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Interactions between improved rural access infrastructure and transport services provision

Final Report

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Cover photos. Paul Starkey: Motorcycles on the Chekimaji-Kawaya road, Hai District, Tanzania and a 35-seat bus rounding hairpin bend with stone soling on the Kavre road studied in Nepal.

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Abstract

The 'Interactions: Maintenance-Provision of Access for Rural Transport Services (IMPARTS)' project has been examining how investments in low-volume rural road (LVRR) construction (provision) and maintenance (preservation) affect rural transport services (RTS). Improved RTS are vital for enabling access to facilities including markets, health facilities, education and socio-economic opportunities. While road investments are often justified by envisaged RTS improvements, few road authorities collect 'before' and 'after' RTS information. IMPARTS researchers surveyed two roads in Nepal that had been built a decade ago, and six roads in Tanzania that had received investments in the past 4-10 years to remove 'bottlenecks' that had restricted all-season access. Historic traffic data sets available from before and after the investments were supplemented by 2019 data collected by this project. Research findings in Nepal and Tanzania have been presented in separate reports.

This report discusses the practical implications of the survey results as well as findings concerning possible options to improve RTS. The Nepal research highlighted the resilience of simple, well-engineered earth roads made with labour-based methods including cobblestones and stone soling on steep gradients and simple drifts for water crossings. The Tanzania research concluded that the investments had created all-season roads but had not affected RTS because the low passenger demand had not changed. The planning would have benefited from greater understanding of the people's travel destinations and market demand. Transport services agencies are small and largely ignore rural transport services. Improving rural transport services is problematic as there are many informal sector operators. Formalising them is possible but difficult. There are few good lessons of how subsidies can improve rural transport services in low income countries. Improvements in RTS are most likely to be achieved through district level participatory initiatives to introduce ways of consolidating passenger numbers, sharing routes and working to timetables. It is recommended that road agencies and transport services agencies collaborate (or integrate). Road agencies should include transport services outcome indicators in their maintenance database. They should use participatory processes in the early stages of planning to prioritise district level road investments and take account of increasing motorcycle use. Roads and motorcycle trails should be fit for purpose for the prevailing vehicles. Regular road maintenance is essential, and much can be achieved through local length workers and spot improvements.

Key words

Tanzania; Nepal; Transport services; Motorcycle taxis; Traffic counts; Rural mobility; Rural road outcomes; Rural road impacts; Rural road preservation; Rural road provision

Acronyms, Units and Currencies

AfCAP	Africa Community Access Partnership
AFCAP1	Africa Community Access Partnership Phase 1
AfDB	Africa Development Bank
ARMP	Annual Road Maintenance Plan
AsCAP	Asia Community Access Partnership
bn	Billion
BRT	Bus Rapid Transit
DFID	Department for International Development, UK
DoLI	Department of Local Infrastructure
DoLIDAR	Department of Local Infrastructure Development and Agricultural Roads
DROMAS2	District Road Management System version 2
DRSP	District Roads Support Programme
eg	for example
EOD	Environmentally Optimised Design
GBP	UK pound sterling (Great Britain pound) In Jan 2020, GBP 1 = TZS 3000; TZS 1 = GBP 0.00033
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HD	High Definition
ICF	International Climate Fund
IMPARTS	Interactions: Maintenance-Provision of Access for Rural Transport Services
IRAT	Improving Rural Access in Tanzania
IRI	International Roughness Index
kg	Kilogram
km	Kilometre
h	Hour
LATRA	Land Transport Regulatory Authority
LIC	Low Income Countries
LTA	Land Transport Authority
LVRR	Low-Volume Rural Road
m	Metre
M	million
Mesa	Million equivalent standard axles (per year)
mins	minutes
NGO	Non-governmental organisation
NTA	National Transit Authority
No.	number
OSM	Open Street Map
PO-RALG	President's Office for Regional Administration and Local Government
ReCAP	Research for Community Access Partnership
RTP	Rural Transport Premium
RTS	Rural Transport Services
RTSI	Rural Transport Services Indicators
SEACAP	South East Asia Community Access Programme
SDC	Swiss Development Cooperation
sq	Square
SSA	Sub-Saharan Africa
SUMATRA	Surface and Marine Transport Regulatory Authority
SuM4All	Sustainable Mobility for All (World Bank, Washington DC)
TANROADS	Tanzania National Roads Agency
TARURA	Tanzania Rural and Urban Roads Agency
TRL	Transport Research Laboratory
Tsh / TZS	Tanzania shilling (TZS). In Jan 2020, TZS 1 = GBP 0.00033 = USD 0.00043; GBP 1 = TZS 3000; USD 1 = TZS 2300
UK	United Kingdom
UKAid	United Kingdom Aid (Department for International Development, UK)
USD	United States Dollar In Jan 2020, USD 1 = TZS 2300 TZS 1 = USD 0.00043
USDc	United States Dollar cents
VOC	Vehicle Operating Costs

Executive Summary

The 'Interactions: Maintenance-Provision of Access for Rural Transport Services (IMPARTS)' research project studied how the provision and maintenance of low-volume rural roads (LVRRs) impact rural transport services (RTS) and the mobility of people and their goods. There should be an integrated approach to the provision-preservation-services continuum to ensure road investments are well planned, cost-effective and appropriate to the transport needs of rural communities. The project was commissioned by the Research for Community Access Partnership (ReCAP), funded by the Department for International Development (DFID) of the United Kingdom (UK).

The first project phase involved literature studies and consultations with ReCAP stakeholders in Africa and Asia. This confirmed that rural road investments can have beneficial impacts, with improved access to markets, healthcare, education and economic opportunities. While transport services provide a mechanism for achieving the impacts, little data is collected on RTS. There are few datasets spanning road investments, with 'before' and 'after' information on the quality and quantity of RTS and their tariffs. Within ReCAP countries, the best sequences of data identified were for LVRR investments in Nepal and Tanzania. This project re-surveyed selected roads in 2019 to try to determine how the road investments had influenced RTS. Concurrently, the researchers reviewed and discussed with stakeholders ways by which RTS could be improved, possible roles of formal sector operators and whether subsidies were a realistic option.

Two roads were surveyed in Nepal that had been constructed ten years ago using labour-based methods. These were well-engineered earth roads, with cobblestones and stone soling sections and labour-based drifts for water crossings. The roads had survived ten years with little maintenance. The new roads had allowed buses to operate, but numbers of daily buses had not increased over the years.

Six roads were surveyed in Tanzania. One was a road rehabilitated in 2012 with experimental sections under an AFCAP1 project. The other five had received investments between 2013 and 2017 to remove 'bottlenecks' (road sections that severely restricted all-season traffic), with funding from the Improving Rural Access in Tanzania (IRAT) project, supported by DFID. Investments included rehabilitated sections, culverts and two bridges. On all six roads motorcycles were the main means of transport. Motorcycle taxis were the only transport services on three roads, and on the remoter sections of two more roads. Only one road had regular bus services along its length. Apart from motorcycle growth, other traffic and transport services had not changed much following the road investments. This was because local passenger demand remained low. The research findings in Nepal and Tanzania have been shared in separate reports.

The team also studied experiences from several countries on the organisation and regulation of RTS and options for improvements. The findings are in a separate report. Transport regulatory agencies are small and typically pay little attention to RTS. They find it difficult to engage with large numbers of informal operators. Operator associations can help to regulate services, but some are powerful cartels and others are unrepresentative. Formalising the rural transport sector is problematic, as are subsidies. The best prospects for improving RTS are through participatory processes with devolved administrations (including road agency staff) to discuss options for consolidating demand, sharing routes and operating to timetables.

This report discusses the implications of research in Nepal and Tanzania and the options for improving RTS. Collaboration between (or integration of) transport services agencies and road authorities is recommended. Examples are provided of simple outcome indicators relating to RTS that road agencies could usefully include in their databases. They should plan with participatory processes and consider the implications of increased motorcycle use, including linking off-road villages by motorcycle trails. Informal private sector operators providing RTS require daily profits. They prioritise market demand over road condition. Road planners need to learn from operators about market demand and from villagers about their travel destinations. They should consider cheaper road standards where most traffic comprises light vehicles. Labour-based road construction and maintenance can be effective. Spot patching is a valuable short-term maintenance solution, but long-term maintenance funds are also needed.

Key elements of these recommendations have been included in another output publication offering guidelines to assist implementing the proposed integrated approach to road planning and improving RTS.

1 Background

1.1 Project Overview

The Research for Community Access Partnership (ReCAP), funded by UKAid, commissioned TRL to undertake this research study to gain, and to disseminate, a greater understanding of how investments in low-volume rural roads (LVRRs) impact rural transport services (RTS) and the mobility of people and their goods. This project is known as IMPARTS (Interactions: Maintenance-Provision of Access for Rural Transport Services). It is exploring the interaction between the effective use of rural access and its dependency on the appropriate provision and preservation of LVRRs, and the resultant changes in rural transport service provision that are brought about through improved sustainable road performance.

There is understood to be a strong correlation between poverty and connectivity. Road access in rural areas can improve social welfare by increasing the proximity to, and quality of, basic services, and broadening livelihood opportunities, including agricultural production and marketing. Improved accessibility through the provision of rural road infrastructure and transport services can improve health and education outcomes by increasing attendance at clinics and schools and improving staff retention. Road infrastructure allows rural women and men to reach markets and income-generating opportunities. However, most rural people in low-income countries do not own motorised transport and therefore depend on various types of transport services for their mobility, access to services and earning potential.

The many benefits of LVRRs are largely dependent on a sustained level of infrastructure performance linked to there being appropriate and affordable transport services: rural roads must be fit for purpose in terms of facilitating the movement of people and freight. Currently, infrastructure provision and preservation are largely disassociated from service provision. Therefore, this project has examined the relationships between LVRRs and transport services, and the links between LVRR-investment planning for provision and preservation, and the actual achievements in terms of rural transport provision.

1.2 Research Objective

The core research objective was to examine the conditions in which rural transport services succeed or fail, and the relevance of infrastructure condition and level of service to that outcome.

Output: definitive guidelines on how the provision-preservation-services continuum can be improved in support of better livelihood opportunities for rural communities and a positive impact on poverty reduction.

Impact: improved accessibility and mobility for rural communities, and improved overall livelihoods of those communities, in particular for vulnerable groups and individuals within those communities.

1.3 Project Phases and Outputs

The project was designed with three phases:

- Phase 1: Scoping phase: A detailed literature review and consultations with roads and transport professionals in ReCAP partner countries to learn from their experiences of how rural transport services respond to investment and also to select suitable countries for Phase 2 work.
- Phase 2: Field work to gain data and understanding about how transport services had changed following road investments in selected countries in Africa and Asia.
- Phase 3: Study of options for improving rural transport services in low-income countries, based on a literature review and consultations with relevant stakeholders involved in operating and regulating transport services.

One of the recommendations of the scoping report, was that Phase 3 tasks should be carried out in parallel with Phase 2 work. This would allow the research team members planning and implementing the Phase 2 data collection activities increased opportunities to engage with transport operators, regulators and associations concerning options for improving transport services. While Phase 2 and 3 activities overlapped, there were different research questions to address and so the reporting has been kept distinct.

This report summarises all the project activities and presents the key findings and recommendations, with further details available in three separate reports. These cover the Phase 2 research in Nepal (Starkey et al, 2020b) and in Tanzania (Starkey et al., 2020c) as well as a report discussing Phase 3 work on options to improve rural transport services (Starkey and Hine, 2020). The guidelines are contained in a separate publication (Starkey et al., 2020d).

1.4 Phase 1 Activities

Phase 1 of this IMPARTS project, which started in May 2018, involved a detailed literature review of the relationships between LVRRs, transport services and the outcomes and impacts for rural populations (Starkey et al., 2019a). The review cited impact studies from around the world on how rural road provision had affected the local populations through improvements in mobility, agricultural production, access to medical facilities, education and poverty reduction. However, despite the large number of rural road projects in Africa, Asia, Latin America and island states, the number of clear lessons relating to improved mobility and transport services are relatively few. Most impact studies attempted to correlate various 'before' and 'after' datasets obtained through socio-economic surveys. Only a very small number of published studies have looked at transport services and the mechanisms by which these impacts had been achieved. Through liaison with road authorities in all 17 ReCAP countries, it was learned that while road investments are often justified by predicted improvements in transport services, few (if any) road authorities regularly collect 'before' and 'after' information on transport service provision. Good datasets relating to rural transport services are rare. Even traffic counts on LVRRs that have been consistently implemented over a period of time are difficult to find.

A project inter-regional stakeholder workshop was held in Arusha, Tanzania, in November 2018 and was attended by 39 participants from 12 ReCAP countries (Starkey et al., 2019b). The participants, who were mainly engineers from roads authorities, were motivated to understand transport services issues, and endorsed the need for more integrated approaches with transport services data informing the planning of road investments (construction and maintenance). The workshop concluded that roads authorities should try to collect, and use in their planning, simple transport services outcome indicators (such as modal distribution, tariffs, frequencies and journey times). Unlike *impact* indicators that may take five years or more to respond to road investments, transport services *outcome* indicators respond rapidly to road improvements. Importantly, they also respond quite quickly to road deterioration due to inadequate maintenance. Such transport services outcome indicators could be incorporated into road planning and Maintenance Management Systems.

1.5 Phase 2 Activities

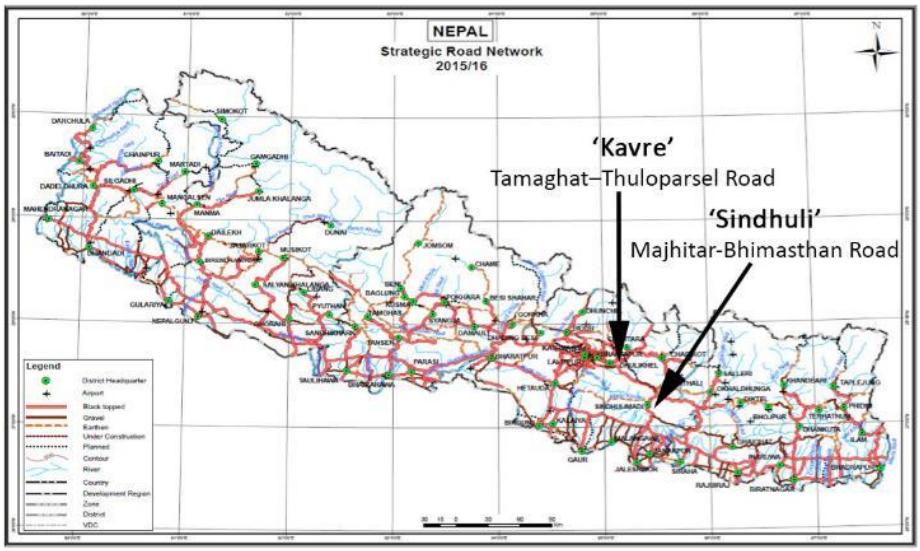
The Phase 2 research questions were:

- Have changes to passenger and freight transport service provision brought about benefits or disbenefits for the rural poor and low income communities?
- Are the engineering solutions sustainable and fit-for-purpose in terms of wider transport service provision and accessibility? What are the effects of poor maintenance and road deterioration on RTS provision following road rehabilitation/upgrading?
- What other constraints to transport service expansion exist, especially where investment has been made to improve the road infrastructure?

The Phase 2 activities started in early 2019. Team members visited roads authorities and rural roads in Ghana, Nepal and Tanzania to select suitable research locations for the 2019 field survey work. The available information and data on road planning and transport services in previous years was found to be better in Nepal and Tanzania. As a result, roads in these countries were selected for the new surveys.

Two roads were selected in Nepal. Both had been constructed between 2002 and 2010 using labour-based methods by the District Roads Support Programme (DRSP). Some of their relevant attributes and issues are summarised in Annex A. The approximate locations of these roads within Nepal, and their historic district names used to refer to them, are shown in Figure 1.

Figure 1 Map of Nepal showing strategic road network and approximate locations of the two roads studied



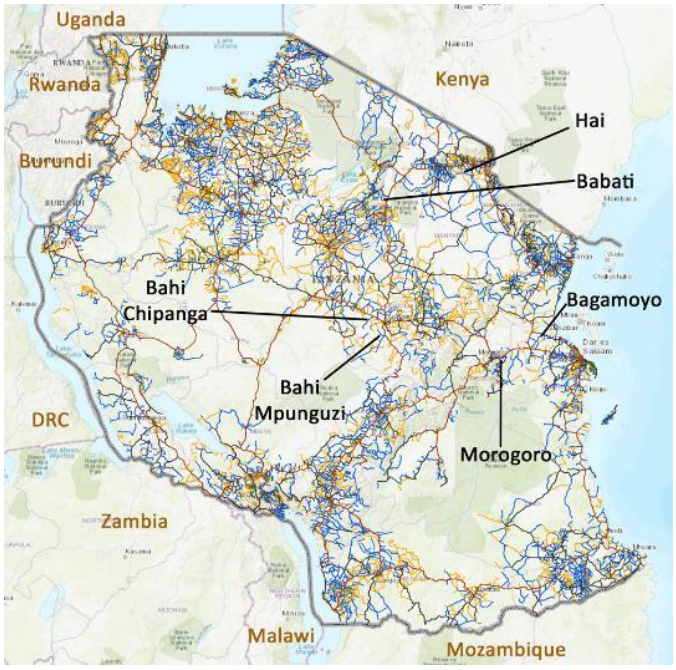
Source of base map: Department of Local Infrastructure (DoLI), Kathmandu, Nepal

The Nepal research was carried out in collaboration with Shuva Sharma of Scott Wilson Nepal. Following the development of the various survey forms, local researchers were trained to implement qualitative and quantitative surveys on the selected roads. The surveys were implemented between September 2019 and December 2019, under the guidance of Sarad Gaihre of Scott Wilson Nepal. Planning and supervisory visits were undertaken by Paul Starkey, Robin Workman and John Hine. Full details of the Nepal studies and findings are available in a separate report (Starkey et al., 2020b).

In Tanzania, six roads were visited for possible selection for surveys. All roads had different and interesting infrastructural and transport services features. It was agreed that research findings and lessons would be limited if only two roads were selected, and it was agreed that the six roads should be studied in order to maximise the research benefits. Some of the relevant attributes and issues of the six roads are summarised in Annex B. Their approximate locations within Tanzania and the names of their districts (used to refer to them) are illustrated in Figure 2.

The research in Tanzania was undertaken in collaboration with the Tanzanian consultant, Hans Mwaipopo, who obtained the necessary research permissions. Following the development of the various survey forms, a senior enumerator, Stanley Soiti, was recruited to implement the surveys. He was trained to implement qualitative and quantitative surveys on the selected roads, allowing the implementation to start in September 2019 and finish in December 2019. Supervisory visits were undertaken by Paul Starkey, Robin Workman and John Hine. Full details of the Tanzania studies and findings are available in a separate report (Starkey et al., 2020c).

Figure 2 Map of Tanzania showing approximate locations of study roads and their districts



Source of base map: Tanzania Rural and Urban Roads Agency (TARURA)

1.6 Phase 3 Activities

As noted, Phase 2 and 3 activities were carried out concurrently but with different objectives. While the Phase 2 research concentrated on the interactions between transport services and infrastructure, the Phase 3 research questions concentrated on market-based solutions to rural transport services provision. The research involved investigating the motivations of the private sector to provide transport services in rural areas and considering the government structures that organise and regulate these services along with the legal and policy frameworks in which they operate. The key research questions were:

- What is preventing rural transport services being scaled up and extended to remote areas where they would have most impact?
- Are rural transport subsidies an option in low income countries?
- What can be learnt from rural transport service operations and the institutional environment in which they function in Africa and Asia?

During the visits to Ghana, Nepal and Tanzania to implement Phase 2 tasks, discussions were held with transport operators and key informants in transport associations and the organisations regulating transport services concerning their experiences and their ideas about how to improve transport services. The field work in Nepal and Tanzania provided many opportunities to interview and hold focus group discussions with a wide range of stakeholders including operators of different forms of transport and the people at various levels in the organisations responsible for their regulation (authorities) and self-regulation (associations). These investigations were complemented by similar discussions in Pakistan and Liberia and through electronic and face-to-face meetings with relevant informants based in other countries. Through these contacts and from further literature review, it was possible to gather additional case history information on how rural transport services have been and might be improved through investments, regulation and/or subsidies. The research findings and discussion are available in a separate report (Starkey and Hine, 2020).

1.7 Research Tools and Methods

Full details of the various research instruments and survey forms used in Nepal and Tanzania were included in a previous report (Starkey et al., 2019c). These included traffic counts, user surveys, operator surveys and key informant interviews. In addition to the quantitative data collection, there were focus group discussions with key informants including vehicle operators and staff of the road authorities and people

aware of the history of the road. Engineering surveys were carried out on each road, using visual assessment, GPS-enabled dashcam videos and RoadLab app smartphone recordings of the International Roughness Index (IRI). RoadLab does not work below a survey speed of 15 km/h and so could not estimate the roughest sections of the road. Data was collected to allow the 'Rural Transport Premium' to be calculated. This is the ratio between the cost of per passenger-km of the available public transport services on low-volume, rural roads and the cost per passenger-km of standard-class, long-distance bus services.

In addition to the road related surveys in Nepal and Tanzania, qualitative research methods were used to obtain information, ideas and insights on the transport market and its regulatory environment. Key informants in transport associations, organisations regulating transport services and transport operators on various roads were contacted about how to improve transport services. These discussions were complemented by similar surveys in Ghana, Liberia and Pakistan, as well as additional literature reviews and contacts with professional colleagues to gather additional case history information on how rural transport services might be improved through investments, regulation and/or subsidies.

1.8 Details of Nepal and Tanzania Research

A detailed report describing and illustrating the two Nepal roads, their transport services, the research methods and findings and the emerging issues has been prepared (Starkey, Workman and Hine, 2020b). Similarly, a detailed report describing and illustrating the six Tanzania roads, their transport services, the research methods and findings and the emerging issues has been prepared (Starkey, Hine and Workman, 2020c). To avoid excessive repetition, these two documents should be considered as complementary resources to this current report. However, for reference purposes tables summarising the key features of the roads, the investments made and the data sets available are provided in Annexes A and B.

2 Road Provision, Preservation and Transport Services Changes

2.1 Survey Findings

2.1.1 Nepal

The two roads selected in Kavre and Sindhuli districts were built by the District Roads Support Programme (DRSP) using labour-based methods in 2005-2009. Both were simple earth roads with stone soling and cobblestone sections at strategic points, notably on steep gradients and bends. Supporting structures were mainly made with stone gabions (see Figure 3). The roads used simple but effective drainage solutions, with emphasis on drifts rather than culverts. The Kavre road was about 28 km and comprised 9.5 km through a busy and productive valley, and two sections climbing steep valley sides in areas with a low population of semi-subsistence farmers. The Sindhuli road was about 18 km and followed an undulating alignment in small hills alongside a wide valley. On both roads the original earth road and cobblestone sections had survived very well in contrast to Otta seal surfacing that had largely disappeared. Both roads have experienced recent widening using machinery that had interfered with the original drainage and created muddy sections. On the Kavre road this was exacerbated by heavy trucks hauling rocks from a quarry. On both roads there were examples of farmers of irrigated crops causing water to flow onto the road.

Figure 3 Sections of the two Nepal roads, showing gabion supporting structures, cobblestones and an earth section

The main transport services on both roads were 35-seater buses (see Figure 3 and front cover). There were four in each direction on both roads. These patterns had not changed since the roads opened in 2007. Transport demand has been increasing on both roads, particularly on the sections nearest the urban end of the road. In road sections with greater transport demand complementary services have developed, operated by autorickshaws, minivans (on roads in relatively good condition) and jeeps/pickups. These charge more per passenger-km than buses but they are popular for their greater timeliness. On the Sindhuli road, buses have increased their daily passenger numbers, although according to the surveys, their popularity had decreased. They were the lowest rated transport services option, with only trucks considered more dangerous.

The number of enterprises along both roads has increased greatly. On both roads, motorcycles had been rare or absent in 2009, but were now rapidly increasing for personal use. Motorcycles were the most common vehicles on both roads. Bus fares have decreased since 2013 and are now about USDc 5 per passenger-km. The Rural Transport Premium (RTP) for buses has decreased from 3.8 in 2013 to about 3.1 in 2019. The RTP is higher for low-capacity vehicles and is around 4 for minivans and jeeps/pickups. It is much higher for autorickshaws due to their point-to-point operations. This is discussed further in Section 3.3 of this report.

The original construction of the two earth roads with strategic cobblestone and stone soling sections had allowed bus services to start operating. The impressive, long-term all-season passability of the roads has allowed buses to continue to operate with reduced fares. However, on the remoter sections of both roads there had been little growth in transport demand as this depends on many socio-economic factors besides road condition. The sections of the road nearest to the local towns were much busier, with more

enterprises, more traffic, additional transport services options and greater diversity within the local economy.

Some of the survey observations from the Nepal roads are summarised in Table 1. Based on the survey findings in Nepal, it was recommended that road condition should be protected by returning to the routine maintenance system of lengthworkers. While it was acknowledged that cobblestones and stone soling are not particularly popular with road users or the road authorities (people aspire to bituminous surfacing), it should be recognised that these surfaces have proved highly effective and enduring. This should be shared with policy makers to facilitate more extensive use of these technologies. The long survival of the roads through many monsoon seasons contrasts with the many short-lived 'bulldozer' roads in Nepal that sometimes do not survive one season. Road building and road maintenance require strict attention to engineering and drainage. While buses will continue as the main transport services, the growth of smaller, complementary services is popular and should be encouraged. Further information on the results of the Nepal surveys are available in Starkey et al (2020b), and some of the key issues are explored in the following sections of this report.

Table 1 Summary of key issues identified on the two roads studied in Nepal

Road	Kavre	Sindhuli
Context	9 km of undulating fertile valley with irrigated rice, mixed farming and diverse economic activity. Then 9 km up and down a steep mountain valley side with a very sparse population. Final 10 km rises up a gentler mountainside with several agriculture-based villages.	Road runs along the edge of a broad valley, with much agriculture including irrigated rice. Passes through several extensive farming villages, with small populations. Little economic diversification, but a few small stores and teashops. Small weekly market dominated by external sellers, including people bringing in vegetables from the Terai.
Intervention	9 km of upgrading informal track to a narrow road in 2002-2005, one bridge and 19 km of new road in mountainous terrain in 2005-2010. All labour-based earth road with mainly cobblestone drifts for cross-drains and cobblestone or stone soling sections on difficult gradients.	18 km of road rehabilitation to create all-season road in 2006-2009. About 2 km of Otta seal on gravel and 16 km of earth road with cobblestone drifts, a few small culverts and cobblestone or stone soling sections on difficult gradients. Road extended by another 17 km of labour-based earth construction with cobblestones/stone soling on some gradients and watercourses. Scope for further extension Three bridges along the road were also built (with different funding).
Problems solved	All-season access to some villages and first road connection to some other villages.	All-season access to several villages that previously relied on dry season riverbeds, with scope for further extension.
Road problems remaining	Road rough and narrow for large vehicles	Half of road very rough
Transport demand	High demand on first 9 km. Little local demand on subsequent sections. No demand for through traffic beyond road.	High demand in first 2-3 km with peri-urban characteristics. On rest of road, a small rural population with a low but steady demand for transport to reach the district town and beyond. Road not yet a through route.
Motorcycle changes	Large expansion in recent years for private use only.	Large expansion in recent years for private use only.
Traffic changes	Motorcycles are now most common vehicles and increasing. Large growth in other traffic on first 9 km. On subsequent road, large growth (from zero) in initial years but little or no growth in recent years (and possible declines) apart from motorcycle use increasing.	Motorcycles are now most common vehicles and increasing. Continued growth of many traffic types in the peri-urban section. On the more rural sections of the road, rapid growth of motorcycles and sustained growth of other traffic over the years.
Transport services	Continued growth in first 9 km, with minivans and autorickshaws complementing buses. On subsequent road, bus services constant for twelve years at 4 return services a day. No development of jeep services and no use of autorickshaws.	Bus services quite constant over past decade at about 4 return services a day. Increased use of jeeps as transport services. Autorickshaws common in the peri-urban section and have started to operate in small numbers on the more rural parts of the road.
Planning issues	The well-designed, labour-based construction of earth roads with cobblestone/stone-soling drifts and gradients has been extremely robust and has allowed fifteen years of all-season access to villages in a difficult mountainous terrain with intense rainfall. First 9 km of road have facilitated economic diversification and growth in transport, but the road is now narrow for the increasing traffic. The subsequent road has allowed daily bus services to operate for many years, but travel has not increased in recent years. The increased use of heavy quarry trucks is destroying the original earth roads and their drainage system. The original maintenance system using length workers has broken down through lack of funding.	The well-designed, labour-based construction of earth roads with cobblestone/stone-soling drifts and gradients has been extremely robust and has allowed fifteen years of all-season access to villages in a hilly, edge-of-valley terrain with intense rainfall. An Otta seal section did not survive as long. The original maintenance system using length workers has broken down through lack of funding. Some recent attempts at widening have disrupted the original simple drainage plan for the earth road, and rapid deterioration of these sections is anticipated unless there is new investment in drainage. Some road problems have been caused by farmers diverting irrigation water onto the road and solutions require road agency gaining community cooperation.

2.1.2 Tanzania

Details of the road investments on the six roads studied in Tanzania were provided in Annex B. Investments included raised carriageways and culverts over low-lying land, some concrete strips, one concrete section and two bridges. Some examples of the condition of the IRAT investment in 2019 are shown in Figure 4, which illustrates a raised carriageway and double culvert, parallel concrete strips and a large 6-cell culvert (locally known as a bridge).

Figure 4 Examples of the IRAT road investments on the surveyed roads in Tanzania

On all the roads, most traffic (83%-95%) comprised motorcycles, many of which were motorcycle taxis. These provided 44%-89% of people's motorised journeys, with men travelling much more than women. Only one road had regular bus and midi-bus services which had not increased after the investments, despite a 20 km rehabilitated section. Two other roads had minibus/minivan services, but only on part of the road, despite several investments including two bridges. The investments had allowed all the roads to become all-season but had not stimulated sustained traffic growth or new transport services. Examples of the transport services on the surveyed roads in Tanzania are shown in Figure 5, that shows a motorcycle taxi, three wheeler, midibus and large bus.

Figure 5 Examples transport services on the roads surveyed in Tanzania

Motorcycle taxis on fares most road sections were around USDc 12 per passenger-km, giving a Rural Transport Premium (RTP) of 6.6 (as explained in Section 3.3 of this report). Based on previous surveys on the Bagamoyo road, the motorcycle taxi fares were around USDc 22 per kilometre in 2014, when long distance bus fares were USDc 2 per passenger-km, giving a Rural Transport Premium (RTP) of 11 (Starkey, 2016c). The significant drop in the RTP from 11 to 6.6 for motorcycle taxis is thought to be mainly due to increased competition. Rural motorcycle taxis numbers have increased in Tanzania in the past five years, leading to a downward pressure in fares. Competition can greatly affect motorcycle taxi fares. In Hai District in Tanzania, some of the lowest motorcycle taxi fares (USDc 7 per passenger-km) were recorded on a busy road section leading to the road surveyed, and yet the highest fares recorded (USDc 21 per passenger-km) were found on a nearby section of the surveyed Hai road, where there was a small transport market and little competition.

In 2019, the fares in the large buses on the Bahi-Mpunguzi road were around USDc 2.5 per passenger-km. The fares for midibuses, minibuses and minivans on the first section of the Bahi-Chipanga road were

around USDc 5.4 per passenger-km. The historical IRAT data was not sufficiently comprehensive to calculate the RTPs of past years, but the 2019 RTP values are presented and discussed further in Section 3.3.The reasons for the limited impact of the infrastructural improvements were analysed. Possible reasons for the lack of new transport services were discussed in the IMPARTS report on the Tanzania roads, with the help of explanatory diagrammatic maps (Starkey et al., 2020c). On some roads there was an alternative and better route, and transport services preferred the better road as the transport demand along the poorer road was weak. Other roads did not seem to serve a purpose as through roads, due to lack of connectivity or due to alternative roads providing better access to people's preferred destinations. A summary of some of the key issues is provided in Table 2.

The evidence from all six survey roads and several associated roads suggests that the key determinants of transport services were road condition and market demand, with transport demand being the most important, provided the road is passable. On rough roads, motorcycle taxis can travel faster and more comfortably than larger vehicles and with their small capacities they are well suited to low transport demand. The study showed that buses, minibuses, minivans and bajajis will travel on rough roads if they perceive a good market which is their key criterion. A good road or a good bridge without appropriate market demand is insufficient to attract transport services.

The report on the six study roads in Tanzania concluded that there should be more involvement of local stakeholders in the planning of road investments. Transport services operators should be consulted about how they might respond to different investment options. This could be achieved during the preparation of district transport plans. The Tanzania Rural and Urban Roads Agency (TARURA) should engage more with transport services operators and include transport services information in its road database. With so many rural motorcycles, rural infrastructure should always be appropriate for their needs. Parallel concrete strips should be avoided. Cheaper narrower roads and bridges could be considered unless it is anticipated that buses or midibuses will operate along the roads. All off-road villages should be accessible using motorcycles, and a TARURA 'motorcycle trails and trail bridge' unit should advise districts on appropriate investments that could be community-supported and implemented.

More detailed information on the survey findings on the roads in Tanzania is available in the IMPARTS report on these roads (Starkey et al., 2020c). In the following report sections, the various issues raised by the research in Nepal, Tanzania and elsewhere will be discussed.

2.2 The Organisation and Regulation of Rural Transport Services

In both Tanzania and Nepal, rural transport services are provided by small scale, informal sector operators. Some own their own vehicles, particularly the smaller transport types. Others lease them on a daily basis from their owners. Bus services are also owned by individuals, but these may hire drivers and conductors to operate them. While a few individuals may own more than one bus, many own just one. This informal sector operation of rural transport services is common in low-income and middle-income countries. It is in contrast to inter-urban transport companies that may own small fleets of vehicles and operate within the formal sector. .

Vehicles operating on the rural roads tend to be quite old (particularly the buses) and dilapidated by wear and tear. The exceptions are the small vehicles, motorcycles and autorickshaws (bajajis in Tanzania) that have generally been acquired quite recently. Owners of larger transport services tend to be members of transport associations, although this was not always found to be the case. Being members of associations is less common for the operators of the smaller means of transport (motorcycles and three-wheelers).

Table 2 Summary of key issues identified on the six roads studied in Tanzania

Road	Hai	Babati	Bahi Chipanga	Bahi Mpunguzi	Morogoro	Bagamoyo
Context	U-shaped 10 km road on flat land with 5 km over a rice growing area. Few villages. Low population.	Old road alignment with new longer alternative route. Low population. Mixed farming, some sugar.	Road between two artery routes to Dodoma. Crosses undulating, semi-arid mixed farming area with low population	First 20 km of a long, branching collector road network serving many villages. Flat agricultural land with sparse population.	Road rises up hills, with decreasing population and a protected forest. Could be a shortcut to Ngeregere, a small market town.	Road traverses undulating land, initially intensive crop farming, then shifting cultivation and herding. Low population.
Intervention	5 km rehabilitation and embankment in 2016	Two culverts and short embankment in 2016	Two bridges and road works from 2016-2018	20 km rehabilitation with embankment in 2016	Several bottleneck works with concrete strips and section in 2014-2016	Full rehabilitation with different surface treatments in 2010-2011
Investment cost *(approx.)*	USD 780,000	USD 216,000	USD 1,660,000	USD 1,480,000	n/a[1]	n/a[2]
Problems solved	Better all season access to small agricultural area	Difficult wet season section now all-season	Difficult wet season sections now all-season	Difficult wet season sections now all-season	Some difficult wet season sections now all-season	Difficult wet season sections now all-season
Road problems remaining	Ongoing road difficult	Half of road very rough	Few: but some rough sections	Few: but road getting rough	Narrow road. Remaining bottlenecks	Few: but some earth sections eroded
Transport demand	Little local demand. No through traffic	Little local demand. Through traffic has better alternative	Little local demand particularly over bridge 2 where through traffic has better alternative	Little local demand but overall good demand from through traffic from several feeder roads	Tiny transport demand over improved sections. Through traffic has better alternative	Little local demand. Possible through traffic has better alternative
Motorcycle changes	Large expansion	Large expansion	Large expansion	Large expansion	Large expansion	Large expansion
Traffic changes	Initial growth then no change	Initial growth then little change	Little change over bridges	Little change	Little change	Little change
Transport services	Increase in motorcycle numbers. More vehicle diversity but no additional transport services options	No change. Only motorcycles	Bridge 1: some minibuses Bridge 2: No change. Only motorcycles	No change: same minibus, midibus and bus services mainly from other roads	No change. Only motorcycles	No change. Only motorcycles
Planning issues	Some agricultural access but lack of useful network connectivity	Better alternative route available	Better alternative route available for bridge 2	None. Important collector road serving many routes. Safety issues	Better alternative route available	Important rural access but lack of good through route

Notes: 1) Investments on the Morogoro road were made over several years from different sources. One tranche of IRAT investment was USD 42,000. 2). Investments on the Bagamoyo road were part of a research project and full details of the various different treatments of the sections and their costs are available in Roughton, 2012 and Roughton, 2013b.

In both Nepal and Tanzania, there are transport services regulatory authorities. These are both small organisations (compared to road agencies), with mandates that cover urban, inter-urban and rural

transport services, and the administration relating to route licences and taxation, driving licences and period inspections of vehicles. They do not have sufficient staff to maintain representation in all districts, and the staff in devolved locations concentrate on the administrative tasks relating to licensing and vehicle testing. At a national level, the regulators in Nepal and Tanzania concentrate on transport services in the main cities and on inter-urban services. Rural transport services tend to receive little attention with no proactive initiatives. Rural bus services operators obtain and generally comply with route licences. They also have vehicle insurance. Operators of other vehicles, including three-wheelers and motorcycles, often do not comply with administrative requirements, but have little to fear as enforcement on rural roads in both countries is minimal.

2.3 Motorcycles

One of the main issues, common to both Nepal and Tanzania, has been the huge growth in the numbers of motorcycles. Much of this growth has been in the same timeframe as the road investments studied. In both countries, motorcycles are now the most common vehicles on the roads, and their increasing use is affecting demand for rural transport services. Similar patterns of greatly increased motorcycle use can be seen in most low and middle-income countries, with South Africa and its neighbouring countries being exceptions.

The big difference between Tanzania and Nepal is that in Tanzania motorcycle taxis are extremely important as rural transport services. This is in addition to their increasing use for person mobility. In Nepal, motorcycle taxi services are not evident in rural areas. On most of the roads studied in Tanzania, motorcycles were the only transport services available every day and throughout the day. Only one of the six roads had 'conventional' transport services operating along the whole road.

In neither Nepal nor Tanzania, the roads authorities had not envisaged there would be a surge in motorcycle use, and neither have fully grasped the significance of this in terms of rural road standards and the options for motorcycle trails. These topics are discussed further in Section 4.

3 Effects of Road Investment and Transport Services on Communities

3.1 Benefits and Disbenefits for Rural People

The literature review included in the IMPARTS scoping report (Starkey et al., 2019a) discussed evidence from around the world of how roads bring benefits to rural communities. Many of these impacts would have been gained thanks to improved transport services, although it was stressed that very little research had recorded or measured transport services outcomes. Some studies reported traffic increases following road investments, but there were few concrete examples of linking investments in roads to specific transport services outcomes and benefits to communities. One example cited related to work in Kenya, where road investments led to higher traffic volumes and lower fares on the low-volume sealed roads (Hine and Bradbury, 2016).

The IMPARTS surveys were not designed to measure the impacts of the various road investments on rural communities. Rather they recorded changes in the number and variety of transport services and their prevailing tariffs.

In Nepal, sections of the two roads had replaced footpaths and informal tracks, and so the initial growth of transport services was from a very low base. After the early growth following the opening of the road, the transport services changed slowly, with bus services remaining constant over the years. Most of the traffic growth was in the busier sections of the road, where the economies and the transport services were diversifying. In general, the users seemed positive about the transport services that appeared to be meeting the low transport demand. The users did not strongly endorse the prevailing bus services (with most average responses being between 'OK' and 'good') and there was clear dissatisfaction with the comfort of journeys.

In Tanzania, the IMPARTS survey investigated a range of interventions on six roads. One road had been rehabilitated with trial sections with funding from AFCAP phase 1. Five of the roads had investments funded by the IRAT programme that was designed to remove substantial 'bottlenecks' to the rural road network. IRAT defined a bottleneck as 'a road network condition that either prevents or severely restricts the passage of appropriate public transport or commercial goods vehicles'. The bottlenecks included slippery slopes, low-lying muddy sections and water crossings prone to flooding. The investments included rehabilitated raised sections, new culverts and two bridges. The road investments were carried out at a time of massive expansion of Tanzania's motorcycle population, and the associated growth of rural motorcycle taxi operations. It was found that the interventions did not lead to changes in 'conventional' transport services, with most rural people increasingly relying on motorcycle taxis as the only transport services available. There appears to have been a reduction in motorcycle taxi fares on the surveyed roads over time. However, there were also substantial year-to year fluctuations. There were also important differences between the more remote and busier sections of some roads, with market demand and competition appearing to be more important considerations than road condition in the setting of motorcycle taxi fares. On three of the roads, motorcycle taxis were generally rated highly even for safety and fares. On the one road with bus and minibus services as transport options, motorcycle taxis were only considered satisfactory. On two roads with particularly low transport demand and no alternative transport services, motorcycle taxis were considered less than satisfactory, and their fares were the highest (about 50% more than the other four roads).

3.2 Outcome Indicators

As already noted, rural roads and transport services can have beneficial impacts on communities, but measuring impacts is not straightforward, and requires significant time and resources. Measuring the outcomes that contribute to impacts is much easier, quicker and cheaper. It is relatively straightforward to collect data for several outcome indicators that show how transport services and road usage change over time, and these can illustrate how transport services respond to road improvements and to road deterioration.

Key outcome indicators studied included:

- Transport tariffs
- Modal shifts in transport types
- Public transport frequency
- Vehicle safety
- Enterprise development
- Average vehicle speed.

Research results relating to these outcome indicators for which data can be easily collected every year or two are presented and discussed in Sections 3.3 to 3.9.

3.3 Transport Tariffs and the Rural Transport Premium

The costs of passenger and freight transport are crucial for determining people's ease of access to markets and services. In general, the highest tariffs per kilometre are charged for small vehicles over short distances while large passenger and freight vehicles travelling long distances provide the lowest tariffs per kilometre. On LVRRs, both passenger and freight movements tend to involve small vehicles and short distances to local markets and towns, so that rural transport is at a premium compared with longer-distance movements, such as intercity transport.

While intercity freight costs are quite easy to measure, freight costs per tonne-km on LVRRs are extremely variable, with differences of 100-fold, or more, on the same road, depending on the vehicle, the type of load, the distance and the operator. For this reason, the RTSI project, this project and other similar initiatives have been unable to develop usable and replicable indicators for small scale freight on LVRRs (Starkey et al., 2013a; Starkey et al., 2018). While it can be interesting to collect data on freight costs per tonne-km for different vehicle types, loads and distances on LVRRs, more valuable information might come through qualitative methods, such as focus group discussions on the problems of rural freight movements on particular roads. While specific outcome indicators relating to rural freight costs cannot be suggested for routine use, passenger fares are much more consistent and can make valuable outcome indicators.

The Rural Transport Premium (RTP) is an indicator of the transport benefits provided by rural roads. The RTP is the ratio between the fare per passenger-km of the available public transport services on low-volume rural roads and the fare per passenger-km of standard-class, long-distance bus services. It was designed as an indicator that could allow comparisons within and between countries. Being a ratio, there are no units or exchange rate issues, and many potential difficult issues, such as changes in fuel prices over time, the cost of living or idiosyncratic local pricing systems that should be cancelled out. There will always be a premium on rural transport prices as long-distance buses are likely to be cheaper, per passenger-km, as they invariably run on better infrastructure (national trunk roads) and benefit from two economies of scale (larger loads and longer distances). Rural transport services typically use smaller vehicles for shorter distances on poorer roads. As roads improve, vehicle operating costs and fares tend to decrease in real terms, particularly if there is competition. If the roads are good, and transport demand is high, rural transport operators will tend to use larger-capacity vehicles, which also allows prices to fall.

The RTP is likely to depend on the prevailing transport types, as smaller vehicles generally have higher tariffs per passenger-km. It may also depend on the road and the road section. Busy roads with more competition tend to have lower fares. On many rural roads there are daily, early morning journeys in minibuses, midibuses or even buses to the local towns (and perhaps onward to a city). Once these 'commuter services' have left, there may only be smaller transport services available, such as motorcycles, three-wheelers or utility vehicles. For this reason, to maximise the understanding of how rural communities are affected by transport services, it is best practice to disaggregate the RTP for different vehicle types. It can also be helpful to differentiate between busy and remote road sections, where certain transport types do not serve the remoter villages. If the RTP were entirely or mainly based on the less robust transport services that operate on the more developed sections of the road, this would not take into account the reality for the disadvantaged villagers living near the more remote sections of the road.

Table 3 shows the average fares paid per passenger-km for the different vehicle options, as reported by the users interviewed.

Table 3 Average fares in USDc per passenger-km on the eight study roads in Nepal and Tanzania

Country	Road	Section	Motorcycle taxi *USDc*	3-wheeler *USDc*	Jeep/ Utility *USDc*	Minivan/ Minibus *USDc*	Bus/ Midibus *USDc*
Nepal	Kavre	*Remote*	-	-	3.7		5.7
Nepal	Kavre	*Busy*	-	11.6		7.6	5.7
Nepal	Sindhuli (	*Remote*	-	39.9	8.7	-	5.2
Tanzania	Bagamoyo	*Remote*	12.2	-	-	-	-
Tanzania	Hai	*Remote*	20.7	-	-	-	-
Tanzania	Babati	*Remote*	12.8	-	-	5.3	-
Tanzania	Bahi-Chipanga	*Remote*	12.1	-	-	-	-
Tanzania	Bahi-Chipanga	*Busy*	12.1	-	-	5.4	-
Tanzania	Bahi-Mpunguzi	*Remote*		-	-		2.9
Tanzania	Bahi-Mpunguzi	*Busy*	12.6		-		2.4
Tanzania	Morogoro	*Remote*	18.1	-	-	-	-

Note: most fares relate to the whole road including the remoter sections.
Some transport types were only available on the busier sections towards the end of the road, and these are presented in separate rows

Table 4 Standard bus fares for various routes in Tanzania and Nepal in December 2019

Tanzania				Nepal			
Origin	Destination	Distance *km*	Fare *TZS*	Origin	Destination	Distance *km*	Fare *NPR*
Dar es Salaam	Chalinze	101	3,500	Kathmandu	Pokhara	200	500
Dar es Salaam	Morogoro	186	7,500	Kathmandu	Butwal	259	519
Dar es Salaam	Iringa	489	22,000	Kathmandu	Illam	676	1,348
Dar es Salaam	Mbeya	797	40,000	Kathmandu	Jhapa	610	1,172
Dar es Salaam	Dodoma	451	18,000	Kathmandu	Krishnanagar	349	686
Dar es Salaam	Moshi	544	27,000	Kathmandu	Janakpur	375	736
Dar es Salaam	Kahama	988	40,000	Kathmandu	Biratnanagar	541	1,043
Dar es Salaam	Arusha	624	27,000	Kathmandu	Tamghas	376	840
Dar es Salaam	Mwanza	1134	45,000	Kathmandu	Ghorahi	434	846
Dar es Salaam	Bukoba	1382	60,000	Kathmandu	Nepalgunj	531	1,025
Average fare per passenger-km *(TZS)*			**42.7**	**Average fare per passenger-km** *(NPR)*			**2.04**
Average fare per passenger-km *(USDc)*			**1.86**	**Average fare per passenger-km** *(USDc)*			**1.80**

Note in December 2019. USD1 = TZS 2300. USD1 = NPR 113

Based on the information presented in Table 3 and Table 4, the RTP figures for the transport services available on each road have been calculated and are shown in Table 5. For Tanzania the denominator of the RTP is USDc 1.86, and for Nepal it is USDc 1.80.

Table 5 Rural Transport Premium (RTP) values for transport services on the studied roads in December 2019

Country	Road	Section	Motorcycle taxi	3-wheeler	Jeep/ Utility	Minivan/ Minibus	Bus/ Midibus
Nepal	Kavre	*Remote*	-	-	2.1		3.2
Nepal	Kavre	*Busy*	-	6.4		4.2	3.2
Nepal	Sindhuli	*Remote*	-	22.2	4.8	-	2.9
Tanzania	Bagamoyo	*Remote*	6.6	-	-	-	-
Tanzania	Hai	*Remote*	11.1	-	-	-	-
Tanzania	Babati	*Remote*	6.9	-	-	2.8	-
Tanzania	Bahi-Chipanga	*Remote*	6.5	-	-	-	-
Tanzania	Bahi-Chipanga	*Busy*	6.5	-	-	2.9	-
Tanzania	Bahi-Mpunguzi	*Remote*		-	-		1.6
Tanzania	Bahi-Mpunguzi	*Busy*	6.8		-		1.3
Tanzania	Morogoro	*Remote*	9.7	-	-	-	-

Note: The Rural Transport Premium is the calculated from the average fares per passenger-km paid on the rural roads divided by average fares per passenger-km for long-distance buses

A few observations can be made on the RTP figures. The lowest figures relate to buses on the Bahi-Mpunguzi road in Tanzania. These were large buses travelling over 100 km along the road network. These had economies of scale, but with the rough road sections, there is a small premium compared to long-distance buses on bituminous roads. The rural buses in Nepal were 35-seat buses travelling on rough roads, so the rural transport premium is higher than the case in Tanzania due to smaller capacity vehicles. The RTP for medium size vehicles is generally intermediate between the higher-capacity buses and the small capacity motorcycles and three-wheelers. The low figure for jeep/utility on the Kavre road seems anomalous and may suggest these vehicles were not regular transport services but what people pay for lifts in vehicles that were travelling anyway. There seems a clear difference between motorcycle and three-wheelers operating on busy sections and remote sections of the road. The premium will always be high for these vehicles due to their low capacity, but it is much higher on the remote sections of the road. One reason may be that on the remoter road sections, these vehicles cannot be sure of having passengers on their return trips, so they may charge single trips as if they were return trips.

3.4 Modal Distribution of Transport Indicators

3.4.1 Motorised transport indicator

One transport services indicator is the percentage of travellers using motorised transport. During the surveys conducted in Tanzania, by IRAT and by IMPARTS, all people travelling were counted, whether they were pedestrians, cyclists or travelling on some form of motorised transport. People walking within villages or to nearby fields were not counted as pedestrians, so the people walking were travelling to a town, between villages or to distant farms. Table 6 shows the percentage of travelling people using motorised transport. In most cases the motorised transport would have been motorcycles, the exceptions being on the Mpunguzi Road and the first section of the Chipanga road where there were regular midibus or bus services.

Table 6 Percentage (rounded) of all travellers using motorised transport on the surveyed roads in Tanzania

Road	Section	2016 %	2017 %	2019 %	2019 N
Hai Road	Start	40	45	49	2739
	After 7 km	61	53	71	1433
	Through road (control road)	71	68	64	5978
Babati road	After 2 km (near town)	68	78	60	6266
	After 9 km (near investments)	65	56	64	2220
	Control road	70	57	57	2550
Bahi-Chipanga road	After 14 km (near bridge 1)	85	80	79	2177
	After 32 km (near bridge 2)	44	39	51	1096
	Control road		48	51	2033
Bahi-Mpunguzi road	After 1 km (near start)	79	75	88	2547
	After 20 km	70	66	95	1317
	Control Road	71	73	85	1469
Morogoro road	Upper section	81	86	65	1900
Bagamoyo road	After 10 km (middle section)			47	1837
	After 20 km (near end)			56	984

Notes: All percentages are rounded to the nearest whole number.
The figures relate to all the people counted as journeying past the traffic count points (= N) whether walking, cycling or in motorised transport. These percentages are based on all travellers using motorised means of transport as a percentage of all people counted. The total number of people counted on all traffic count days (N) is provided for 2019. The yellow shading highlights road sections where over 50% of journeys were by foot or by bicycle.

To provide an example of how this motorised transport indicator could be used, a 'bench mark' of 50% of journeys being by motorised transport has been used, and road sections that have been below this have been highlighted in yellow in Table 6. This shows that all roads achieve this standard on all or some of their sections. However, on three of the survey roads, (Hai, Bahi-Chipanga and Bagamoyo), there are some

sections that do not reach this (arbitrary) standard. The reasons for this could be investigated, and possible problems could be addressed.

It will be noted that there is considerable variation between the years, a point that was discussed in the IMPARTS Tanzania report (Starkey et al., 2020c). Variations tend to be high in small data sets and LVRRs generally have small, and very variable numbers of vehicles and pedestrians, depending on the weather, time, day, month, markets, local festivities, political and social activities and the reliability of the enumerators. While these factors do lead to some unexplained fluctuations between years and the roads, relevant differences and trends can generally be seen. This is true for the motorised transport indicator and the other indicators to be discussed.

3.4.2 Motorcycle transport indicator

Table 7 shows the percentage of people travelling who used motorcycles, which include those operating as motorcycle taxis and those being used for personal transport. Values of the motorcycle transport indicator over 40% have been highlighted in yellow. The table shows two separate trends. On most roads there has been an increase in the use of motorcycles over the years, with the figures for 2019 generally the highest. This is consistent with national patterns of increased motorcycle ownership and use. The second on trend is that the relative importance of motorcycles tends to decrease on road sections where minivans, minibuses, midibuses and buses operate. This is unsurprising as where none of the larger public transport modes operate, people have few choices: just motorcycles, bicycles or walking. Nevertheless, this motorcycle transport indicator allows planners to see clearly the importance of motorcycles and the influences of alternative transport services.

Table 7 Percentage (rounded) of all travellers on motorcycles on the surveyed roads in Tanzania

Road	Section	2016 %	2017 %	2019 %	2019 N
Hai Road	Start	35	21	42	2739
	After 7 km	36	32	56	1433
	Through road (control road)	41	33	46	5978
Babati road	After 2 km (near town)	40	41	41	6266
	After 9 km (near investments)	35	47	49	2220
	Control road	55	38	43	2550
Chipanga road	After 14 km (near bridge 1)	24	17	26	2177
	After 32 km (near bridge 2)	35	32	42	1096
	Control road		19	22	2033
Mpunguzi road	After 1 km (near start)	14	28	36	2547
	After 20 km	13	18	28	1317
	Control Road	46	55	62	1469
Morogoro road	Upper section	52	71	54	1900
Bagamoyo road	After 10 km (middle section)			39	1837
	After 20 km (near end)			55	984

Notes: All percentages are rounded to the nearest whole number.
The figures relate to all the people counted as journeying past the traffic count points (= N) whether walking, cycling or in motorised transport. The figures in this table are based on the all the riders and passengers on motorcycles as a percentage of all people counted. The total number of people counted on all traffic count days (N) is provided for 2019. Figures in excess of 40% use of motorcycles have been highlighted in yellow.

3.4.3 'Bus' passengers indicator

Table 8 shows the percentage of all travellers riding in minivans, minibuses, midibuses and large buses on the surveyed roads in Tanzania. This bus passenger indicator is most effective on roads with a high frequency of services provided by the various bus types. Where there are few public transport 'bus-type' services, the use of private minivans can suggest there are some public transport buses in operation, even though there may be no route-based conventional services. In Table 8, the bus passenger indicator values over 20% have been highlighted in yellow. This clearly shows the roads where there were route-based

buses operating: the Bahi-Chipanga road first section, the Bahi-Chipanga control road and the Bahi-Mpunguzi road. The only other value over 20% was near the start of the Babati road, where minivans travelling on the national highway may drop off or pick up people. Most of the figures below 20% would have been due to chartered vehicles or private minivans with passengers passing the traffic count points.

Table 8 Percentage of all travellers riding in buses, minibuses and minivans on the surveyed roads in Tanzania

Road	Section	2016 %	2017 %	2019 %	2019 N
Hai Road	Start	0	10	5	2739
	After 7 km	10	14	11	1433
	Through road (control road)	6	11	9	5978
Babati road	After 2 km (near town)	10	23	9	6266
	After 9 km (near investments)	11	1	4	2220
	Control road	5	7	3	2550
Bahi-Chipanga road	After 14 km (near bridge 1)	43	57	48	2177
	After 32 km (near bridge 2)	1	1	5	1096
	Control road		26	26	2033
Bahi-Mpunguzi road	After 1 km (near start)	57	34	48	2547
	After 20 km	45	33	56	1317
	Control Road	11	8	14	1469
Morogoro road	Upper section	5	2	5	1900
Bagamoyo road	After 10 km (middle section)			1	1837
	After 20 km (near end)			0	984

Notes: All percentages are rounded to the nearest whole number. The figures relate to all the people counted as journeying past the traffic count points (= N) whether walking, cycling or in motorised transport. These percentages show the proportion of all people counted who were travelling in buses, midibuses, minibuses or minivans. The total number of people counted on all traffic count days (N) is provided for 2019. The shaded figures are all over 20%.

3.5 Bus Frequency Indicator

Table 9 shows the number of buses, midibuses, minibuses and minivans for the surveyed roads in Tanzania. This bus frequency indicator is most effective on roads with a many services provided each day by the various bus types. As with the bus passenger indicator, where there are few public transport bus services, a number of private minivans being logged by traffic count enumerators can suggest there are some public transport buses in operation, even though there may be no route-based conventional services. In Table 9, values of fewer than 10 bus-type vehicles per day have been highlighted in yellow. Most of these small number of 'buses' would have been private minivans or chartered services. The road sections with 'bus' routes (Bahi-Mpunguzi) and Bahi-Chipanga (first section) and the Bahi-Chipanga control road all show more than 10-15 'buses' a day, although none of the roads appears to be well served, with services every 30 minutes (on average), equivalent to a bus passenger indicator of over 48. The high figures for the first section of the Bahi-Chipanga road are considered anomalous and due to many minivans providing short-distance shuttle services on market days, but very few route-based services on other days (Starkey et al., 2020c).

Table 9 Frequency of buses, minibuses and minivans on the surveyed roads in Tanzania

Road	Section	2016	2017	2019
Hai Road	Start	0	20	4
	After 7 km	4	18	3
	Through road (control road)	9	21	17
Babati road	After 2 km (near town)	23	30	24
	After 9 km (near investments)	8	3	5
	Control road	10	15	4
Bahi-Chipanga road	After 14 km (near bridge 1)	42	55	31
	After 32 km (near bridge 2)	1	1	6
	Control road		33	20
Bahi-Mpunguzi road	After 1 km (near start)	30	13	20
	After 20 km	13	10	15
	Control Road	11	11	13
Morogoro road	Upper section	4	1	7
Bagamoyo road	After 10 km (middle section)			3
	After 20 km (near end)			0

Notes: All figures are rounded to the nearest whole number. The figures relate to the number of buses, midibuses, minibuses and minivans counted per day in all directions. Some of the minivans would have been private vehicles. The shaded figures are those below ten per day.

3.6 Gender Distribution of Mobility Indicator

Table 10 shows the gender distribution of people travelling on the surveyed roads in Tanzania and also the percentage of children travelling. Most people travelling were men, with generally 2-4 men travelling for each woman. In most cases, children comprised fewer than 15% of the people counted. Where figures were higher than this, it was probably due to local schools, with children walking to and from schools from outlying villages or suburbs. In the IMPARTS Tanzania report (Starkey et al., 2020c), the gender distribution of passengers on particular types of vehicles are provided for some of roads. These figures showed that men were the main travellers by all modes (foot, bicycles and motorised transport), with the gap smallest in the pedestrian category. The gender differences in travelling and transport are thought to be related to cultural issues with gender-equity and socio-economic factors. During the surveys, no female drivers of motorised vehicles were observed on the surveyed roads, and few women rode bicycles. The gender distribution of mobility indicator is valuable for quantifying gender disparities in transport and this could facilitate the planning of possible mitigating strategies.

Table 10 Percentage of all travellers who were men, women or children on the surveyed roads in Tanzania

Road	Section	Men %	Women %	Children %	All people (N)
Hai Road	Start	59	31	10	2739
	After 7 km	69	17	14	1433
	Through road (control road)	55	28	17	5978
Babati road	After 2 km (near town)	62	17	21	6266
	After 9 km (near investments)	73	19	8	2220
	Control road	80	17	3	2550
Chipanga road	After 14 km (near bridge 1)	64	23	13	2177
	After 32 km (near bridge 2)	64	21	14	1096
	Control road	53	28	19	2033
Mpunguzi road	After 1 km (near start)	74	22	4	2547
	After 20 km	66	28	6	1317
	Control Road	70	21	9	1469
Morogoro road	Upper section	66	20	14	1900
Bagamoyo road	After 10 km (middle section)	60	14	26	1837
	After 20 km (near end)	55	21	25	984

Notes: All percentages are rounded to the nearest whole number.
The figures relate to all the people counted as journeying past the traffic count points whether walking, cycling or in motorised transport. The total number of people counted (N) includes all the surveyed days (generally two days).

3.7 Safety Helmet use Indicator

With small traffic volumes and low traffic speeds, LVRRs appear relatively safe, compared to faster and busier inter-urban and urban roads, although there is generally insufficient disaggregated data to demonstrate this statistically. Nevertheless, good road safety practices should be encouraged on LVRRs, where vehicles are frequently overloaded and fail to conform to national regulations. One indicator of compliance that is very easy to collect is the use of crash helmets for the operators and passengers of motorcycles. In most countries, helmet use is compulsory for motorcycle drivers and passengers, and enforcement for drivers, at least, is common in urban areas. Enforcement and compliance in rural areas is generally weak.

During the traffic counts organised by this project, not only were the numbers of motorcycles and their passengers counted, but also the number of helmets per motorcycle were recorded. This allowed the calculation of an indicator for the percentage of riders and passengers wearing helmets. Observations suggested that if there was one helmet used on a motorcycle, it was almost invariably worn by the driver, as it was rare to see a helmet on a passenger while the driver was without one.

Table 11 summarises the use of crash helmets by people travelling by motorcycle on the various sections of the roads surveyed in Tanzania. Overall, nearly 10,000 motorcycles were counted, with a total of about 15,000 people travelling on them (driver and passengers), giving an average of about 1.5 people per motorcycle. A small proportion of these could have been counted twice if they passed two counting locations. This is unlikely to influence the results significantly. Only 17% of people on motorcycles were wearing helmets. There was an average of 0.26 helmets per motorcycle. Based on the observation that helmets are mainly worn by drivers, the data suggests that about 26% of drivers were wearing helmets.

The helmet indicator shows variations between the roads and the road sections. The lowest levels of compliance (6-8% of people wearing helmets) were on the remoter parts of the network around villages on the Hai and Bagamoyo roads. Compliance appeared greater on road sections where riders were close to towns or national roads, where enforcement is more likely. The highest recorded levels of compliance (29-39% of people wearing helmets) were on rural sections of the Bahi-Mpunguzi and Morogoro roads, suggesting some local enforcement initiatives have been picked up by this indicator.

Table 11 Crash helmet use by people travelling by motorcycle on the surveyed roads in Tanzania

Road	Section	No. of motor-cycles	No. of people *	People per motor-cycle	No. of helmets	% people with helmets	Helmets per motorcycle
Hai Road	Start	720	1,110	1.5	132	12%	0.18
	After 7 km	513	795	1.5	51	6%	0.10
	Through road (control)	1,725	2,667	1.5	498	19%	0.29
Babati road	After 2 km near town	1,709	2,492	1.5	411	16%	0.24
	After 9 km nr investment	707	1,086	1.5	182	17%	0.26
	Control road	679	1,082	1.6	136	13%	0.20
Bahi-Chipanga	After 14 km (nr bridge 1)	329	568	1.7	91	16%	0.28
	After 32 km (nr bridge 2)	291	358	1.2	47	13%	0.16
	Control road	254	440	1.7	45	10%	0.18
Bahi-Mpunguzi	After 1km (near start)	540	812	1.5	190	23%	0.35
	After 20 km	278	368	1.3	143	39%	0.51
	Control Road	514	912	1.8	122	13%	0.24
Morogoro road	Upper section	791	1,016	1.3	297	29%	0.38
Bagamoyo road	After 10 km	507	712	1.4	159	22%	0.31
	After 20 km	303	538	1.8	41	8%	0.14
Total		**9,859**	**14,956**	**1.5**	**2,545**	**17%**	**0.26**
** Numbers of people on the motorcycles including the driver and any passengers*							

These observational findings in Tanzania are in marked contrast to a survey of motorcycle taxi drivers and passengers in eight villages in four districts in Mbeya and Pwani regions of Tanzania. Eighty-one percent of 103 motorcycle operators self-reported that they always wore a crash helmet, and 45% of 116 passengers self-reported they also always wore a helmet (Bishop et al., 2018). While the discrepancies could be due to sampling or local factors, it seems more likely respondents wished to appear compliant when they self-reported their behaviour.

Compliance with helmet use for drivers and passengers is much higher in Nepal, particularly near urban centres. Table 12 shows the survey results, with 781 motorcycle counted (many fewer than in Tanzania) with an average of 1.8 people per motorcycle counted. The helmet indicator suggests 46% of people were wearing helmets. Using the assumption that the driver is the most likely person to be wearing a helmet, compliance by drivers is very high, at 83% overall, and 96-99% on the sections closest to the towns. As in Tanzania, compliance was lower on the remote road sections at 59-64%. Even these lower figures were much higher than on any of the road sections in Tanzania.

Table 12 Crash helmet use by people travelling by motorcycle on the surveyed roads in Nepal

Road	Section	Number of motorcycles	Number of people *	People per motorcycle	Number of helmets	% people with helmets	Helmets per motorcycle
Kavre Road	After 5 km	131	227	1.7	130	57%	0.99
	After 10 km	46	75	1.6	44	59%	0.96
	After 20 km	22	38	1.7	13	34%	0.59
	Road total	**199**	**340**	**1.7**	**187**	**55%**	**0.94**
Sindhuli Road	After 5 km	267	421	1.6	257	61%	0.96
	After 20 km	315	635	2.0	203	32%	0.64
	Road total	**582**	**1056**	**1.8**	**460**	**44%**	**0.79**
Overall total		**781**	**1396**	**1.8**	**647**	**46%**	**0.83**
** Numbers of people on the motorcycles including the driver and any passengers*							

3.8 Enterprise Development Indicator

In Nepal, data had been collected in 2012 about the number of enterprises visible along the road. This was part of a Rural Transport Services Indicators (RTSI) survey (Starkey et al., 2013a and b) and the same methodology was used by this project in 2019. These did not include traditional farming but did include agricultural enterprises geared to specific urban markets such as chicken farms, market gardens and dairy

processing enterprises. Other enterprises included retail stores, food and drink outlets and workshops. Enterprise numbers are seen as a useful outcome indicator, and the information can be collected easily. On both roads in Nepal, the number of enterprises had increased. The growth in the number of enterprises and their diversity was greatest along the busier sections of the road, nearer the start of the road and closer to a town. In the remoter sections the number of small stores and tea shops had increased, but there was less diversity of businesses, with fewer workshops, dairies and chicken farms.

In Tanzania, there was no data on enterprise numbers from previous years, and so enterprises were not counted. However, it was clear from the observations of team members that there were concentrations of enterprises in the busier sections of the road, and that these sections were also diversifying their economies, with more small workshops (carpentry, metal work and vehicle repairs) and cash crop production (pineapples on the Bagamoyo road and grapes on the Bahi-Mpunguzi road).

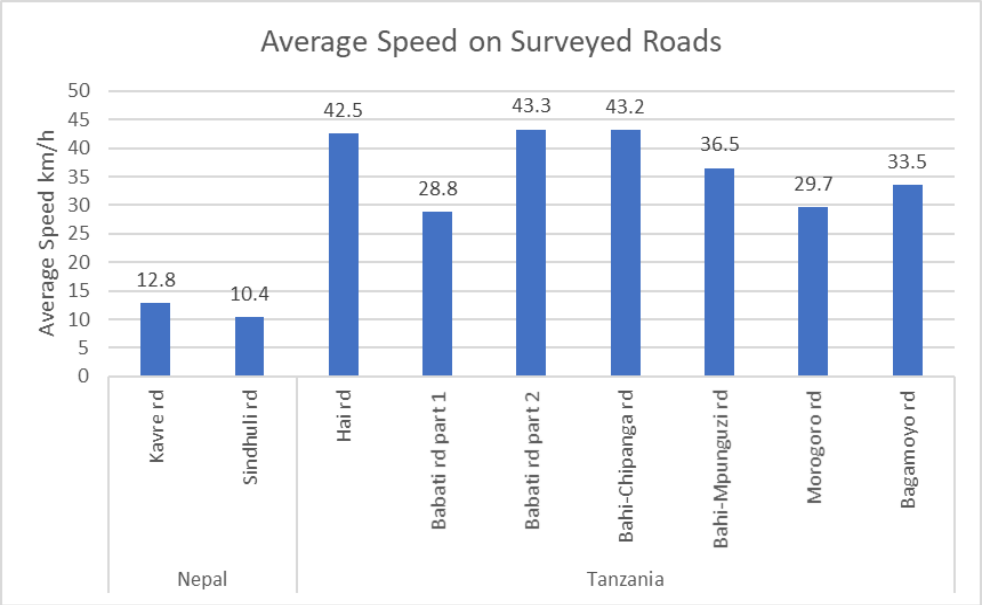
While the survey results cannot provide evidence of cause and effect, they suggest there is an upwards spiral of enterprise growth and transport services. This was particularly apparent on the first 9 km of the Kavre road in Nepal. It was also evident on the first 5-7 km of the Sindhuli road in Nepal and the Babati, Bahi-Chipanga, Bagamoyo and Morogoro roads in Tanzania. On all of these roads, the traffic patterns were different in the first few kilometres, with more traffic, including some minivans and three-wheelers that did not normally travel further up the road, into the remoter areas. The positive spiral of growth that links transport services and enterprise development appears to be a 'chicken and egg' scenario with both benefitting each other without being able to ascribe the cause and the effect.

Figure 6 Roadside enterprises on the busier first 9 km section of the Kavre road surveyed in Nepal

3.9 Vehicle Travel Speed Indicator

The average speed of travel is a reasonable proxy for many aspects of road condition, notably roughness. It is also relevant to the prevailing terrain and alignment. During the surveys in Nepal and Tanzania, the time taken to travel the length of the road at typical driving speed while responding to the prevailing environmental and traffic conditions. Figure 7**Error! Reference source not found.** shows the average speed recorded on each of the surveyed roads. It is noticeable that the roads that received the most recurrent maintenance, i.e. spot gravelling and reshaping, returned the highest average speeds. These were the Babati road part 2 and the Bahi-Chipanga road, both in Tanzania. The Hai road was also good even though it had received little maintenance; the good condition can be explained by the low levels of traffic and the relatively recent rehabilitation. The Nepal roads had many sections of stone soling or cobblestones, which although providing all-season access are very rough and slow to drive on. These two roads also had mountainous sections. Both of these factors will have contributed to the slower average speeds.

Figure 7 Average speeds on the drive-through surveys in Nepal and Tanzania



However, the research findings showed that the condition of the road does not necessarily determine the transport services that use the road. Transport services operators take many other factors into account. On the Nepal roads studied, with low average travel speed and surfaces that made them uncomfortable to travel on, the traffic levels were primarily determined by transport demand, with the higher demand on the road with a slower average travel speed.

4 Implications for Planning Road Investments

4.1 Planning and Prioritisation

4.1.1 The need to plan and prioritise

Budgets for investment in rural roads and other infrastructure are finite. It is not possible to connect all villages with good quality roads. Decisions have to be taken about where to construct new roads, which roads should be prioritised for rehabilitation and upgrading and what standards should apply. Roads authorities may have specific criteria for road prioritisation, and some examples of these were provided in the IMPARTS Scoping Report (Starkey et al., 2019a). Criteria may include:

- Cost of the intervention, and possibly some estimation of the life-time cost of the asset
- Condition of the road (if it already exists), or the anticipated maintenance burden
- Potential for providing accessibility to services, such as education, health and local markets
- Potential for economic development of an area including agricultural potential
- Population served
- Current traffic flows or predicted 'generated traffic' based on economic models.

This research has shown that the envisaged benefits of road investments may be over-estimated due to insufficient understanding of people's travel requirements. Local people and transport services should be consulted, as part of the planning and prioritisation processes.

4.1.2 Involve stakeholders

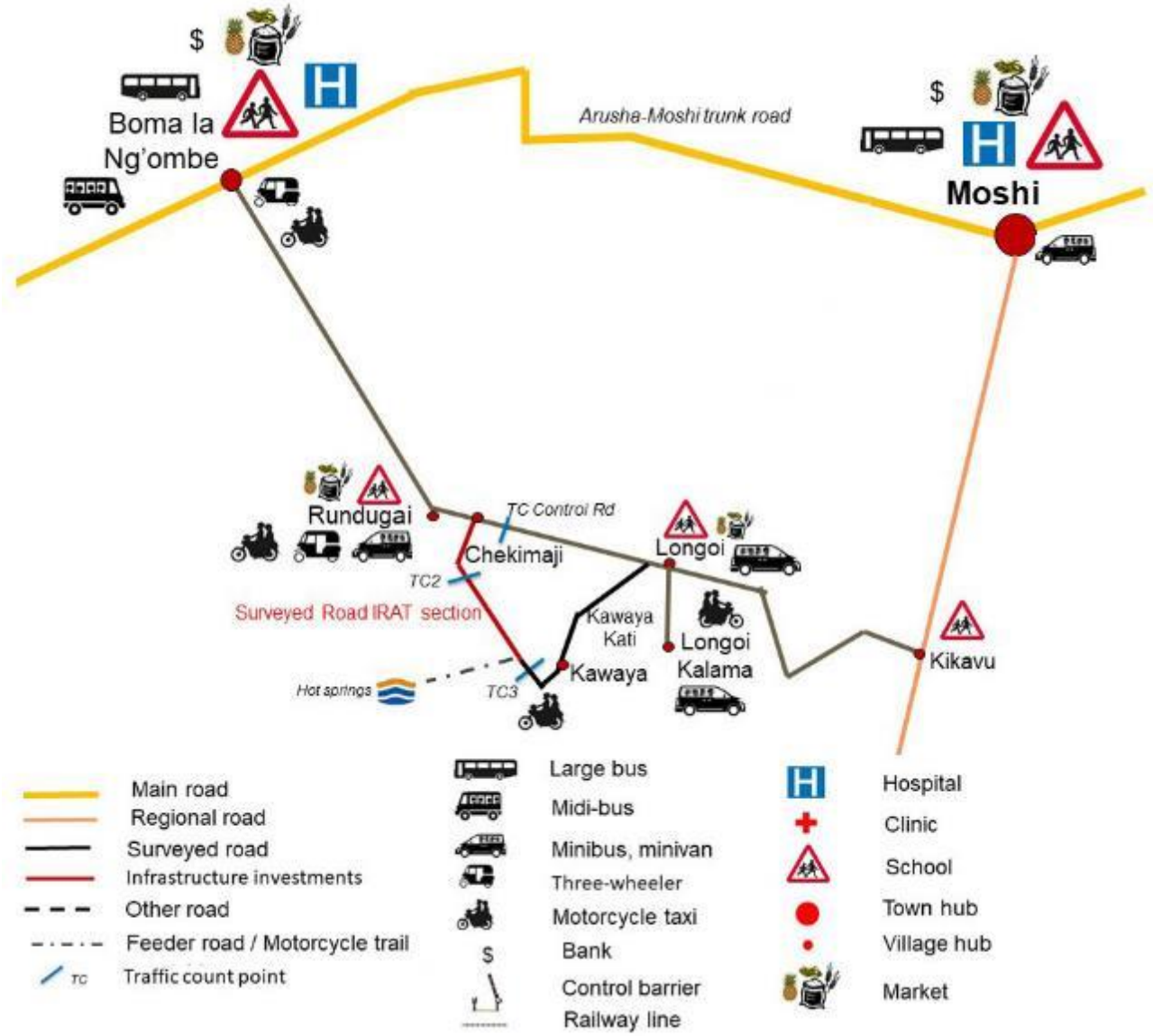
On the two roads in Nepal, there had been substantial involvement with district officials and local stakeholders living along the route concerning the road alignments and their construction methods. This was part of the DRSP methodology and was also in accord with national policy and the recommended procedures to enable all districts to develop District Transport Master Plans. This was discussed in the IMPARTS report on the Nepal surveys (Starkey et al., 2020b).

It is less clear how much discussion with local stakeholders there had been ahead of the IRAT and the AFCAP1 investments in Tanzania. It appears that the planning discussions mainly involved the road agency (now known as TARURA) at national and district levels. There does not appear to have been discussion with local inhabitants concerning their preferred destinations. There also do not appear to have been focussed attempts to gain the views of transport services providers, including their observations on local transport demand and what they thought about alternative route options. With the benefit of hindsight, it is now clear that had such discussions been held, some of the selected investments to remove bottlenecks might have been altered in scope, or might have led to alternative priorities being selected.

It is important to understand to where people want to travel: what are their desired destinations? It is not sufficient to survey people's current travel patterns, as these will be constrained by the existing infrastructure and transport services. In New York Central Park, footpaths were only paved once it was clear where people wanted to walk (their 'desire lines'). The design principle of understanding 'desire lines' can be used in situations such as when a new university campus is opened, with footpath construction delayed until the users' desire lines have been clearly established. This methodology avoids redundant footpaths and unsightly, unpaved short cuts (Lidwell et al., 2010). The principle of desire lines or people's preferred destinations is highly relevant to planning roads and transport services.

The village beyond the Hai road investment in Tanzania was approximately equidistant from the large town of Moshi and the small district town of Boma N'gombe. Market demand from that village favoured travel to Moshi, so improving the road to Boma N'gombe did not stimulate much new traffic. For those villagers (but not necessarily district officials) it might have been better to have invested in improving bottleneck sections on the road going towards Moshi. Figure 8 shows the U-shaped Hai road and the key destinations. The people in Kawaya village predominantly wanted to travel to Moshi, and so improving the road towards Boma la N'ombe (the improved section is shown in red) did not stimulate an increase in transport services.

Figure 8 Diagrammatic map of the Hai-road and connecting roads in Tanzania summarising key destinations



Concerning the Morogoro road, the preferred destination for most people is the busy town of Morogoro. Improving the link with the small market town of Ngeregere was not a priority for transport services, given that there was a good alternative route to Ngeregere, albeit a longer distance. The low population and small market demand on the upper half of the road was insufficient to divert existing transport services or justify new ones. Similarly, had transport service operators been consulted on the Babati road, it should have been clear that through transport services would be unlikely on that road given there was a small population with little transport demand and the alternative route was on good roads. Had there been discussions with transport operators on the Bahi-Chipanga road, it should have been clear that the road had a small population with low transport demand. Through transport services were unlikely as there was a better alternative route between Chipanga and Dodoma. There were also regulatory complications due to a weighbridge and the fact that the two roads served different bus stands in Dodoma.

The lesson is that when considering and prioritising road investments, local people should be consulted about their preferred destinations. Transport services operators of different types should be asked about the potential market demand, alternative route options and whether on-road or through transport services are likely to be desirable and warranted. The planned road investments may still be made for social, strategic or political reasons, but the early dialogue will have informed planners of the likely consequences.

4.1.3 District transport master plans

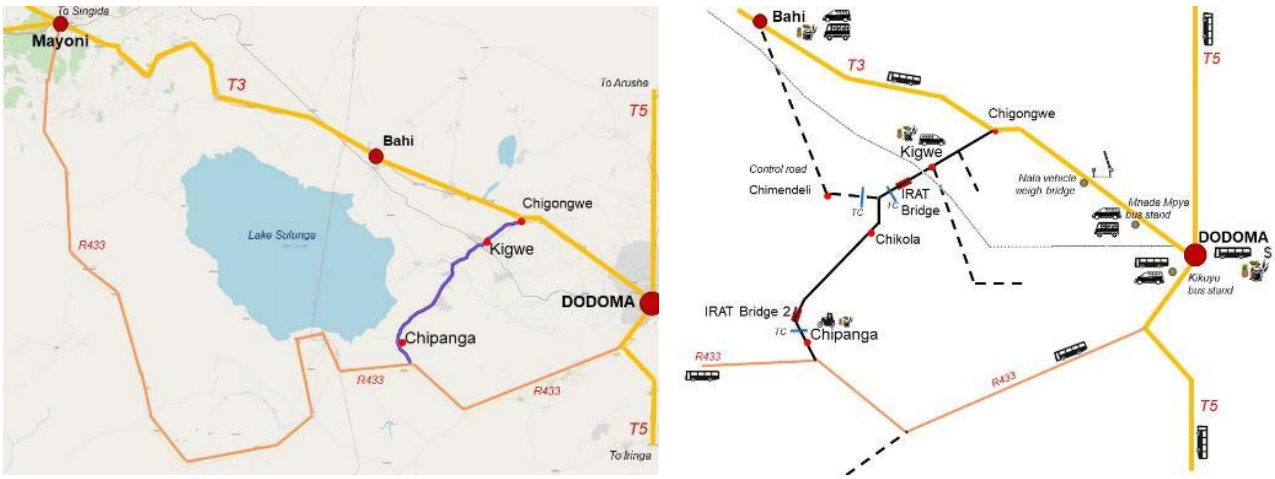
In Nepal, participative processes have been involved in developing District Transport Master Plans (which were primarily about infrastructure as there was no planning for the transport services). Road prioritisation involves stakeholder discussions and includes technical, social, environmental and commercial perspectives. District maps identify the core national network, the strategic district level roads to be kept open, and duplicate alternative routes that can be valuable in the case of landslides, but have a lower priority for district-level resources (DoLIDAR, 2012). The benefits of the district level planning with stakeholders was discussed in the IMPARTS report on the Nepal roads. It was recommended that this approach to local planning and prioritisation be adopted elsewhere (Starkey et al, 2020b).

Stakeholder involvement is a prerequisite of district transport plans. It is important that the views of local residents are heard to learn of their preferred destinations. Transport services providers should be involved to learn of the possible consequences of road investments or of road deterioration through inadequate maintenance. These voices must be heard, because district level officials themselves may overestimate the importance of within-district travel, when people's preferred destinations (and transport services routes) may be out of the district.

An example of the danger of emphasising within-district travel patterns was discussed by Starkey (2007a) and cited in the IMPARTS scoping report (Starkey et al, 2019a). In the Hintalo Wajirat district (woreda) in Ethiopia, district officers had prioritised a road joining two parts of their district. This good new road had generated very little traffic, and no regular transport services. The problem was the two parts of the district were on different arterial spokes leading to Mekelle, the capital town of Tigray Region, and people's preferred destination. Therefore, the district was in two separate transport catchment areas and there was little transport demand to cross between these roads. The road had strategic benefits for the district itself and allowed district officials to travel between the two parts of the district, provided they had vehicles. However, the road investment had little social or commercial value as it did not change transport services or most people's movements.

The example of the Bahi-Chipanga road studied in Tanzania appears to be a similar scenario. Two bridges and other rehabilitation work were provided on a road that was effectively a cross-link between two arterial spokes leading to the capital city of Dodoma. This is illustrated in Figure 9. As with the example in Ethiopia, little new traffic was generated by this investment, and transport services did not change. Looking at a map of Bahi District, the road does provide an important link between two parts of the district, without the need to travel into and out of Dodoma. However, it currently has negligible through traffic and there is little likelihood of this changing in the foreseeable future. The population along the road is small, and both ends of the road are already served by transport services travelling to and from Dodoma on separate routes. In Bahi District, as in Hintalo Wajirat in Ethiopia, appreciating how the transport hub and spoke systems operate is crucial for understanding the existing patterns of rural transport services and how they might be improved.

Figure 9 GPS trace (left) and schematic map (right) of the Chigongwe-Chipanga road in Bahi District, Tanzania



4.2 Rural Road Construction Options

4.2.1 Labour based construction for LVRRs

Labour based construction can be defined as an appropriate technology for building LVRRs that maximises the use of labour (skilled and unskilled), together with the support of light equipment, whilst using locally available materials and resources. In Nepal this is embodied in the Green Roads Approach (Acharya et al., 1999; Mulmi, 2009), which inspired subsequent projects, including DRSP which was responsible for the two trial roads in Nepal. In Tanzania the technology is also used, but to a lesser extent than in Nepal.

It is important to recognise the limitations of labour-based technology, but it does lend itself particularly to earth and gravel road construction, as well as some surfaced pavements such as cobblestones and stone soling. It is not appropriate where large excavations or haulage of materials is necessary, and it may not be able to provide higher quality outputs in certain circumstances, compared to equipment-based methods. Labour-based methods are also particularly appropriate to bio-engineering, which is the technology used to stabilise both cut slopes and landslides in mountainous countries such as Nepal. This involves a combination of basic engineering structures such as gabions, and planting to reinforce unstable slopes, which can only be effectively achieved using labour.

4.2.2 Earth roads

Engineered earth roads are an established technology for LVRRs in low income countries. A study by Rolt et al (2008) explored the conditions under which earth roads are a reasonable choice of road surface, using data from 91 sites in Cambodia. The study quantified how such roads deteriorated and illustrated the complexity of the performance of earth roads confirming why it has been elusive to derive general specifications. Rolt (2008) concluded that locally derived flexible specifications that are relevant to the local materials and road tasks are most appropriate.

The surveyed roads in Nepal were constructed using labour-based methods. Both roads were essentially earthen roads with specific mitigation in vulnerable areas, including drifts at water crossings, and cobblestones or stone soling on steep or vulnerable areas. The provision of transport services was not specifically considered during the planning process for these roads. These interventions were made more than 10 years ago using labour-based technologies but have lasted with minimal deterioration in an environment of heavy monsoon rains and frequent landslides. This is illustrated in Figure 10. Some of the cobbled surfaces seem in perfect condition, which is in marked contrast to the 'bulldozer' roads seen throughout the hilly regions of Nepal.

Figure 10 Earth sections on the Kavre road studied in Nepal that have allowed buses to operate for ten years

Note: the inset photo (top centre) shows the context of the section illustrated

Earth roads tend to be narrower than fully engineered roads. This can be an issue when vehicles try to pass on single lane roads, but also in the mountainous areas where hairpin bends and tortuous hillside alignments are difficult to negotiate and can be frightening for the driver when there are no retaining structures on steep sections. Road operators and authorities often aspire for sections of the road to be widened. Whilst this could be achieved through labour-based methods, the tendency has been to use

heavy machinery to undertake the work. On both roads in Nepal this method has been applied and has led to problems with the road surface and slope stabilisation.

A review of DRSP (Starkey et al., 2013) found that labour-based operations were perceived as old-fashioned, difficult to organise and with no financial 'benefits' to those commissioning the work. In contrast, hiring contractors for earthworks and bituminous surfaces was modern, quick, easy and often resulted in 'kickbacks' to the commissioning officials. In Nepal much progress has been made in developing labour based construction, primarily for earthen roads, but there is still work to do to mainstream this into standard government practice.

Although earth roads do not provide the best riding quality and the surface is vulnerable to the environment, the results show that if the road can be reliably maintained as an all-season road throughout the year, it will be effectively utilised. This seems to be regardless of the comfort of ride and travel times.

4.2.3 Gravel roads

In Tanzania the majority of the surfaces on the trial roads were gravel and were selected for rehabilitation by IRAT as they had 'bottlenecks', or areas where the road condition was causing accessibility issues. As the IRAT and ReCAP works carried out were only on limited sections of each road, and in some cases only included drainage structures, it was not always possible to define precisely from previous reports what proportion of the whole road was gravel and what was earth. However, it was clear from the surveys that all of the rehabilitated sections were gravel. Similarly to the Nepal trial roads, there is no evidence that transport services were considered during the planning process.

Gravel roads tend to be engineered to a higher standard than earth roads and have more conventional drainage, such as side drains, culverts and some drifts. They can still be constructed using labour-based methods, as they have been in Nepal. The trial roads in Tanzania have largely gravel surfaces with 6% camber, and 4% camber on the paved surfaces. In most cases the gravel was sourced locally. The nature and specification of gravel production was not recorded, but it is likely that the rehabilitated areas used local specifications. It however appears from the surveys that many sections have used gravel with oversize materials, leading to a rough surface when the road starts to deteriorate through traffic. There is also evidence of areas where the gravel has been eroded to leave earthen surfaces. When a gravel road starts to lose its shape the surface becomes waterlogged and is vulnerable to damage. On steep sections with no protection the gravel has eroded in the form of longitudinal gullies along the road surface, which makes it very difficult to traverse for smaller vehicles.

4.2.4 Low-volume, low-cost seals

On the trial roads there are a variety of low volume seals. On the Sindhuli road in Nepal Otta seal was used, and in Tanzania there is a range of bituminous seals as well as concrete strips, geocells, and stone soling. In reality the surface itself did not have a great influence on the transport services that use it, but some had specific issues such as the dangerously exposed edges on the concrete strips.

The bituminous surfaces on Bagamoyo road all provided a similar surface when first constructed but they deteriorated at different rates. An example of such deterioration is shown in Figure 11. Given that this was a trial road for different surfaces, this was not unexpected. Low-cost seals by their nature are minimal surfacings designed for low traffic levels, so if traffic increases in advance of expectations they become more vulnerable to premature deterioration, although for LVRs other deterioration factors such as climate also play a part.

Figure 11 Bituminous slurry seal section on the Bagamoyo road in Tanzania showing deterioration

Bituminous and concrete sealed surfaces are more reliant on equipment and heavy machinery than labour, although labour would still be an essential component of the construction. Surfacings such as cobblestone and stone soling rely on skilled labour to produce a good result, so are more appropriate for labour-based construction.

4.3 Design Standards for Rural Roads Appropriate to Prevailing Traffic

Box 1 summarises some general considerations for LVRR designs. In Nepal the trial roads were designed to DRSP standards, which broadly followed the Green Roads Approach (Acharya et al., 1999) established by the Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR) in collaboration with Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and Swiss Development Cooperation (SDC). They were designed as earth roads, but were engineered appropriately to the local situation, applying some experimental surfacings for LVRRs in Nepal, such as Otta seal and cobblestones. Given that the majority of DRSP roads were in hilly or mountainous terrain, they adopted the mass balancing approach, to minimise earth movement and facilitate labour based construction, with minimal transportation of materials (Mulmi, 2009). When used in conjunction with basic structures and bio-engineering measures, this can be an effective and sustainable solution to LVRR design. In Tanzania the trial roads are designed as gravel roads, but with some surfaced sections as part of LVRR surfacing trials.

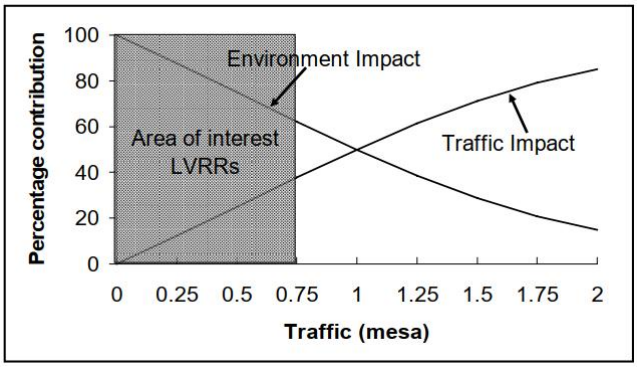
4.3.1 Drainage

Effective drainage is key to LVRR designs. The most important aspect for the design of a road is the provision made for protecting the road from water. If water is allowed to enter the structure of the road, the pavement can become weakened and will be more susceptible to damage by traffic. The road surface must be constructed with a camber to shed rainfall, and the road formation should be raised above the level of the surrounding land to prevent it from becoming saturated. In addition, drainage structures are important for taking water away from the road. Where drainage fails, this can limit the types of vehicles that can use the road.

In the hilly (mountainous) regions of Nepal, the district road projects preferred to use stone soling or gabion drifts (referred to as causeways in Nepal) instead of concrete culverts. These were considered more flexible than concrete, and so could adjust themselves to the mountain slope. Drifts were simpler to build on site using local labour and resources, and they could be maintained by local people. Concrete culverts required more external materials and supervision and were vulnerable to erosion and blocking (Acharya et al., 1999). Most water courses in Nepal have minimal flow for most of the year but are susceptible to flash flooding and therefore erosion during the monsoon season. Water crossings are designed to allow the water course to overflow the road, without causing damage to the structure. Gabion boxes filled with local stone are the most common, but concrete or block paving may be used in vulnerable areas.

Box 1 Design standards for LVRRs

There are many LVRR designs around the world that have been tailored for a country's specific conditions and needs, but the basic framework for design is similar. The first step is to decide whether a potential new road or rehabilitation does fall within the LVRR envelope, if not it will require a higher standard of geometric design.



(Source: SEACAP, 2008)

Geometric Design

It is important to recognise that LVRRs are designed for low traffic, and that the deterioration of these roads is higher through the environment than through the action of traffic, as shown in the figure above. This is especially true for unpaved roads, so this is a key factor in designing LVRR cost effectively.

The established steps for geometric design are as follows:

- Assess the traffic mix and general terrain to determine road geometry.
- Assess key environment issues, including climate, terrain, available materials, local maintenance.
- Assess available resources, including budget, in relation to access requirements and road environment.
- For spot improvements, assess priorities and risk, i.e. will it achieve the required objectives.
- Decide basic design options along the alignment.
- Carry out a detailed traffic assessment and predict traffic growth.
- Carry out a road alignment survey and detailed assessment of environmental impact, resettlement, subgrade and hydrology, as well as identifying and testing local materials.

These steps (SEACAP, 2008) will vary for different countries and situations, but there is no specific consideration for transport services in this process. LVRRs are designed for standard vehicles, based on predicted traffic volumes and weights. The design of LVRRs varies around the world, but a general rule of thumb is:

- Up to 300 motorised 4-wheeled vehicles per day, max. design cumulative traffic load over the life of the road of < 0.5 million equivalent standard axles (mesa).
- Upper axle load limit of 4.5 tonnes
- Upper vehicle width of 2.3 metres

It should be noted that the LVRR definition is not an established international standard and will vary from country to country. Burrow et al. (2016) reviewed 10 LVRR projects in Africa and Asia with sealed surfaces, and seven with unsealed surfaces, to assess the sustainability of the LVRR approach.

Other design considerations for LVRR are (SEACAP, 2008):

- Design speed: Based on terrain (flat, rolling, mountainous)
- Width: Determined by traffic using the road, typically 2.5m to 3.5m
- Gradient: Limits for different surfacing types
- Crossfall/Camber: Typically 4% for sealed and 6% for gravel/earth
- Stopping sight distance: Defined by design speed and surface type
- Minimum horizontal curve radius: Defined by design speed and surface type
- Minimum vertical curve radius: Defined by design speed and surface type

Again, these design considerations do not specifically account for transport services within their design. In particular, the design speed, the width of the road, the gradient and curve radii could be linked more overtly to the type of transport services required to serve the local communities.

In Tanzania the trial roads are all situated in flat or rolling areas. The standard design in Tanzania is to install culverts or concrete drifts on LVRRs, and in some instances turnouts are used (Babati road), which divert side drain water onto surrounding land. Drainage was a key aspect of the rehabilitation that was carried out on most roads, as water crossings were causing bottlenecks on the roads. The Bahi-Chipanga road included two main bridges that allow reliable all-season access across river courses. The key rehabilitation on the Babati road and the Bahi-Mwitikira road included installing culverts and surface rehabilitation. In these situations, culverts are an appropriate solution, as long as they are designed according to appropriate standards and specifications and take account of potential increases in volume due to climate change.

4.3.2 LVRR surfacing options

LVRR principles dictate that maximum use should be made of locally available materials, whilst minimising expensive or high-quality materials, especially if they have to be hauled long distances. This translates into meeting the requirements of the road by using the thinnest base layers possible, and using a capping layer where appropriate (SEACAP, 2008b).

The key surfacings normally considered for LVRRs are:

- Unsealed: Gravel, cobblestone, stone soling, etc.
- Flexible: Bituminous surfacings, i.e. surface dressing, slurry seal, Otta seal, etc.
- Rigid: Concrete, concrete strips, etc.

The trial roads in both Nepal and Tanzania use a wide variety of all of these surfacings. Some have been designed specifically for the prevailing situation (i.e. cobblestones on steep areas in Nepal) and some were essentially constructed as test sections and monitored to see how they performed on LVRRs. In Nepal, even small motorised vehicles were able and willing to negotiate the rough steep sections that had cobblestone or stone soling surfaces.

Gravel surfaces provide a way to protect the road structure, but gravel is an erodible resource, requiring constant maintenance and replenishment to maintain its effectiveness. This is evident on the roads in Tanzania, where some have eroded to the extent that the subgrade is visible. More durable surfaces such as cobblestones are used on vulnerable areas in Nepal.

Many low-cost seals have been produced in recent years and are continuing to be developed. The type of surface selected will depend on the availability and cost of suitable aggregates. Typical surface dressing and Otta seal surfaces are usually designed to last 8-12 years, and the life can be extended at the end of this period by applying a further overlay. Some thinner surfacings such as slurry seal were also trialled in Tanzania but performed less well than the traditional flexible pavements.

Concrete is less common on LVRRs because of the high initial cost, and the need to import materials. The cost has led to the experiment with concrete strips, which only provide a narrow, paved surface in the wheelpath. This was trialled on the Morogoro road and the Bagamoyo road in Tanzania. Although the condition of the strips was good, there were some problems with erosion of the materials surrounding the strips, making them less appropriate for two and three wheeled vehicles.

4.4 Motorcycle Trails

4.4.1 Side trails

On most of the roads in Tanzania there were clear examples of motorcycles creating ‘motorcycle trails’ on road shoulders or on paths parallel to the road, as illustrated in Figure 12. These generally did not require specific initiatives, but they evolved after some individual drivers had chosen slightly smoother routes and subsequent motorcycles followed these to gradually create smoother paths that more and more motorcycles followed. These are also used by bicycles. These trails make the journeys more comfortable, and for this reason they allow faster speeds. The trails do not seem to get highly rutted, and so when motorcycles have to pass another vehicle, it is not difficult to move off the trail and then move back. The trails alongside the road generally cease when it comes to water courses, and motorcycles re-join the road to cross bridges, culverts and drifts. This potentially creates a risk if there is another vehicle travelling

straight along the road, and the two drivers do not take sufficient notice of the other vehicle's trajectory. In the dry season the side trails may continue off the road, across the dry water course.

Figure 12 Examples of side trails that have developed on three of the surveyed roads in Tanzania

In Nepal, there was evidence of motorcycles following smoother trajectories along the roads, but the steep topography meant that side trails were not a realistic option.

It is not immediately clear what the road authorities could or should do to assist motorcycles with regard to smooth rides. If there were larger smooth side strips designed for motorcycles, they would probably also be used by other vehicles, creating possible hazards. On the Babati road, one section was so rough with oversize stone that even cars and pickups used a side trail alongside the road for greater comfort and speed.

4.4.2 Connecting off-road villages

The motorcycle operators on all six roads in Tanzania were questioned about paths and trails that link houses and villages off the road to the road network. Most operators were aware of, and used, such trails to reach off-road houses and take people to markets, shops and medical facilities. Such motorcycle trails were regarded as being important for their businesses. All the trails referred to appear to be informal trails that evolved from footpaths. However, certain authorities or organisations in several countries in Africa and Asia have developed simple standards for such trails, to allow off road villages to be connected by all-season trails, which can be earthen, concrete, brick or gravel (SuM4All, 2019). Examples of motorcycle trails made by projects or local authorities are shown in Figure 13. Simple trail bridges can traverse water crossings. The construction of motorcycle trails is not yet a policy in Tanzania, but it appears to be a valuable and inexpensive approach to improving rural mobility and such a policy is recommended.

Figure 13 Examples of constructed motorcycle trails in Liberia (left), Bangladesh (centre) and Myanmar (right)

4.5 Maintenance Strategies for LVRRs

4.5.1 Background

Road maintenance is often neglected in LICs, which can have a negative effect on people's livelihoods and the economy of a country. This is especially true for rural roads, and even more so for unpaved rural roads. Many LICs have a high percentage of unpaved roads, with the overall figure for percentage of unpaved

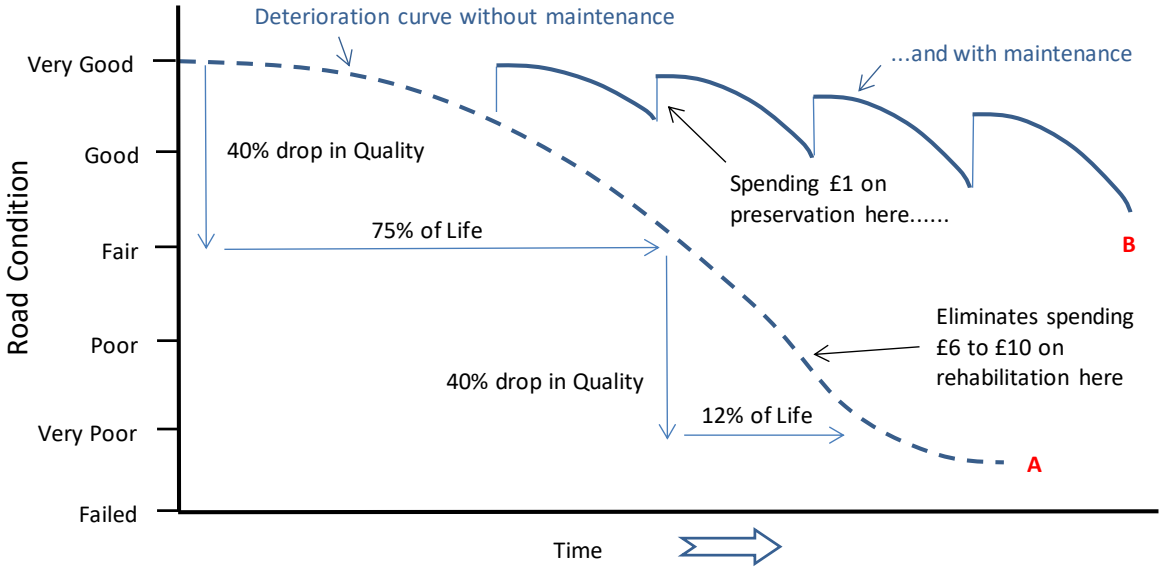
classified roads standing at 53% for Africa, according to the African Development Bank figures for 2014 (AfDB, 2014). Very few countries, if any, can afford to fully maintain their road network.

Investment decisions and maintenance actions are interdependent and together affect how roads authorities implement maintenance based on available funds. Countries have to make the most of the resources they have by spending their limited funds in the most cost-effective way. Transport services are seldom considered in these decisions.

In most LICs there can be relatively weak public pressure to maintain road quality, as has been shown in recent publications (Suthanaya, 2017 and SuM4All, 2019). This can be due to a number of factors, such as lack of empowerment, a low value of time in models and a lack of appreciation of the potential for road quality. There is commonly more demand to provide access, with less demand to maintain it to any level of quality. The institutional structure of road agencies and inadequate funding also have a bearing on the demand for maintenance, making it hard to implement effective maintenance policies. For example, Tanzania officially has 109,000 km of rural roads, but only half of these are officially classified. TARURA is only mandated to maintain the half of the network that is classified, which means that half of all rural roads in Tanzania are not maintained or are maintained by communities to a lower standard than the core rural network.

Road condition is an important input to planning and prioritising road maintenance on all types of road. If road maintenance funds are not used wisely throughout the life of the road, the road asset will deteriorate exponentially, as shown in Figure 14.

Figure 14 Typical deterioration curve with and without maintenance



Source: after FHWA (2006)

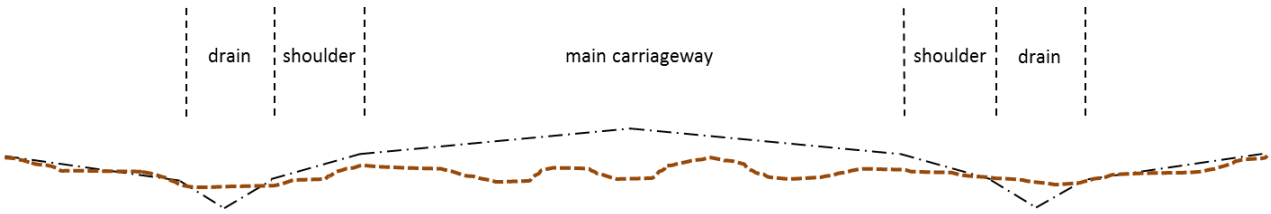
Unpaved roads are cheaper to construct, carry less traffic and lighter vehicles, and are more vulnerable to climate effects. They can however have a substantial impact on poverty, especially in rural areas. The need to plan and prioritise their maintenance is therefore important, but the development and continuation of transport services also needs to be considered.

4.5.2 Road deterioration and condition

When the road loses its shape and the camber has gone, rainfall will sit on the road surface and saturate the surface materials, because there is no longer any mechanism for water to be drained away. This causes soft spots and eventually potholes. Figure 15 shows the cross section of a typical deteriorated gravel road with large potholes in the centre section. When the before and after road profiles are compared, as in Figure 15, it can be seen that the road has lost its shape through lack of maintenance, with carriageway material being transferred into the drains and serious deterioration in the centre section. At this stage the

road has lost its ability to drain water from the surface, which will lead to rapid deterioration. The extent of deterioration will have an effect on the vehicles that are able to use the road.

Figure 15 A deteriorated unpaved road compared to the original cross section



A typical maintenance process aims to identify where the maintenance funds are most needed. This usually involves some assessment of the condition of the existing road. There are many different ways to assess the road condition, but some of the more common methods for rural road networks include:

- Roughness
- Visual Inspection
- Speed

Roughness

Roughness is usually measured as the International Roughness Index (IRI), in m / km. There are numerous methods used to measure roughness, from visual estimation, to laser profilometers, although these are not generally used on unpaved roads. Smartphone apps can also be used, although they tend to be less reliable for unpaved roads and at low speeds (the RoadLab app does not record a speeds less than 15 kph).

Visual Inspection

This is usually achieved by a drive through or walk through inspection of the road, using pre-prepared data collection forms that are designed to make the assessment as objective as possible. This is often accompanied by photographs and measurements of key distresses, such as cracking and potholes.

Speed

The average speed of a standard vehicle can also be used to measure the condition of a road. The condition levels are typically defined as a range of speeds achievable.

4.5.3 Survey findings on maintenance in Nepal and Tanzania

It was found in both countries that the level of maintenance was minimal on the trial roads. In Nepal there was some spot gravelling that is used to keep roads open, and emergency maintenance for clearing landslides and repairing damage from the environment. When the roads were constructed there was regular routine maintenance using lengthworkers and maintenance gangs (see Figure 16). These helped to keep the road open during periods of heavy rainfall and also helped to maintain a smoother running surface. However, this system ceased soon after the DRSP project was completed, and no routine maintenance is now carried out.

Figure 16 Lengthworkers maintaining earth roads in Nepal

The effects of a lack of maintenance can be seen, especially in the Otta seal areas, which have deteriorated to the extent that very little surface remains. This is also in part due to local people using the road drains and surface to channel irrigation water between fields, a problem largely ignored by the local roads' authority. Despite some efforts to maintain roads, the current maintenance regime has not been effective in improving transport services especially on the Bhoredovan road, mainly due to the problems with landslides and the poor road surface.

In Tanzania the situation was similar. Although all roads are allocated a maintenance budget and had received some maintenance recently, this was inadequate to prevent deterioration of the road surface and drainage. On some roads local communities were engaged in maintenance activities, but this was not consistent and depended on the attitudes of the local maintenance office.

There was evidence of recent grading/regravelling on the Babati and Bahi-Chipanga roads, but the other four roads had only received emergency or routine maintenance. Even then there were only relatively short sections of these two roads that has seen any significant maintenance. The Hai road was constructed most recently and had little traffic, so exhibited a better condition. Many of the roads exhibited a rough surface, due to deterioration and oversize materials.

Key maintenance issues on the Morogoro road were erosion on the steeper sections, and muddy areas where drainage has become blocked or ceased to function effectively. These areas are dealt with on a needs basis. Small maintenance gangs have been formed in the area and work on a labour-based principle. The Bagamoyo road had different types of surface, many of them paved. Although these were essentially experimental, they are deteriorating to different extents due to lack of maintenance. For example, the slurry seal surface was badly deteriorated. Most of the maintenance activities include routine maintenance and spot improvements, using local labour where possible. It was the opinion of the local key informant that maintenance over the past three years had improved the riding quality, making travel more comfortable and improving travel times.

Lack of maintenance can also have safety implications, for example the erosion alongside concrete strips. Although the concrete surface itself is in good condition, the gravel alongside had deteriorated, forming a sharp edge that can be hazardous for motorcycles. This particular construction is difficult to maintain effectively and may not be appropriate for rural roads.

5 Implications for Improving Transport Services

5.1 The current situation and the need for improvements

The IMPARTS studies in Nepal and Tanzania were complemented by the 'Phase 3' activities designed to understand the limiting factors for rural transport services and ways in which these might be overcome. This involved learning from international experiences about the prevailing operational features of transport services and their institutional environment, how rural transport services could be scaled up and improved, and whether subsidies were a realistic option. The findings were presented in a separate report (Starkey and Hine, 2020) and the implications of these are discussed in the following sections.

Most rural transport depends on small-scale, informal sector entrepreneurs with limited capital. Market demand for their services is the key criterion for their operational decisions as they attempt to make a profit on every journey. Conventional vehicles (cars, minibuses, vans and buses) tend to be old, and are often overcrowded, with mixed loads of passengers and freight. Motorcycle numbers are growing rapidly, and in some countries motorcycle taxis are the main means of rural transport. Three-wheelers are increasingly used in rural areas (but much less than motorcycles). Rural transport services generally operate with hub-and-spoke patterns, with the larger vehicles (buses) using large towns or cities as their hubs. Villages are mainly served by smaller vehicles that terminate in nearby market towns. Operators often form associations, which are important for controlling loading and queuing at the urban terminals. Some associations become powerful cartels, controlling market entry. Transport services regulatory bodies tend to be small organisations that concentrate on regulating urban and inter-urban transport services. There is little planning of rural transport services and minimal regulatory presence at the district level. There is weak regulatory enforcement by police on rural roads. Local police tend to be sympathetic to rural transport operators, although, in some countries, they extort payments to allow non-compliant operations (Starkey and Hine, 2020).

While rural transport services in high-income countries depend on subsidies, most rural transport in low-income countries is unsubsidised with authorities showing little interest in subsidising informal-sector operators. There are few examples of subsidised parastatal companies providing rural transport services. Some countries have tried to make informal operators join together in formal companies or cooperatives, mainly to improve urban or peri-urban operations. The processes have been slow and difficult (Starkey and Hine, 2020).

5.2 The Importance of Promoting Market Demand

The IMPARTS research in Nepal and Tanzania as well the synthesis of experiences from elsewhere has found that market demand appears to be the key factor limiting the provision of transport services on passable rural roads. This implies, some of the best ways to improve transport services would be to increase and/or consolidate market demand and/or make it easier for transport operators to recognise and meet the existing demand. The following sections of this report explore some options to try to stimulate market demand. In all cases, there would be need for stakeholder consultations and participative processes for implementation. This research has highlighted the importance of learning from local inhabitants and rural stakeholders to inform decision making and ensure the solutions proposed would work in the local circumstances.

5.3 Service Frequency and Predictability

Increasing predictability and frequency increases market demand. People do not like waiting for long periods, uncertain when and whether transport will arrive. When transport is regular and predictable, people can plan to travel, whether daily or occasionally (Starkey, 2007b; 2016b). Many rural bus services (and passenger truck services in some countries) assure a daily market, by leaving predictably (often early morning) and returning later in the day. Everyone in the terminal village and along the road knows the departure time(s) and the predictability. *Simple timetables can increase market demand*.

In areas where there are surges of demand on market days, the predictability that transport services will arrive on market days ensures many people will plan to travel on those days. They do not bother to travel

on other days except in an emergency, knowing that they cannot depend on transport services. *Predictability can increase market demand*.

The morning departures and afternoon returns are convenient for those travelling to a distant city but are less suitable for people (often women and children) that need to travel to nearer rural clinics or small shopping centres. Similarly, market day only transport is not suitable for many other needs, particularly as clinics and other service providers are always stretched by demand on market days. People (particularly rural women with multitasking responsibilities) need more frequent transport, allowing them to return in an hour or two.

In Tanzania, on a connecting route to the Hai road, three-wheeler (bajaji) operators run frequent route-based services between Boma Ng'ombe and Rundugai. If possible, they wait until four passengers are ready to travel, but will generally leave anyway every 10-15 minutes, hoping to pick up passengers on the way. This ensures people at the terminus do not have to wait long before departures (Starkey et al., 2020c).

A similar pattern of operations to the three-wheelers on the Hai road in Tanzania was developed by operators of three-wheelers and pickups on a road in Pakistan, they shared the route with a queuing system, and left as soon as they had a load, or after 15-20 minutes even if they did not have a full load (Starkey et al., 2020a). Pickups and three-wheelers at their joint village departure stand are shown in Figure 17. Both these examples were on quite busy sections of the road and did not extend to the more remote parts of the road. However, this frequency stimulated demand, and people from further villages would walk to the 'shuttle' terminal because they knew they would leave quickly and have a frequent service for their return journeys.

Figure 17 Village transport hub in Pakistan where pickups and three-whelers operate a joint timetabled service

There is evidence from around the world that suggests market demand can grow by increasing transport frequency. This introduces an element of risk for operators, as they cannot be guaranteed a full load on each trip. Through the mutual support available within associations, it should be possible to protect the more vulnerable operators. All association members have to learn that provided their overall earnings are sufficiently high, it is possible to operate with some disappointing trips. Formal sector transport operators use business models based on overall profitability, and with appropriate reassurance and support, informal sector operators can learn to operate in this way too.

5.4 Consolidating Demand

Where transport demand is low, there will still be people in villages wanting to travel or to send freight. There needs to be some mechanisms for consolidating this demand, and persuading transport operators to respond. Once a regular service has been established, more people will want to travel (see Section 5.3). Ride-sharing apps are likely to achieve this in the future (see Section 5.8). However, similar results can be achieved more slowly through discussions and negotiations (Starkey, 2007b). For example, operators need to agree the minimum load that is viable for them without losing money. An initial timetable for the trial should be agreed and a village committee, group of transport users, NGO or other rural entity should then guarantee the operator will earn at least the tariff associated with this minimal load. The village organisation could 'sell' this number of tickets. However, this may not be necessary, as payments will only need to be made for the 'missing' passengers where there is insufficient transport demand to cover the minimum load required. Such payments will be minimal (if any), provided the villagers or association

members continue to travel and/or encourage other people to do so. The operators will make a profit on all the extra passengers above the minimum load, and the start of the service should encourage more people to travel. The mechanism is only necessary to 'prime the pump' and initiate regular transport services. Any early costs are likely to be less, overall, than if the users had to pay for the more expensive motorcycle taxis and/or chartered vehicles. The arrangements and mechanisms required will depend on local circumstances but should be achievable with trust and cooperation within and between the villages concerned and the operator(s). Facilitating such arrangements and spreading the mechanism to other communities could be the work of a local NGO or of a devolved local government official (e.g. district-level staff from a roads and transport agency). Where there are community-based organisations implementing maintenance contracts on rural roads, the responsible persons could be introduced to this system, so that the roads and transport services work become integrated even at this devolved level. *Consolidating existing transport demand leads to greater transport demand*.

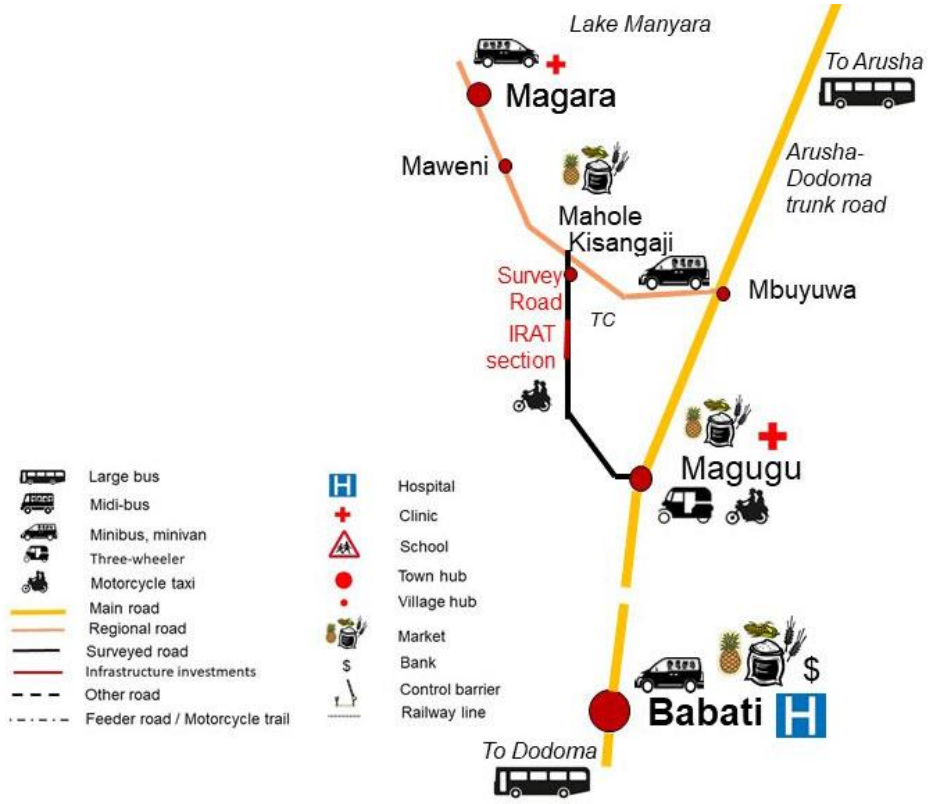
5.5 Route Planning and Sharing

Informal transport services providers are good at optimising the transport services they run but may lack the skills and collaborative mechanisms to develop services that are more inclusive. For example, they may serve remote villages on market days, but not on other days due to poor transport demand. Through planning and sharing routes, it may be possible to increase transport services in an area. On two of the roads in Tanzania, the improved road had no conventional transport services, but geographically they were shortcuts between two other destinations that were served by minibuses and midibuses. The individual operators did not want to travel on the short cut routes, due to a lower density of demand (Starkey et al., 2020c). However, although transport demand was low on the shortcuts, there was some daily demand on those roads. This meant the total overall demand on both of the two road options was greater than that on just the currently preferred route. While it would not be in any operator's own interest to switch to the shortcut, it would be in the association's interest to gain income from that untapped demand. One answer would be to share that road on a rota basis by increasing the overall number of daily trips. Depending on the relative demand, one in three trips could pass along that road, while advancing the timing of the next trip on the alternative road so the gap between services is not excessive. This should increase the overall income of the operators, with each operator gaining a few extra trips per week.

From the IMPARTS research in Tanzania (Starkey et al., 2020c), this mechanism should work on the Babati road. This is illustrated in Figure 18. This system could also work on the Bagamoyo road (with through services to Chilinze). On both these roads, the operators said market demand on those roads was too low for them if they only operated on that route. By sharing this additional route this extra demand could be captured by all the operators. Route sharing would probably not work on the Morogoro road studied in Tanzania, as that road is very poor and there is only a small population living on the upper sections of that road, with minimal market demand

Route sharing requires planning, trust and collaboration. It can be facilitated/imposed by operator associations and/or by route licences. If implemented successfully, a positive feedback loop should be created, as the additional services should generate increased transport demand, benefiting both transport operators and rural residents.

Figure 18 Diagrammatic map with example of a route-sharing option for the Babati road studied in Tanzania



Notes: Only motorcycle taxis currently operate on the surveyed road (in black). Several minibuses share the route between Babati and Magara, going via Mbuyuwa as the road is much better and the demand on the surveyed road is quite low. They currently do 2-3 trips a day per vehicle. However, if they also shared the surveyed road (e.g., every third trip passed via that road) their total market would increase, and their regular operations should stimulate addition transport demand along the surveyed road.

5.6 Hub and Spoke Complementarity

Various transport services have different advantages and disadvantages. Buses are can provide cheap transport over distances of tens of kilometres, or more. They are unsuitable for short-distance journeys with few passengers. Smaller means of transport such as motorcycles, three-wheelers, pickups and minivans are well-suited to shorter journeys with few passengers. The two types of transport are complementary and smaller vehicles can provide feeder-transport to carry passengers to and from longer-distance bus routes. With careful planning, the feeder transport can be coordinated with the bus timetables. If the medium-distance buses pass through large villages/small towns with clinics, schools and shops, these small centres can act as short-distance hubs for the surrounding villages. Low-capacity feeder transport can provide shuttle services between outlying villages and these small-town hubs, with onward connectivity by bus to the more distant town or city. In some countries, such as Ghana, Liberia, Sierra Leone and Tanzania, motorcycle taxis are already providing such feeder transport to and from bus routes (Starkey and Hine, 2020).

Hub and spoke systems are widely used ways of consolidating transport demand, using complementary large and small means of transport. Indeed, most land transport systems are based on such models. There is scope to improve rural transport by developing additional small-scale hubs. While this may take place spontaneously, it can be stimulated through careful planning and good collaboration between the various stakeholders. This could be a task for a local NGO or district-level road and transport officials, supported by a national level capacity building unit.

5.7 Motorcycle Trails

As mentioned in Section 4.4, motorcycle trails can allow people living in off-road villages to reach the road network using motorised transport (SuM4All, 2019). This is already happening for some villages in Tanzania, as motorcycle taxi drivers interviewed on all roads studied in this research said they regularly collected people from off-road villages. Evidence collected following trail construction in Liberia showed that people in off-road villages travelled more to markets, clinics and other destinations. Some people would travel all the way by motorcycle taxi, but many took the motorcycle along the trail to the nearest road, and then took other public transport (Starkey et al., 2017; Jenkins et al., 2020). Similarly, urban-based family members would travel on public transport to the start of the trail, and then take a motorcycle taxi from the junction to their relatives' village. In other words, the motorcycle trails boosted overall transport demand for all forms of rural transport services. The junctions of the road network and the end of the trails become complementary small transport hubs, and start to diversify economically and develop, stimulated by the greater number of people passing through and those waiting for connections. Therefore, constructing motorcycle trails to off-road villages can be a way to stimulate additional market demand for rural transport services, increasing the probability of greater transport frequency and predictability.

5.8 Telecommunications and Ride-Sharing Apps

With increasing use of mobile phones and tablet computers throughout the world, and greater rural coverage from telecommunication satellites and masts, there are many implications for rural transport services. Sometimes external sources can reduce the need to travel, for example if information on health, education, agriculture or market prices can be obtained by phone or the internet, there is no need to travel to seek it.

In countries such as the USA, transport firms offering low-cost travel to and from airports started by using call-centres to consolidate demand and optimise routings. Their shuttle passenger vans (referred to as paratransits) had no predetermined timetables or specific route, but as requests came in the operators would assign vans to pick up passengers from two or three hotels to take their clients to the airport. At the airport, a liaison official would assign arriving passengers to a certain van, who would then take their clients to their different, but nearby, destinations. A similar, simple paratransit model is used to consolidate loads for subsidised transport services for vulnerable people (such as the elderly and people with disabilities) in some high-income countries. With rural transport demand insufficient to justify fixed routes and timetables, the paratransit model allows clients to phone in transport requests, and the operator to consolidate the dispersed demand into viable journeys serving several villages. This paratransit model is very simple to operate, requiring only a central phone hub and several transport operators ready to respond flexibly. Fares would probably need to be above those of a route-based vehicle travelling with a full load, but below those that would be charged by a chartered point-to-point taxi. In many countries, operators of minivans and minibuses wait for hours in a queue for their turn on the main route, and so such a system (run by the local transport association) would allow them to serve additional roads that did not justify daily trips. However, the authors are not aware of such practices, which, if well-run would benefit both the operators and the users.

Increasingly in USA and in many countries, the paratransit market is now using communal ride-sharing apps that can perform similar functions to the older phone-based systems. Ride-sharing apps are widely used in some cities as are ride-hailing apps (similar to Uber) that can be used for single clients wanting motorcycle taxis (as in Pakistan, Kenya and Rwanda), three-wheelers, 4-wheel taxis or larger vehicles. Such apps have much potential to be used for rural transport services. The increasing use of mobile phone payment services (such as M-Pesa across Africa, and Tigo Pesa in Tanzania) can not only make payments easier, but can be used to make small deposits with bookings to give the operator confidence to travel to a remote area.

Mobile apps offer a highly effective method of improving rural transport supply and demand. These should be encouraged for use by small-scale transport services (motorcycle taxis and three-wheelers) and also for larger services such as minivans and minibuses. For the larger vehicles, the management of the system might be easier if they were embedded within hub-based associations. However, formal sector

organisations (using Uber-type systems) could help link supply and demand over larger areas. Consolidating dispersed rural transport demand would have many benefits and offers great scope for entrepreneurs, devolved administrations and/or NGOs.

5.9 Potential to Scale Up and Extend Rural Transport Services

Rural residents require transport services that are readily available, affordable, predictable, accessible, comfortable and safe. They also need them to carry their produce and goods to and from markets. Rural transport operators need to be assured of a market and be able to make a profit. Most rural transport operators struggle to make a good livelihood and may use substandard vehicles and risky practices to make a living. With passengers glad of any transport, sympathetic local enforcers and a lack of scrutiny from transport regulatory authorities, there are few incentives for operators to improve their rural transport services.

It is difficult for the current, under-resourced transport services authorities to improve rural transport services. With pressures from politicians and urban middle-classes and media encouraging modernisation, there is a tendency to try to raise standards through national legislation. Raising standards is likely to lead to higher transport costs. However, in the absence of rural enforcement things change little on rural roads. Where there is strict enforcement, as in China, rural transport services may disappear completely as the informal sector cannot operate, and the formal sector prefers to operate on the more profitable inter-urban routes. In such circumstances, private motorcycles become the main means of medium distance transport for rural families who cannot afford to own cars.

Regulators would like transport services to be run by formal sector operators, either companies or cooperatives. This would make negotiations and enforcement more straightforward. There have been attempts to formalise transport services (mainly in urban or peri-urban areas), but these have taken many years of patient negotiations. Without strict enforcement, compliant formalised operators are vulnerable to competition from non-compliant individuals reverting to the informal sector model of minimal capital investment, high loading factors and attractive journey times and/or prices.

At the devolved district level, it may be possible for local planners to work with transport associations and local user groups to improve transport services. This would not be practicable for most existing regulating bodies due to their small staffing levels and limited presence at district level. However, it could be feasible if rural roads agencies and transport services agencies collaborated and formed ‘Roads and Transport’ units (with various administrative options to allow effective collaboration or even institutional integration). One aim should be to start upward spirals of transport services and market demand. With greater market demand, there is more scope for improvements in vehicle type and transport frequency as well as price reductions per passenger-km. On some routes, operators can quite easily stimulate greater demand by agreeing to work to timetables as greater predictability increases transport services use.

As discussed in Sections 5.2 to 5.8, transport demand (the main criterion for the operation of transport services) can be stimulated by increasing and/or by consolidating the number of people wishing to travel. This can be achieved through community collaboration and dialogue with transport operators to initiate (or increase) services. Local NGOs or ‘Roads and Transport’ officials could help initiate the processes and discuss options for timetables, ride-sharing apps (or simple call centres) route sharing and improved hub-and-spoke patterns (possibly involving motorcycle trails). This would involve participatory collaboration and could be facilitated by ‘Roads and Transport’ officials, or a local NGO.

6 Conclusions

6.1 Roads, Transport Services and Rural Impacts

The IMPARTS literature reviews and field observations highlighted the many beneficial impacts of rural roads and transport services, including improved access to markets, health facilities, education, livelihood options and social opportunities. Rural transport services are crucial for rural mobility in low-income countries and they are a main mechanism to achieve the impacts. However, little research has been carried out on transport services. Road agencies do not regularly gather transport services data or consider the needs of the prevailing transport services when planning and prioritising roads. An IMPARTS workshop, attended mainly by road engineers from many ReCAP countries concluded that road agencies should regularly gather simple, road-related transport services data, for inclusion in road planning and maintenance databases. This would allow the measurement of simple outcome indicators relating to transport services types, volumes, tariffs and frequencies. This would help to monitor the likely positive and negative impacts of road investment and road deterioration on rural transport services. Some examples of simple outcome indicators that are easy to calculate from disaggregated traffic counts and low-cost surveys are summarised in Table 13.

In most low and middle-income countries, there has been a large expansion in motorcycle numbers. In many countries, motorcycles are the most common vehicles on rural roads. On some LVRRs in Tanzania they represent over 90% of the traffic and passenger movements. In Tanzania, and many other countries, motorcycle taxis are often the only public transport services available on rural roads. The six LVRRs studied in Tanzania had all been privileged with significant infrastructure investments including rehabilitation, culverts and bridges. Only one of these roads had 'conventional' transport services operating along the entire length. On three roads, the only transport services were motorcycle taxis. The road investments had not convinced 'conventional' transport services to provide regular transport services. In Nepal, motorcycle taxis are not used for rural transport, and most people travel in buses or jeeps/pickups. On the two roads surveyed in Nepal bus services had been able to operate all year-round providing rural communities with relatively low fares for transport on LVRRs (a Rural Transport Premium of 3). On the road in Tanzania with bus services, the RTP was even lower at 1.5, as those buses had twice the capacity of those in Nepal. However, on the Tanzanian roads reliant on motorcycle taxis, the RTP was around 7, and even higher on the remoter sections of the roads.

Three-wheelers are mainly used as small urban taxis, but they are increasingly used in Africa and Asia for providing both point-to-point and route-based services. Three-wheelers have started to have an impact on the rural roads studied in Nepal and Tanzania, notably on the busier sections near to the urban areas.

While the number of buses a day on the two roads in Nepal had remained constant for the past seven years, the number of enterprises along the road had increased greatly. The largest increases were observed on the sections of the road nearest to the market town. On these road sections, there were also greater numbers of smaller transport services (three-wheelers and minivans) and higher traffic volumes. Similar patterns of greater economic diversity (indicated by more small stores and workshops) and more frequent, small scale transport services were seen on the sections of the Tanzanian roads nearest to the urban areas. This suggests synergies between transport services and rural enterprise development.

Table 13 Some outcome indicators derived from traffic counts and simple surveys

	Indicator	Data source	Comments
Outcome: Improved road condition			
	Average travel speed for typical vehicles and journeys (for main vehicle types)	Time required to drive the length of the road (measured in km) under typical driving conditions	Easily measurable. Highly relevant as average speed is a reasonable proxy for many aspects of road condition, including roughness (and is also relevant to the prevailing terrain and alignment). Likely to increase as roads improve. Over time, may show differential changes for the various vehicle types.
Outcome: Improved transport services			
	Rural Transport Premium: the ratio of LVRR passenger fares to long distance bus fares	Information on fares per passenger-km obtained from simple surveys of transport users and transport operators	Easily measurable. Highly relevant for movements of people. Values should be calculated for each vehicle type and for different sections of each road if transport services are not uniform along road. Likely to decrease as roads improve. Being a ratio, the indicator should not be affected by devaluation or fuel prices.
	Motorised transport indicator: the percentage of all people counted who were using motorised transport	Disaggregated traffic counts with people counted, including pedestrians and cyclists	Easily measurable. Highly relevant for movements of people and goods. Likely to increase as roads improve and there is more economic development
	Motorcycle transport indicator: the percentage of all people counted who were using motorcycle transport	Disaggregated traffic counts with people counted, including pedestrians and cyclists	Easily measurable. Highly relevant for movements of people and goods. Allows planners to appreciate the importance of motorcycles for rural transport. Likely to be affected upwards by the increasing use of motorcycles and downwards by the availability of other transport options.
	'Bus' passenger indicator: the percentage of people travelling using 'bus' type vehicles	Disaggregated traffic counts with people counted, including pedestrians and cyclists	Easily measurable. Highly relevant for movements of people and goods. Likely to increase as roads improve and transport demand grows. The types of vehicle included can be adjusted to suit local conditions. The aim of this indicator is to capture the relative importance of 'conventional' transport services for rural people (as opposed to motorcycles and three-wheelers).
	'Bus' frequency indicator: the number of 'bus' type vehicles per day.	Traffic counts	Easily measurable. Highly relevant for movements of people and goods. Likely to increase as roads improve and transport demand grows. The types of vehicle included can be adjusted to suit local conditions.
	Gender distribution of mobility indicator and child mobility indicator: the relative proportion of people travelling by gender and children	Disaggregated traffic counts with people counted, including pedestrians and cyclists. Genders of people and child numbers recorded	Easily measurable. Relevant to local socio-economic development issues.
	Safety helmet use indicator	Traffic counts including numbers of passengers and helmet count	Easily measurable. An indicator of safety-related compliance and enforcement.
Outcome: economic growth and diversification			
	Roadside enterprise indicator: number of road-side enterprises, disaggregated for retail, agricultural sales, and 'productive' (local manufacture)	Visual survey along road by a walking enumerator or in a vehicle that stops frequently	Numbers and business types easily measurable if clear guidelines. Traditional farming not included. Highly relevant to local economy. Likely to increase as roads improve with greatest concentration of businesses in most accessible road sections. The gender of enterprise operators and employee numbers can be recorded but this complicates data collection.
Note: Many of these indicators come from disaggregated traffic counts with recording of pedestrians and passenger numbers. While such detailed counts would not be feasible on busy roads, by definition LVRRs have small traffic volumes and this research shows such detailed traffic counts can be achieved at a low cost. *It should be noted that on LVRRs traffic volumes can vary greatly, particularly on market days, and this needs to be well recorded. Average daily figures can mask the reality of the inadequacy of transport services on non-market-days.* *In some countries there are big differences between transport services provision and use between the dry season and the rainy season. This should be considered when assessing indicators. Repeat surveys should be in the same season.*			

6.2 Organisation of Rural Transport Services and their Responses to Road Condition

The IMPARTS observations and literature review suggest rural transport services are predominantly provided by individual operators working in the informal private sector. Smaller vehicles may be owner-operated or may be leased on a daily basis. Owners may hire drivers to operate buses. Few informal sector operators own more than one vehicle. In certain countries, there are examples of parastatal bus services and private sector formal services. These mainly operate on urban and inter-urban routes. Where buses do provide rural transport services, they generally start in villages and travel over 100 km to a major town or city, with much of their route on main roads. Medium distance transport between villages and local market towns is almost invariably by smaller vehicles such as minibuses, minivans, pickups, three-wheelers and, in some countries, motorcycle taxis.

Operators of rural transport services may join with others to form associations for mutual support. This is most common for the operators of services that operate from urban stands. This research found that many operators based in rural areas are not members of associations. Associations frequently control queuing and loading at urban stands. Such associations can become strongly anti-competitive cartels. In some countries strong national associations are cartels with great influence and power.

Enforcement of regulations concerning rural transport services is minimal. Transport services regulatory bodies have few staff and low budgets and concentrate on urban and inter-urban transport services. They seldom engage with rural transport services operators or plan rural transport systems.

The informal sector rural transport services are market driven and expect to make a profit on each trip. They therefore only operate when and where they perceive market demand. No journeys or profits are possible when roads are impassable. When roads are in poor condition, journey times and operating costs are high. This research demonstrated that while rural transport services prefer good quality, all-season roads, passenger numbers are a greater priority. They will operate on poor but reliably passable roads if there is a market. They will not use better quality roads and bridges if they see little market potential. It is evident that transport services operators and other stakeholders should be consulted prior to rural transport investments, to ensure the infrastructure is appropriate and fit for purpose.

6.3 Planning and Providing LVRRs Fit for Purpose

The planning, design and maintenance of LVRRs requires participative processes starting at an early stage. In Nepal, the DRSP engaged with the District Transport Master Plan process that involved grass roots consultations to understand the travel priorities and preferences of many different stakeholders.

The level of grass roots participation in the IRAT planning in Tanzania was less clear and some of the investment decisions can be questioned with the benefit of hindsight. Two of the roads in Tanzania had parallel concrete strips with proud vertical edges that can be hazardous to smaller vehicles, particularly motorcycles that are the prevailing mode of transport on these roads. In the circumstances, such concrete strips are inappropriate. Some of the IRAT/TARURA investments, including the Hai road and the bridges on the Bahi-Chipanga road appear to be over-designed for the current traffic, which mainly comprises motorcycles. The issues of people's preferred destinations and the alternative routes for transport services do not seem to have been sufficiently considered in prioritising the Tanzanian road investments.

All LVRR planning would benefit from the consideration of the type and volume of transport services that are likely to be provided, and the key destinations to which rural people wish to travel.

The two roads studied in Nepal were basic earth roads constructed using labour-based technologies that employed disadvantaged rural people. They have survived ten years in difficult mountainous terrain despite heavy monsoon rains. This shows how the provision of narrow, but well-engineered all-season basic earth roads can lead to the development of enduring, reliable and popular transport services. High-clearance, short-chassis buses are a key mode of rural transport in Nepal and can cope with rough roads and patches of mud, but slippery gradients can pose problems. The DRSP solution to this was the construction of cobblestones and stone soling surfaces on critical slopes. These stone surfaces are rough and therefore unpopular with bus passengers and motorcyclists. However, they permit all-season transport and protect the road from deterioration, and their use has proved durable and highly effective for a decade. Where

required, the roads were supported by stone-filled gabions which have also proved durable. Where possible, cross-drains were constructed as stone-lined drifts rather than culverts. These have lasted well, despite minimal maintenance. After enduring 10 years of monsoons, there is remarkably little water damage to the earth road. Some Otta seal sections have eroded and have largely disappeared. The principles of labour-based construction, simple stone surfaces and well-engineered, simple drifts can be recommended for future planning, although most stakeholders aspire to bituminous surfaces.

There is scope for providing cheaper infrastructure that would be appropriate where most traffic comprises smaller vehicles. Narrow roads would be cheaper, but less popular with users, and could discourage larger public transport vehicles from operating. However, the research suggested that the main determinant of transport services provision for smaller vehicles was market demand, and not the width or condition of the road. For large buses and midibuses, road width can be an issue if there is much traffic, but the narrow earth roads in Nepal have allowed rural buses to operate successfully. There is therefore a case for providing infrastructure that is aimed towards smaller vehicles. These should be designed to be upgradeable as demands increase.

Motorcycles can travel on simple trails as well as roads. In Tanzania, motorcycle taxis already travel on some footpaths to reach off-road villages. Such trails allow rural transport services to carry passengers from off-road villages to health facilities, markets and other destinations. With some engineering advice local organisations (such as NGOs, local communities or road maintenance groups) could ensure other off-road villages are connected to the road network by inexpensive trails.

6.4 Preserving LVRRs that are Fit for Purpose

In Nepal routine road maintenance has declined since the study roads were rehabilitated and should be reintroduced to ensure water flows do not damage roads and make travelling difficult. Water on the road caused by small landslips, or caused by farmers diverting irrigation channels, can be addressed by maintenance workers based on the road.

Routine maintenance systems, such as length workers or maintenance gangs can be an effective and timely solution to maintain rural roads with minimal resources. They also provide employment locally and instil a sense of ownership of the road.

Spot gravelling of poor areas has an influence on the types of vehicles that can use the road and should be the focus of maintenance activities to prevent bottlenecks developing. For paved roads such as the Otta seal sections, timely maintenance could save the investment made and prevent complete deterioration. The longevity of transport services benefits of the labour-based road construction and maintenance techniques used should be learned and widely shared.

In Tanzania, although maintenance had been undertaken on most of the roads, it was intermittent, with some sections experiencing serious erosion that made the road difficult to pass in the wet season. Since there are funding challenges for maintenance, spot improvements can be adopted in the short term to eliminate the bottlenecks and keep them motorable using limited funds. However, spot improvements of poor sections and spot patching of specific defects are fast becoming normal practice, so deliberate long-term planning is required to secure adequate funding.

Spot improvements and spot patching can also be a cost-effective solution on bottlenecks to keep a road motorable throughout the wet season. However, it is not advisable to rely only on spot improvements and patching in the long term as the road is likely to deteriorate beyond the stage where it can be effectively maintained using this system. On the Morogoro road in Tanzania, five spot improvement investments were applied, but the road deteriorated on some of the other sections which then became the bottlenecks that limited traffic use.

Climate change is also an emerging issue in road maintenance. Many of the expected problems related to climate susceptibility can be minimised by good maintenance. However, as in most low-income countries there is a significant maintenance backlog resulting from historical climatic events and many other factors.

This research has highlighted several clear issues regarding road maintenance and the provision of transport services. These included increased use of motorcycles, lack of traffic growth, lack of growth of

'conventional' transport services, the importance of road connectivity and the need for ongoing maintenance to retain the benefits of the road investments. Comprehensive maintenance interventions across the whole LVRR network are necessary to provide roads with all-season access. Rural residents depend on transport services for their mobility, so a greater understanding of these rural transport services could assist in planning more appropriate road investments and maintenance strategies.

6.5 Improving Rural Transport Services

Rural residents require transport services that are readily available, affordable, predictable, accessible, comfortable and safe. They also need them to carry their produce and goods to and from markets. Rural transport operators need to be assured of a market and be able to make a profit. Most rural transport operators struggle to make a good livelihood and may adopt substandard vehicles and practices to make a living. With passengers glad of any transport, sympathetic local enforcers and a lack of scrutiny from transport regulatory authorities, there are few incentives for operators to improve their rural transport services.

It is difficult for the current, under-resourced transport services authorities to improve rural transport services. With pressures from politicians and urban middle-classes and media encouraging modernisation, there is a tendency to try to raise standards through national legislation. Raising standards is likely to lead to higher transport costs. However, in the absence of rural enforcement things change little on rural roads. Where there is strict enforcement, rural transport services may disappear as the informal sector cannot operate profitably, and the formal sector prefers to operate on inter-urban routes.

Regulators would like transport services to be run by formal sector operators, either companies or cooperatives. This would make negotiations and enforcement more straightforward. There have been attempts to formalise transport services, but these have taken many years. Without strict enforcement, they are vulnerable to competition from individuals operating with the informal sector model of minimal capital investment, high loading factors and attractive journey times and/or prices.

At the devolved district level, it may be possible for local planners to work with transport associations and local user groups to improve transport services. This would not be practicable for small regulating bodies but might be feasible if rural roads agencies and transport services agencies collaborated (with various administrative options including institutional integration). One aim should be to start upward spirals of transport services and market demand. With greater market demand, there is more scope for improvements in vehicle type, transport frequency and price reductions per passenger-km. On some routes, operators can quite easily stimulate greater demand by agreeing to work to timetables as greater predictability increases transport services use.

Transport demand (the main criterion for the operation of transport services) can be stimulated by consolidating demand. This can be achieved through community collaboration and dialogue with transport operators to initiate (or increase) services, but local NGOs or 'Roads and Transport' officials could help initiate the processes. Ride-sharing apps offer another good and increasingly viable option to consolidate loads. Route sharing allows operator associations to share routes with different transport demand. Taking on and sharing a new route by a local association can create a larger transport market, and lead to improved overall incomes for the operators sharing it. This process also requires participatory collaboration and could be facilitated by 'Roads and Transport' officials, or a local NGO. Planning for more effective integration of large and complementary small transport service types can be achieved by ensuring smaller vehicles provide effective feeder services for the large capacity vehicles (mainly buses). This tends to happen spontaneously but can be improved through planning and simple modelling.

Subsidies are essential for rural transport services in high income countries. In some low- and middle-income countries there are subsidised formal sector bus operations, but these mainly serve inter-urban routes, and only benefit a small number of rural villages directly. There is little enthusiasm in low-income countries for direct subsidies for informal sector operators. However, as part of inducements to participate in district-level load consolidation and route improvement schemes, targeted subsides could be used to help 'prime the pump' leading to increasing ridership and improving transport services.

7 Recommendations

7.1 Develop Integrated Approaches to Rural Roads, Motorcycle Trails and Transport Services

The following recommendations are intended for national ministries concerned with roads and transport, road authorities (or agencies), transport services authorities (or agencies) and devolved government authorities (such as district administrations).

7.1.1 Ensure rural road planners and transport services planners work together

- Roads authorities/agencies and transport services authorities/agencies should actively collaborate, to share knowledge and understanding to help improve rural transport. In the long term, institutional integration could assist in this process but in the short term collaborative operational units can be developed. Transport services agencies should use participative processes to develop and implement realistic strategies for improving rural transport services. This should involve collaboration with the devolved staff of roads agencies and delegation for overseeing implementation to devolved, multi-disciplinary coordination groups including representatives of local authorities, transport services operators and transport users.

7.1.2 Road agencies to include transport services information in databases

- Rural residents depend on transport services for their mobility, so a greater understanding of these rural transport services should be fostered within roads agencies to assist in planning more appropriate road investments and maintenance strategies.
- Simple road-based datasets on transport services including vehicle types, tariffs, volumes and frequencies should be collected periodically (preferably annually) and included in road planning and maintenance databases. This will allow outcome indicators to be calculated, helping to predict positive impacts of road investments and negative impacts of road deterioration.

7.1.3 Engage in devolved level multi-agency participatory rural road planning processes

- Transport services and rural mobility issues should be included at an early stage in the planning of rural road investment. Transport services operators should advise on market demand issues and villagers should advise on their preferred travel destinations.
- Grassroots participatory methods should be employed to develop district transport master plans, such as those in Nepal.

7.2 Ensure Roads and Rural Infrastructure are Fit for Purpose

7.2.1 Ensure understanding of traffic types

- LVRRs should be designed more specifically for realistic numbers of the anticipated traffic types and volumes, estimated through stakeholder engagement.
- Where motorcycles and small, light vehicles are the main traffic, consider whether cheaper standards might be appropriate and cost effective and whether these could be upgradeable as traffic demands increase.
- Avoid parallel concrete strips if motorcycle, bicycle or three-wheeler traffic is anticipated.

7.2.2 Consider connecting off-road villages to the road network

- Road authorities should develop a national strategy to ensure that off-road villages in suitable locations can be connected to the road network by low-cost motorcycle trails and trail bridges that could be constructed by community-based groups, with appropriate advice and support.

- Roads authorities should establish units to provide guidance on the construction and maintenance of motorcycle trails and trail bridges. These units should provide technical advice and capacity building to local authorities and/or interested NGOs and community-based groups that can support the local construction of motorcycle trails and trail bridges to connect off-road villages.
- Local authorities, working in coordination with roads agencies and other actors, should endeavour to ensure off-road villages in their areas are connected to the road network through appropriate trails, trail bridges, waterways or other appropriate infrastructure

7.2.3 Consider simple construction options

- Benefits of the simple labour-based road construction and maintenance techniques used in Nepal should be learned and widely shared. Benefits include the employment of disadvantaged rural people and local 'ownership' of the roads.
- Lasting benefits should be learned and shared of the simple, well-engineered roads in Nepal with cobblestones, stone soling and simple drifts that proved durable and highly effective.

7.3 Preserve and Maintain Rural Road Assets

- Routine maintenance systems implemented by local people such as length workers or maintenance gangs should be considered to ensure effective basic maintenance of rural roads is carried out using minimal resources. These can ensure water flows do not damage roads and the activity will instil a sense of road ownership.
- Spot patching/improvement should be considered as cost-effective strategies to ensure all-season roads.
- Long-term maintenance should not rely entirely on spot patching as road deterioration is inevitable. Mechanisms should be planned and adopted to secure adequate long-term funding for maintenance.

7.4 Work with Stakeholders to Improve Rural Transport Services

The following recommendations are intended for those people or groups working at a devolved level to improve rural transport services. Depending on the institutional arrangements and agreements, these might be district level committees, staff of devolved 'Roads and Transport' authorities/coordination groups and/or local development-oriented NGOs working in collaboration with others. Further information on the various participatory options are provided in the IMPARTS Guidelines (Starkey et al., 2020d).

- At devolved levels, initiate participatory processes and initiatives to stimulate discussion with transport operators and users on ways of improving rural transport services, including frequencies, routings, vehicle types, tariffs and safety.
- Working with local partners, NGOs, local transport associations and user representatives, consider ways of introducing load-consolidation schemes, timetabled services, route sharing on alternative routes and the introduction electronic methods such as apps to consolidate transport demand.

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Annex A Summary of the roads surveyed in Nepal

Road	Investments	Data	Present situation	Infrastructure issues	Transport services issues	Planning issues
'Kavre road' Tamaghat–Thuloparsel road is in Kavre District (a historical name but still in use). The first 9.5 km of the 32 km road go along a fertile plain with much mixed agriculture and increasing investments in enterprises. At Boharedovan (9.5 km) a bridge crosses the Jhiu Khola river and the road climbs a steep valley side and descends to the large Sun Kosi River at Khahareghat (18 km). The road then ascends up the side of the Sun Kosi valley to Thuloparsel.	The road is a well-engineered earth road, with cobblestone and stone soling paving at critical points. DRSP rehabilitated the first 9.5 km in 2002-5 and constructed an entirely new road from Boharedovan to Thuloparsel from 2005-2010. Initially there were lengthworkers. Now minimal routine maintenance. Land-slides are cleared when required. Parts of the road have been widened for the benefit of quarry trucks	DRSP planning documents. 2013 evaluation with surveys 2019 IMPARTS surveys	Road is accessible all year, with minor disruptions to clear landslides in the wet season. Where the surface becomes muddy it restricts the type of vehicles that are able to access the road. Busy first section but little traffic after 9.5 km (Boharedovan) apart from 4 daily buses and large trucks carrying stone from a quarry. Landslides are always a threat to the road in the rainy season.	Opportunity to study performance of engineered earth road with stone surfacing on steep sections and some Otta seal. Also, effects of heavy vehicles on a basic earth road. Drainage is crucial and farmers wanting irrigation can disrupt road drainage. Lack of maintenance is an issue. In some areas, landslides are prevalent in the wet season. Recent widening has led to muddy sections (impassable to low-clearance vehicles).	The first section is agricultural and quite economically active. This is served by buses travelling onto Kathmandu and as well as minivans (shared rural taxis) and autorickshaws (mainly point-to-point taxis). The minivans and autorickshaws do not serve the rest of the road, which seems largely due to low demand as the road has been motorable by such vehicles for several years. The long-distance bus services between Thuloparsel started soon after road construction, but do not seem to have diversified much. There are few public transport jeeps/pickups on this road, which may be linked to bus cartel issues. There are no motorcycle taxi transport services.	The road is the main access road for the catchment areas served, but the population density is quite low, beyond Bhoredovan (9.5 km). While longer, through routes are now possible with connecting roads. The low population density and rough roads do not currently favour such though services.
'Sindhuli road' Majhitar-Bhimasthan is in Sindhuli District (a historical name but still in use). The 18 km road was constructed in 2006-2009 to Bhimasthan and then extended to Chakmake at 35 km. The road is mainly on the undulating side of a large river valley with mixed agriculture and irrigated rice production. Prior to the road, access was seasonal along dry riverbeds (that are still used by some vehicles for dry-season access).	A new road alignment on the side of a river valley built by DRSP using labour-based construction methods between 2002 and 2007. Regular lengthworkers are no longer present but there has been some maintenance and widening in the past year.	DRSP planning documents. 2009 evaluation traffic counts. 2013 evaluation with surveys 2019 IMPARTS surveys	All-season road with gradually growing mixed traffic, including regular buses. Some muddy and difficult areas due to drainage issues and/or landslips, but still passable by most vehicles. Many steep areas protected by stone soling or cobblestone sections that are rough but passable. Freight traffic mainly retail suppliers and haulage of building materials (including by tractors and trailers).	Opportunity to study performance of engineered earth road with stone surfacing on steep sections and some Otta seal. Drainage is crucial and farmers wanting irrigation can be in conflict with road drainage needs. Generally insufficient maintenance. Water crossings sound. Minimal slope instability.	While buses are the main means of public transport, there are many Jeep/pickups also operating on the road. The buses complain of loss of market share and feel the jeeps/ pickups are being protected by local politicians. Autorickshaws are gradually extending their operations, but mainly operate close to Majhitar. There are no motorcycle taxi transport services.	The road serves a rural catchment area without other roads. Apart from the study road, only dry season riverbeds allow some use of motorised transport. The road could be extended to join up with a national road, allowing through traffic to develop in the future

Annex B Summary of the six roads surveyed in Tanzania

Road	Investments	Data sets	Present situation	Infrastructure issues	Transport services issues	Planning issues
'Bagamoyo road' Talawanda-Bago Road, Bagamoyo District, Pwani Region. 20 km road though rolling countryside. Pineapple farms near Bago. Mainly mixed agriculture but fairly low population density	AfCAP 20 km road rehabilitation in 2010-2011 including several different surface trails (bituminous seals, different gravels, engineered earth, geo-cell blocks, stone, parallel concrete strips)	Roughton, RTSi, Amend, Transaid 2019 IMPARTS surveys	All season road, quite smooth, most traffic motorcycles. No 3-wheelers, minibuses or buses	Opportunity to evaluate performance of different surfaces from engineering and users' perspectives. The parallel strips are proud due to design/erosion and so dangerous for the prevailing traffic (motorcycles and bicycles). Proud cross ties would make it very difficult for 3-wheelers	Mainly used by motorcycles and bicycles. How to get 3-wheelers and/or minibuses to operate on road? There had been minibuses after the initial investment but these stopped due to a difficult stone section and low demand. Infrastructure is no longer a limiting factor for minivans or minibuses, but the transport demand is insufficient to get them to start services. Some services tried through services as shortcut to Chalinze but insufficient local demand to justify the time on the rough road.	For many people in Talawanda, their preferred destination is not Bago (or Bagamoyo) but Lugoba, Chalinze or Mlandizi in the other direction
'Hai road' Chekimaji-Kawaya road in Hai District, Kilimanjaro Region. 11 km U-shaped road from Chekimaji to Kawaya. Connected to west to Boma N'gombe district town by 15 km rough road. Connected to east by 20 km rough road to Moshi town. Alternative through road across top of U. First 5 km rehabilitated section of road serves fertile farming area with rice production and one village.	2016 IRAT investment was rehabilitating first 5 km with an embankment and several culverts, to allow all-season motorability on a very difficult section of the road. New section is now best road in the local network	IRAT traffic counts before and after 2019 IMPARTS surveys	all season road with first 5 km very good and rest of road rough. Little traffic other than motorcycles. Only motorcycle taxis public transport. Connecting road to east is rough, but has motorcycles, Bajajis, minivans and minibuses operating regularly. Connecting road to west is rough but has minivans and minibuses to Moshi. Trucks of buyers use road at harvest time. Tourists use road to access hot springs.	Good quality 5 km road section produced allowing access to agricultural lands and one village, but connected to rough roads	Bajaji and minibus/minivan transport services from district town still stop at Rundugai, just before the new section and do not use the good new part of the road. Minivans and minibuses operate from Kawaya but go other way to Moshi. Operators in both directions say little reason to use the road as a) the village served has a small population and access to rice and agricultural fields does not require regular public transport. b) through traffic can bypass the road with a shorter route.	The local population and there are other ways of reaching the local villages. For many people in Kawaya, their preferred destination is not the district town, but Moshi, in the other direction. While the road provides all-season access to an irrigated agricultural area, agricultural traffic is very low, and has alternative routes.

Road	Investments	Data sets	Present situation	Infrastructure issues	Transport services issues	Planning issues
'Babati road' Magugu-Mahole road in Babati District, Manyara Region. 18 km road from Magugu to Mahole (with weekly market) road. Relatively flat agricultural land with sugar cane plantation around 6 km-8 km. Extensive livestock grazing land in final 8 km and beyond	2016 IRAT investments of one 4 m box culverts, two 2m ring culverts and 800 m of embankment on a low-lying section c. 9 km from each end to allow all season motorability on a very difficult section that had been impassable in rainy season	IRAT traffic counts before and after 2019 IMPARTS surveys	All season road, with good short rehabilitated section across some swampy land, allowing all year access. Rest of the road is very rough, (eroded surface with over-size stone). Some new TARURA investments near both ends of the road.	Culverts successfully transformed road into all-season road. Non IRAT road sections very rough. Main traffic comprises motorcycles which prefer to use side trails. They also use a local footpath (motorcycle trail) in dry season to avoid several km of rough road sections	Motorcycle tariffs in rainy season reduced by intervention. Road mainly used by motorcycles. Bajaj and minibus/minivan/midibus transport services from Magugu to Mahole (the two ends of the road) take an alternative route that is 3 km longer, but half is bituminous and the other half is graded and smoother. The operators say there is little transport demand along road to justify the time and discomfort of using the rough sections.	Very little transport demand to use the bottleneck section due to an alternative route. Bottleneck removed one limiting factor, but not the roughness that inhibits transport 3- and 4-wheel transport services travel up and down the road.
'Bahi-Chipanga road' Chigongwe-Chipanga, Bahi District, Dodoma Region. 32 km road from Chigongwe (Singida Road) to Chipanga (clinic, monthly market). Low-population density, semi-arid area with grazing and some cultivation (sorghum, millet sunflowers).	IRAT 2016-2018 investment in two significant two-lane bridges at 10 km and 27 km from start and also 8.6 km of rehabilitation. Some recent rehabilitation work on first sections of the road before the bridges.	IRAT traffic counts before and after bridges were finished. 2019 IMPARTS surveys	Now all-season road. Most non-IRAT road sections rough so discouraging transport services, other than motorcycles. Minibuses and minivans provide shuttle services to Dodoma from Kigwe village 8km from start. One minibus and one midibus do daily return trips crossing first bridge to serve one village on road and one on connecting road. More trips on market day. No transport services other than motorcycle taxis serve upper half of road and very little traffic crosses second bridge each day.	Good quality bridges but connected by rough roads.	No obvious changes in transport services, except that motorcycles can operate all year round. Ambulances from Chipanga clinic can move on the road all year if required. Regular transport services connect Kigwe to the Dodoma northwest bus stand. Two daily vehicles serve villages beyond first bridge. Numerous extra public transport services on Kigwe market days. Low transport demand prevents the services extending their routes further up the road. Chipanga, at the 'end' of the road, is served by buses that travel to Dodoma by another better road to the different southwest bus stand. These do not have to pass a weighbridge. The heavily reinforced old buses fear they exceed limits if they passed the weighbridge on the Singida road, and so avoid the surveyed road.	There seems little justification for a two-lane bridge near Chipanga. Little traffic uses it. Dodoma is the main transport destination and this road connects two separate arterial routes to Dodoma. There is little transport demand for cross-district traffic. The road could usefully serve within-district traffic in the medium-to-long term if there were better connecting roads and much economic development. As Dodoma grows, this is possible.

Road	Investments	Data sets	Present situation	Infrastructure issues	Transport services issues	Planning issues
'Bahi-Mpunguzi road' Mpunguzi-Mwitikira road Bahi District, Dodoma Region. 19 km road from Mpunguzi (twice monthly market on Iringa Road) to Mwitikira (large village). Flat land with semi-arid cropping (sorghum, millet sunflowers) with many vineyards near Mpunguzi. Livestock grazing. Road continues to many further villages	Finished in 2016, IRAT rehabilitated 22 km of road with embankment and culverts across low lying land.	IRAT traffic counts before and after. 2019 IMPARTS surveys	Now all-season road, although improved section had seldom been impassable for long but was difficult in the rainy season.	The 22 km is a good straight road but is now getting rough as fine parts of gravel have been washed away leaving stones. Motorcycles generally use the slightly smoother edges or travel on motorcycle tracks off the road (in the dry season)	No new transport services have started from Mwitikira. Motorcycles have reduced their tariffs. The existing three bus services to Dodoma starting in villages further up the road continue similar services but have reduced their tariffs. Mwitikira residents complain passing buses are already over-crowded by the time they reach their village and no minibuses or buses start in their village.	Seems logical investment but producing straight, smooth road increased vehicle speeds leading to many crashes (reported 7 deaths, two in car, 5 on motorcycles) on new rehabilitated road section apparently attributable to high speeds. Rough surface has now reduced speeds and so road appears safer
'Morogoro road' Mikese-Ngeregere Road, Morogoro District, Morogoro Region. Approx 35 km road from Mikese (near Morogoro on Dar es Salaam road) to Ngeregere (market town). Road rises in hilly terrain, from medium density rural population and mixed farming near start decreasing to low density shifting cultivation and finally protected forest (and military zone).	2014-2016 IRAT invested in six bottleneck interventions, including one concrete section on a steep hill section, one parallel concrete strip section on a steep hill, a drift, some lined drains and some gravel surfacing. All the road investments were in the final 15 km of the road (towards Ngeregere).	IRAT traffic counts before and after. 2019 IMPARTS surveys	All-season road with some very rough and badly eroded sections making. Dry-season travel slow. Rainy season travel difficult. At the time of the IRAT investments, the road started at Metegowa Simba closer to Morogoro, but the first road section was severed by the construction of a new railway. Traffic was diverted to a regional road from Mikese that crosses the survey road after about 10 km.	While some bottle-necks have been removed, the road still has many other bottlenecks of badly eroded sections (failed drainage and culverts). The parallel concrete strips are proud due to design/erosion and so dangerous for the prevailing traffic (motorcycles and bicycles). The proud cross ties would make it very difficult for 3-wheelers	Minibus and minivans provide services from the midpoint on the road to Mikese and Morogoro (travelling only on the first half of the road). Only motorcycles provide transport services on the last 15 km of the road (where the IRAT interventions were). Midibus services from Morogoro run on a national highway and good regional road to Ngeregere. The surveyed road offers a 20 km shorter route. But the transport demand to Ngeregere along the road is very low as few people live in the last 15 km and people in first half of the road want to travel to Morogoro. The poor condition and narrow width of the road do not attract the midibuses to use of the short cut, as the journeys would take longer and be more uncomfortable.	The first half of the road has transport demand to reach Morogoro. The population density and transport demand in the final 15 km (where the IRAT investments were) is very low. It was expected that some midibuses on the Morogoro-Ngeregere route would operate on the studied road as it is shorter. However, the road is rough and slow, narrow for midibuses and without local transport demand.