder of the interactions between the sub-themes. One respondent suggested conducting research into appraisal methodologies for estimating the impacts on sustainability (presumably with regards to environmental climate change). Research into passenger subsidies and harmonisation of taxes at a regional level to encourage international trade and trucking was also recommended;
> HVT Corridors and Networks – the qualitative responses did not necessarily recommend additional new areas of research into corridors /networks, however, some of the following areas were reiterated. Two respondents recommended considering IT systems across entire networks with a focus on internet-based money transactions (with one respondent specifically highlighting block chain technologies). One respondent highlighted the need for research into inclusive access. The need for research into encouragement of the private sector and regulation of freight rates across networks were also recommended (this it could be argued was addressed by research area 6 in sub-theme 3).

Appendix 3: Capacity Building Analysis – Self-Assessment Questionnaire

1 Building Block 1: External

Key objective: Recognise and support highways research within research organisations in the country.

Element: Government, donor / MDB and industry engagement

Issue: Facilitate an enabling environment which helps to support:

- Research and research uptake;
- Research organisations in the highways sector;
- Organisations to carry out research financially.

QUESTION	YES/NO	JUSTIFICATION/COMMENT
1.1 (a) Does the government have a policy to support transport research in the country?		
1.1 (b) Is government funding available for transport research institutions?		
1.1 (c) Is the government funding < $ 1 million USD annually?		
1.1 (d) Is the government funding > $ 1 million USD annually?		
1.2 (a) There are no research organisations in the country.		
1.2 (b) There are no transport focused research organisations in the country.		
1.2 (c) The country has organisations actively carrying out transport related research.		
1.2 (d) The country has at least one university active in transport related research.		
1.3 (a) There is no funding available for highways research in the country.		
1.3 (b) Organisations in the country are engaged in highways related research projects to the value of up to £500, 000/year		
1.3 (c) Organisations in the country are engaged in highways research projects worth to the partaking organisations of between £500, 000 - £1,000, 000 / year		
1.3 (d) Organisations in the country are engaged in highways research projects worth to the organisations of over £1million.		

2 Building Block 2: Institutional

Key objectives: Recognise and support highways research within the entity, by providing an adequate organisational structure, an adequate number of trained staff and adequate facilities.

Element: Research policy and strategy

Issue:

> The existence of research policy and strategy that is supported by senior leadership;
> Need to recruit and retain capable staff by offering competitive salaries;
> An appropriate organisational structure with an adequate complement of appropriately trained staff with the necessary core competencies;
> The extent to which staff involved in the process understand and support it and are willing to contribute and improve it;
> Engagement locally and nationally in highways research.

QUESTION	YES/NO	JUSTIFICATION/COMMENT
2.1 (a) Does the entity have an informal research policy and associated strategy?		
2.1 (b) Does the entity have a formal research policy?		
2.1 (c) Does the entity's formal research policy take into account stakeholder needs & expectations?		
2.1 (d) Is the entity's formal research policy developed in conjunction with stakeholders?		
2.2 (a) Does the entity carry out transport research?		
2.2 (b) Has the entity attracted transport research funding in the last five years?		
2.2 (c) Has the entity had transport research funding in the last year?		
2.2 (d) Is the entity currently involved in multi-disciplinary international transport research?		
2.3 (a) Does the entity's organisational structure identify roles, responsibilities and competencies of key research staff?		
2.3 (b) Are the roles, responsibilities and organisational commitment for research staff documented?		
2.3 (c) Are key staff subject to a review of their roles, responsibilities and competencies at least every 3 years?		
2.3 (d) Are key staff subject to a review of their roles, responsibilities and competencies at least annually?		
2.4 (a) Does the entity offer research training opportunities for staff?		
2.4 (b) Does transports specific research training occur for primary staff?		
2.4 (c) Does the entity have an on-going transport specific training programme for primary staff?		

QUESTION	YES/NO	JUSTIFICATION/COMMENT
2.4 (d) Does the on-going transport specific training programme for primary staff include assessment?		
2.5 (a) Are the entity's salaries for research staff much lower (+/-50%) than comparable private sector jobs?		
2.5 (b) Are the entity's salaries lower (+/-20%) than comparable private sector jobs?		
2.5 (c) Are the entity's salaries roughly the same as comparable private sector jobs?		
2.5 (d) Are the entity's salaries greater than comparable private sector jobs?		

3 Building Block 3: Technical

Key objective: Staffs' information literacy (skills in finding and appraising academic literature), thematic topic knowledge, knowledge application and justification of research methodologies, critical analysis sills, ability to develop research proposals.

Element: Research skills of staff

Issue:

- Information literacy (skills in finding and appraising academic literature);
- Thematic topic knowledge;
- Knowledge application and justification of research methodologies;
- Critical analysis sills;
- Ability to develop research proposals.

QUESTION	YES/NO	JUSTIFICATION/COMMENT
3.1 (a) < 25% of research staff have a PhD		
3.1 (b) 25% ≤ research staff < 50% have a PhD		
3.1 (c) 50% ≤ research staff < 75% have a PhD		
3.1 (d) 75% ≤ research staff have a PhD		
3.2 (a) < 25% of research staff have attended a research related training course in the last year.		
3.2 (b) 25% ≤ research staff < 50% have attended a research related training course in the last five year.		
3.2 (c) 50% ≤ research staff < 75% have attended a research related training course in the last five year.		
3.2 (d) 75% ≤ research staff have attended a research related training course in the last year.		
3.3 (a) < 25% of research staff are the main supervisor of at least one student.		
3.3 (b) 25% ≤ research staff < 50% are the main supervisor of at least one student.		
3.3 (c) 50% ≤ research staff < 75% are the main supervisor of at least one student.		
3.3 (d) 75% ≤ research staff are the main supervisor of at least one student.		
3.4 (a) ≤5% of research staff lead current research projects		
3.4 (b) 5% ≤ research staff < 10% lead current research projects		
3.4 (c) 10% ≤ research staff < 30% lead current research projects		
3.4 (d) 30% ≤ research active staff lead current research projects		

4 Building Block 4: Dissemination

Key objective: The ability to disseminate research to a non-specialist audience.

Element: Research dissemination skills

Issue:

- Academic writing skills;
- Knowledge management;
- The utilisation of e-communication tools;
- Skills in communicating with end users and non-specialists.

QUESTION	YES/NO	JUSTIFICATION/COMMENT
4.1 (a) < 25% of research staff have an active presence on an online research website (e.g. Research Gate)		
4.1 (b) 25% ≤ research staff < 50% have an active presence on an online research website (e.g. Research Gate).		
4.1 (c) 50% ≤ research staff < 75% have an active presence on an online research website (e.g. Research Gate)		
4.1 (d) 75% ≤ research staff have an active presence on an online research website (e.g. Research Gate).		
4.2 (a) < 25% of research staff have published an article in a peer reviewed publication (journal or conference) in the last two years.		
4.2 (b) 25% ≤ research staff < 50% have published an article in a peer reviewed publication (journal or conference) in the last two years.		
4.2 (c) 50% ≤ research staff < 75% have published an article in a peer reviewed publication (journal or conference) in the last two years.		
4.2 (d) 75% ≤ research staff have published an article in a peer reviewed publication (journal or conference) in the last two years.		
4.3 (a) < 25% of research staff have presented a paper at an international conference in the last two years.		
4.3 (b) 25% ≤ research staff < 50% have presented a paper at an international conference in the last two years.		
4.3 (c) 50% ≤ research staff < 75% have presented a paper at an international conference in the last two years.		
4.3 (d) 75% ≤ research staff have presented a paper at an international conference in the last two years.		
4.4 (a) < 25% of research staff have been asked to present a key note lecture outside their institution in the last five years.		

QUESTION	YES/NO	JUSTIFICATION/COMMENT
4.4 (b) 25% ≤ research staff < 50% have been asked to present a key note lecture outside their institution in the last five years.		
4.4 (c) 50% ≤ research staff < 75% have been asked to present a key note lecture outside their institution in the last five years.		
4.4 (d) 75% ≤ research staff have been asked to present a key note lecture outside their institution in the last five years.		

5 Building Block 5: Uptake

Key objective: Research of high impact

Element: Industrial enthusiasm for research

Issue:

> if and how the products of research are embraced by the local and national transport industry

QUESTION	YES/NO	JUSTIFICATION/COMMENT
5.1 (a) < 5% of research staff have a research grant.		
5.1 (b) 5% ≤ research staff < 10% have a research grant.		
5.1 (c) 10% ≤ research staff < 20% have a research grant.		
5.1 (d) 20% ≤ research staff have a research grant.		
5.2 (a) < 1% of research staff have a patent.		
5.2 (b) 1% ≤ research staff < 10% have a patent.		
5.2 (c) 10% ≤ research staff < 20% have a patent.		
5.2 (d) 20% ≤ research staff have a patent.		