HIGH VOLUME TRANSPORT:

Rapid assessment of research gaps in road engineering and technical aspects

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Report Summary

Evidence on Demand has been commissioned by the Department for International Development (DFID) to conduct a rapid desk based study on research gaps in road engineering and technical aspects of high volume transport in Low Income Countries (LICs). The objective of the study is to inform DFID's thinking and scoping of future work.

The methodology adopted to address the study needs has been to:

- Develop a framework for structuring and presenting the research needs based on an understanding of current strategies in the sector
- Contact with key experts to identify gaps they perceive in research
- Perform a desk based scan of publicly available information
- Collate identified research gaps and present within the proposed framework

Publicly available strategies for research have been reviewed including those of the World Road Association (PIARC), the Organisation of Economic Cooperation for Development (OECD), the Conference of European Directors of Roads (CEDR), the European Commission and the Forum of European Highway Research Laboratories (FEHRL).

Generic drivers of research needs specific to LICs have been identified. Following informal contact with various experts and a brief scan of key themes, research gaps have been identified in all areas of technical engineering and transport services as follows:

- Road planning, design and construction
- Road maintenance and management
- Road operations
- Road safety
- Road traffic and transport services
- Road financing and fund allocation

For each theme, a summary of the key issues relevant to LICs is given to show the area of the gaps and specific examples are given where applicable.

SECTION 1

Introduction

Purpose

Evidence on Demand has been commissioned by the Department for International Development (DFID) to conduct a rapid desk based study on research gaps in road engineering and technical aspects of high volume transport in Low Income Countries (LICs). The objective of the study is to inform DFID's thinking and scoping of future work.

Scope and Focus

Road Engineering and Technical Aspects

DFID has requested that the study has a focus on the technical aspects relevant to the sector, as broader institutional and cross-sector programmes are either already addressed or will be covered elsewhere. For example, in road surface engineering, the focus should be on technical issues (e.g. design or specification requirements) rather than wider sector issues which may impact on delivery of appropriate quality road surfacings (e.g. corruption in road maintenance contracts).

The distinction between 'technical' and 'wider' aspects is not precise but has been used as a guideline with regard to the focus of effort in the study. It should be noted that there are areas where the boundary is not clear: for example, road maintenance delivery in many countries is compromised not only by lack of adequate technical understanding, nor only by wider cross sector issues as exampled above, but also by management arrangements for delivery (e.g. forms of contract and approaches to contracting). Where the distinction of whether the issue is 'technical' or 'wider' is potentially unclear, the principle has been to focus on aspects which are usually within the management control of a typical road authority responsible for the high volume road network.

High Volume Road Transport

The definitions which describe 'high' and 'low' volume are not rigid. Most authors define low volume roads as being less than 200 to 300 vehicles per day and the definition of a high volume road is then, by implication, any road with traffic levels in excess of this range. The study has adopted these definitions with a more general recognition that the primary focus is on strategic, national, urban and inter-urban road networks and their related transport services.

Issues which set high volume roads apart from low volumes roads include:

- Complexity of assets. The complexity of the assets and the operations involved increases with higher traffic volumes. Interchanges, non-carriageway assets (e.g. street lighting, significant structures, information technology assets etc.) take on increasing significance.

- Diversity of users. Particularly in urban situations, the road space is shared by numerous types of road users and vehicular traffic has to be managed to interact more significantly with non-vehicular users.
- Freight and loading. The proportion of heavy vehicles on high volume inter-urban roads usually becomes higher.
- Within urban areas high traffic levels will impact on the efficiency of public road transport as well as the safety of pedestrians and cyclists.

Low Income Countries

Low Income Countries are defined by development agencies as those countries with a Gross National Income of US$1,035 per capita or less. As noted later, it may be that research gaps in other countries are equally applicable or transferrable into this context. However, the contextual issues which might set the technical aspects of research gaps in road engineering and transport services apart in these countries in comparison with other countries are:

- The costs of labour are significantly lower when compared with the cost of credit.
- There is often a general lack of technical capability such that expertise to undertake a range of functions, including transport planning, infrastructure design, traffic management; public transport and freight operations is lacking.
- The lack of technical capability often means that resources are not allocated towards research even though that may generate significant benefits over the long-term.

SECTION 2

Identifying Research Gaps

Methodology

The methodology adopted to address the study needs has been to:

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Strategies for High Volume Road and Transport Services Research

Review of the research and development objectives of organisations which represent the interests of high volume road transport stakeholders gives an indication of where current gaps and priorities are perceived. In this section, a review of various key organisations is included. Review of further relevant organisations is included in Annex A.

World Road Association

The World Road Association (PIARC) represents the road and road transport services sector of both the developed and developing world and addresses both institutional and technical issues. One aspect of its stated mission is to 'consider within its activities the needs of developing countries and countries in economic transition'. It delivers its outcomes primarily by establishment of a four yearly cycle of various technical committees which are charged with delivering on specific objectives within its mission. Its current strategic plan has established committees under four theme areas as shown in Table 1 (PIARC, 2011).

Theme Area	Technical Committee
Management and Performance	1.1 Performance of Transport Administrations 1.2 Financing 1.3 Climate Change and Sustainability 1.4 Road Transport System Economics and Social Development 1.5 Risk Management
Access and Mobility	2.1 Road Network Operations 2.2 Improved Mobility in Urban Areas 2.3 Freight Transport 2.4 Winter Service 2.5 Rural Road Systems and Accessibility to Rural Areas
Safety	3.1 National Road Safety Policies and Programs 3.2 Design and Operations of Safer Road Infrastructure 3.3 Road Tunnels Operations
Infrastructure	4.1 Management of Road Assets 4.2 Road Pavements 4.3 Road Bridges 4.4 Earthworks and Unpaved Roads

Table 1 World Road Association Strategic Themes and Committees

OECD

The Organisation for Economic Cooperation and Development (OECD) has developed a policy document describing the long term infrastructure challenges for electricity, water and transport (OECD, 2007). It notes that, in particular for OECD countries, infrastructure investment will be challenged by a range of fundamental long-term trends. These include:

- Demographic developments – ageing populations, population growth or decline, urbanisation trends, and population movements to rural and coastal areas;
- Increasing constraints on public finances due to ageing populations, security concerns, etc;
- Environmental factors, such as climate change and rising quality standards;
- Technological progress especially, but not only, in information and communication technology;
- Trends towards decentralisation, and growing local public involvement;
- The expanding role of the private sector; and
- The growing importance of maintenance, upgrading and rehabilitation of existing infrastructures.

The report identifies that infrastructure will need to work more efficiently but also notes that ‘for most developing countries, by contrast, the lion’s share of investment is likely to go on new construction as governments strive to expand inadequate networks’.

Multi-Lateral Development Banks and Assistance

Multi-lateral organisations in the development sector such as the World Bank, the regional development banks and Development and Cooperation - European Aid (DG-DEV) provide assistance for transport development in LICs. Typically, the organisations might fund elements of research as part of larger implementation programmes, but do not have large established research funds in their own right. For example, two sample projects recently funded by the European Development Fund (part of DG-DEV):

- Multi-country: Study to draw up a transport policy up to 2025, and the road and rail infrastructure development plan up to 2020 and 2025, in the Central African Economic and Monetary Community (CEMAC) zone
- Cameroon -Yaoundé: Technical assistance to the Ministry of Public Works included support to the research division

There has been a recent drive for transport to be made more sustainable, evidenced by a joint commitment in 2012 at the RIO+20 conference from 8 development banks to allocate US$175 towards sustainable transport projects over the next decade (International Institute for Sustainable Development, 2013).

Typically, outputs of any research are published through policy updates and new agendas. For example, led by the African Development Bank, the Africa Infrastructure Knowledge Program resulted in a flagship report summarising the status of and challenges facing infrastructure in Africa (Foster & Briceño-Garmendia, 2011). Occasional papers are often produced in response to specific issues and themes (see, for example, UN, 2005). Research needs are often disseminated by industry stakeholders and practitioners at international transport forums such as the annual Transportation Research Board (TRB) meeting in January each year, which also appoints on-going committees to address general transport research topics.

In summary, such institutions are aware of the challenges but their focus remains on implementation of development programmes and as a result, they have not published specific transport research strategies of their own.

Search of Relevant Publications

A literature search of relevant transport publications by theme was undertaken, by accessing the TRID database, using key words and restricted to publications between 2003 and 2013.

TRID is an integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database. It is the world's largest and most comprehensive bibliographic resource on transportation research information (TRB, 2013a). It covers all modes and disciplines of transportation and contains more than 1,002,000 records of published research. More than 90,000 records contain links to full-text documents. The results of the scan are shown in Table 2.

Theme	Sub-theme	Number of Citations
Road financing and fund allocation	Fund allocations	323
Road planning, design and construction	Planning	557
	Road design	78
	Materials specification and testing	228
	Road construction	202
Road maintenance and management	Procurement	182
	Asset management	129
	Road decisions support systems	148
Road operations	Axle load management	78
	Urban road transport	212
	Demand management	90
Road safety	Traffic calming and safe urban streets	211
	Vulnerable road users	101
	Road workforce safety	98
	Driver training	311
Road traffic and transport services	Traffic growth prediction	220
	Interchange	138
	Costs of transport services	87
	TOTAL	***3393***

Table 2 Results from scan of TRID database

It is difficult to draw too much from the results given that:

- The search is not mutually exclusive so that a publication may appear (correctly so) in more than one theme or sub-theme;
- The scan is focused worldwide, and not targeted at high volume and/or low income country issues. Limiting the scan by these terms would reduce the number of publications found and it would be questionable how much reliance to place on such results given that they are not common target terms for road researchers; and
- The scan is very dependent on keywords adopted and the approach taken to categorising the range of issues across the road transport sub-sector.

However, the results do indicate a reasonable spread of literature across the various themes and sub-themes.

Key Drivers for Research

Based on the review of strategies for research and the challenges noted by the organisations above, it is considered that many drivers will be common but that the application of solutions will be different when applied to LICs. The following factors have been identified which are cross-cutting and have provided a focus for the development of the research gaps by theme in the next section:

- *Climate and environment.* Many LICs are located in areas where the effects of climate change are projected to be significant, either due to rising sea water levels or more extreme temperatures and weather events. There are therefore climate adaptation issues to consider. Also, the drive for lower carbon growth affects the way roads might be built, operated and maintained and the transport services that might use them.
- *Ageing infrastructure.* Whilst this issue has been of more concern in high income countries with ageing stock, it is still considered a potential concern in LICs, particularly on the high volume road networks.
- *Urbanisation and population.* Significant population increase is predicted for LICs and there will be an increase in the proportion living in urban areas, placing increased challenges on the urban infrastructure and transport services. There will also be significant growth in motorised transport modes as the countries develop and the vehicle fleet might be quite different to that experienced in HICs (e.g. increased low cost motorbikes as a proportion of the traffic stream).
- *Technology.* Increasing availability of and developments in technology (particularly information and communications) is enabling significant advances in the way traffic is managed and operations are carried out on road networks.
- *Materials.* Availability and cost of construction materials change over time. The relative prices of different materials (e.g. bitumen, cement) have a major impact on road design considerations and high volume infrastructure requires more stringent specification.
- *Public/private sector share.* Innovative forms of financing and partnering with the private sector, such as public private partnerships, are most applicable for high volume infrastructure where a clearer case can be made for attracting private sector investment.
- *Costs and efficiency.* Transport systems enable and support social activity and economic growth and it remains a fundamental challenge to deliver transport at optimum costs. Costs of road construction and maintenance are significant, as shown in Table 3.

Activity	**Cost (US$ per km at 2000 prices)**	
	Average	**Range**
Surface Dressing	27,500	10,000 to 45,000
Thick Asphalt Overlay	178,000	73,000 to 480,000
Rehabilitation (Asphalt road)	235,000	20,000 to 1,170,000
New construction (Bituminous 4-lane)	2,755,000	2,123,000 to 4,006,000

Table 3 Typical rates for road maintenance and construction (World Bank, 2000)

The applicability of existing research and development from Middle Income and High Income Countries (MICs and HICs) has been considered in the context of each of these drivers. In some cases, the issue might primarily be one of transfer of existing knowledge from a similar context in a HIC (e.g. a country with similar climatic challenges).

Much research represents incremental advancement of earlier developments. In some cases, there may be opportunities for ‘skipping’ infrastructure development steps that need to be investigated (e.g. based on the significant advances in information communication technology of recent years, advancing traffic management operations in major cities in LICs may be able to avoid some intermediate evolutionary steps that have been experienced in higher income countries).

SECTION 3

Research Gaps by Theme

Overview

The following theme areas have been identified as a basis for structuring the identification of research gaps in LICs, to enable a focus on the technical aspects of high volume road transport:

- Road planning, design and construction
- Road maintenance and management
- Road operations
- Road safety
- Road traffic and transport services
- Road financing and fund allocation

For each theme, a summary of the key issues relevant to LICs is given to show the area of the gaps and by giving specific examples where applicable.

Road planning, design and construction

A wide range of issues have been identified to address road planning, design and construction issues.

In terms of ***planning***, much work has been done in recent years looking at opportunities to maximise use of the road space for all road users. Safety related concerns are a key consideration and are highlighted later.

Environmental aspects are fundamental to road planning and design, and climate change has driven a need for increased and wider focus in this area. Solutions need to be considered which minimise the carbon footprint of transport, both in terms of infrastructure construction and vehicle use. Opportunities for the incorporation of recycled materials taking account of local issues may need exploration, and greater use of local materials can reduce the environmental impacts associated with transportation (and cost). Air quality and noise emissions become greater issues with increasing urbanisation and more motorised traffic, with the potential to affect health. Appropriate designs for the provision of affordable public transport and safe facilities for non-motorised transport should be explored.

In many LICs, a major barrier to the reliability of road networks is the impacts of extreme weather, such as heavy rains and storm events. Climate change projections indicate that the frequency and severity of many extreme events are likely to increase in the future, and developing countries are the most vulnerable. Appropriate planning and design approaches which adequately account for projected changes need to be implemented, for example in terms of calculating appropriate drainage capacity or planning road alignment to avoid landslide prone areas. Better understanding of the impacts of climate change on transport, identification of weather thresholds for different assets, methods of assessing the climate change risk to existing infrastructure, engineering solutions to improve the resilience of vulnerable areas/assets and actions to manage traffic and repair infrastructure in the event of extreme weather are all additional research topics which would help to increase the resilience of road networks to climate change. It should also be noted that roads in poor condition are more at risk of damage from weather events, and therefore effective maintenance plays an important role in making infrastructure resilient.

The impact of the road network on local communities has also been a subject of major research and development in developed countries in recent years[1]. The conditions for residents adjacent to road networks in many LICs are often extremely challenging. High volume roads can also cause community severance and there may be technical aspects of design which need to be addressed which are suitable for the local environment, to mitigate against such effects.

The relationship between land use and transport planning needs better management. Unrestricted development leads to urban sprawl which is hard to serve with public transport and encourages more car use and congestion in urban centres. Understanding how development plans will impact on transport needs – and vice versa – is crucial especially as incomes and vehicle ownership increase[2].

With regard to inter-urban road planning, across the world there is increasing interest in long distance rail solutions. But new railways are extremely expensive and decisions need to be made on the best available advice. Much improved forecasting models are required to determine the appropriate modal split and traffic growth. For example, the rapid growth in availability of low cost motorbikes in Africa has led to very different vehicle fleet composition to that typical of HICs. There is also a need to look much more carefully at the issue of 'wider economic benefits' (including social and environmental impacts) that are not captured by existing cost benefit analysis procedures such as the HDM-4 tool[3].

Pavement design is an area requiring significant research. There are several sets of data that indicate that the traditional criterion for the protection of the subgrade is overly conservative[4]. The first is simply that the subgrade strain criterion developed at the Association of American State Highway Officials (AASHO) Road Test in 1962 is based on the likely failure of a very weak subgrade. The criterion is based on critical strain and has been used by theoreticians for road design for 50 years. It has been applied to all subgrades irrespective of material type, strength, density, moisture content etc. Some research organisations and some highway authorities have produced their own subgrade criteria which are less conservative than the AASHO result but it is still applied universally to all subgrades. A relatively recent study by the US Army indicated that there are more than 3 orders of magnitude difference in the failure criteria between the weak subgrades and the strong ones in terms of traffic carrying capacity. There is clearly a need to use different criteria for different subgrades and there is considerable potential for reducing thicknesses and therefore for significant cost reductions.

A key discovery of the last 20 years is that asphaltic concrete surfacings for main roads very rarely fail through the type of fatigue that is expected from basic theoretical considerations. For example, it has been shown in the UK that if the critical stress/strain is below a threshold value then fatigue failure does not occur and pavements do not need to be built to increasing thicknesses as traffic increases. In the UK, pavements designed on this basis are called 'long-life pavements' (Highways Agency, 2013). However research in this area is difficult and current criteria are conservative.

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1 See, for example, CABE (2007).
2 See, for example, TRB (2013).
3 Email from HDMGlobal consortia to author when developing this paper.
4 See, for example, results from Jamaica (Rolt et al, 1987)

The phenomenon was first isolated in tropical developing countries because the real reasons for poor performance were identified there (more severe conditions)[5]. Identification of threshold stress/strain values, demonstrating the effect of higher temperatures on performance and many more aspects are all projects waiting to be done. A further major question in hot tropical environments where serious vehicle overloading is endemic is the simple question: ‘At what traffic level is asphaltic concrete a poor choice (it is very difficult to design an asphaltic concrete for very severe loading conditions) and at what stage might concrete pavements become a better alternative?’

Each country has specific local needs which must be properly understood if ***materials specifications*** are to be economic, achievable and sustainable. The more that road user behaviour is understood, the easier it is to identify the real causes of deterioration and the better qualified experts can be to set appropriate specifications. This has been long understood for low volume roads but similar arguments apply to more heavily trafficked roads where research is more difficult. The fundamental challenge of any road engineer is to maximise use of local materials to minimise costs, and a major aspect of research for all countries is to ensure appropriate use of local materials. As traffic volumes increase, so the requirements for materials become more stringent and so the need for robust performance evidence is required.

Related to road safety and operational efficiency is the issue of ***geometric design***. Geometric design standards have often been based on those developed for industrialised countries and there have been attempts to ensure appropriate local application (see, for example, SATCC Technical Unit, 1995). However, as vehicle technology continues to develop, and based on the very different vehicle fleets that are often in evidence in LICs, there may be need for research and development to ensure appropriate application in such environments.

Quality of ***road construction*** remains a major concern in many LICs. Often, it has been found that testing and quality control procedures used in LICs are derived from a wide range of sources (e.g. American, European and Australian standards) and some of these overlap and have different testing requirements. Inconsistent application on different projects may result in inefficiencies and poor outcomes[6]. An area of specific relevance to LICs (particularly in Africa) may be the increased use in recent years of Chinese contractors. Concerns have been raised over safety at roadworks, quality control and long term durability, and these can be set within the need to understand and learn from wider socio-economic impacts of Chinese engagement in LICs and its own development lessons[7]. Research to establish the true basis for any concerns and possible aspects to address is needed.

Technical Research Needs for Road Planning, Design and Construction

- Development of planning techniques to take full account of local environmental conditions and resilience concerns, communities and the needs of all road users
- Research and development into pavement design approaches to reduce long term whole life cost
- Research to optimise use of recycled and locally available materials
- Research into appropriate geometric design standards
- Research and development to establish improved road construction quality control and materials specifications

5 See, for example, Smith et al (1990).
6 See, for example, Pinard and Netterberg (2012).
7 See Economic and Social Research Council (2013) for evidence of recent wider research interest.

Road maintenance and management

A common concern is that much effort is often directed towards identifying and winning funds for road management, but that if funds can be secured, road agencies might then be challenged in delivering the allocated spending at the required rate. Whilst many of these issues might be institutional (for example, human resource capacity) there may be opportunities to consider wider use of innovative procurement models (for example, early contractor involvement) to assist removing such blockages.

The above concern is part of a wider general research initiative that might be needed in forms of ***procurement***. In many countries, performance based road maintenance contracts have been heavily promoted which aim to deliver road management and operations requirements based on defined outcomes rather than outputs, and often for long contract periods. The success of such initiatives in the long term requires research, and applicability with specific reference to LICs needs to be considered[8].

Most developed countries are adopting the concept of ***asset management*** as the basis for understanding, planning and programming their road maintenance operations (Chartered Institution of Highways and Transportation, 2012). This approach is an evolution from more generic management approaches that were promoted as a result, for example, of the Road Maintenance Initiatives in Africa. Implementation of asset management has concentrated attention on some key areas including:

- Definition and maintenance of user focused levels of service for road maintenance activity and operations
- Establishment of appropriate performance monitoring and reporting frameworks
- Application of risk management across all asset types and operations
- Decision-making supported by comprehensive information systems

The final item in the list above possibly warrants a particular focus given the context in LICs. Within the wider context of ***road decision support systems***, HDM-4 has been promoted by PIARC and the various development agencies as a basis by which rational decisions on road investment, based on whole life total transport costs, can be made. The HDMGlobal consortium supports its on-going use and has identified various enhancement opportunities (HDMGlobal, 2013). However, it might be that a specific focus for LICs is that simpler models, which recognise the more constrained availability of human resources, could be further developed as evidence suggests that system initiatives in such countries too often fail for reasons of inappropriate application of technology (Parkman and Bennett, 2011).

Technical Research Needs for Road Maintenance and Management

- Review of success of various procurement approaches and consideration of potential improvement opportunities
- Application of asset management principles and approaches into LIC contexts
- Development of systems and tools which are adapted for use in LICs

Road operations

A key issue for many countries is that of ***axle load*** management. Engineers and policymakers are often concerned in LICs that poor regulation of axle loads and lack of adequate weight and dimension restrictions are a cause of much of the infrastructure deterioration. However, as noted in the section on design, research in recent years has

8 Evidenced from various informal discussions with World Bank staff in recent years.

suggested that there could be significant savings to be made due to potentially overly conservative designs commonly being implemented in developing countries.

Conversely, some countries have identified that increasing the allowable weight and dimensions for the freight industry could lower the transport cost, even accounting for changes that might be required to existing infrastructure. For example, the Austroads programme of research for Australia (Austroads, 2013) has identified that increased loads and dimensions of freight will reduce their total transport costs, but they have needed to undertake considerable research and development looking into changes that will be required to infrastructure (e.g. load control on structures, road space requirements particularly at junctions and in urban areas, road surface design requirements).

The issue of ***urban road transport*** infrastructure requires research. Worldwide, most people now live in large cities; urbanisation is happening in developing countries at a fast rate. Yet developing country major cities are massively congested with journey to work travel times of two hours and more not uncommon[9]. Congestion will almost certainly become a worse problem. The Dar es Salaam Urban transport study (Dar es Salaam City Council, 2008) showed urban investments gave very high rates of return - particularly compared with other investments – and this is consistent with other experiences of urban planning[10].

There appears to be very wide scope to improve flows on major routes in most developing countries with relatively low cost traffic engineering and public transport measures. Research could provide a platform to identify and advocate solutions. Traffic modelling could be improved and take account of differences in driver behaviour, fleet composition (for example, increased use and availability of cheap motorbikes), enforcement etc.

An area of significant development for most countries has been the use of ***demand management*** techniques to maximise the capacity of the existing road space[11]. For example, variable speed limits, lane management (peak hours use of different lanes etc.) and intelligent transport systems including mobile phone and satellite technology[12] to give travellers real time information. Given the pressures of population growth and increasing motorisation, issues of congestion are growing and LIC governments are becoming more interested in travel demand management as a means of managing the operation of the road network. The specific applicability of such techniques to LICs warrants research.

Demand management techniques are relevant, but more specific junction design and management research may be needed. The systems that have been developed to optimise traffic flows in an urban environment in the developed world have been based on typical vehicle mix and driver behaviours relevant to those countries. Where vehicle fleet mix is different (for example, greater proportions of non-motorised transport) and driver behaviour varies (for example, stopping near junctions etc.), then use of such systems will need to be modified. A final consideration is that of reducing private vehicle use in urban areas by schemes such as introducing bus rapid transit and public transport priority, park and ride etc. Again, specific considerations for LICs will be needed.

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9 See, for example, Pucher et al (2005).

10 See, for example, World Bank (2002).

11 See, for example, TRB (2013).

12 The appropriate application of mobile phone and advancements in satellite technology are areas which may have impacts on all themes, but are highlighted here, for operations, as most significant.

Technical Research Needs for Road Operations

- Investigation of optimum axle load and vehicle dimensions to minimise total transport costs
- Development of systems and design approaches to optimise urban road transport and improve urban congestion
- Need for and application of travel demand management approaches into LIC contexts

Road safety

Road safety remains a major concern for LICs. For example, in urban areas, figures have suggested that nearly 0.5 million people die and up to 15 million people are injured in road accidents in developing countries each year, at a direct economic cost of between one and two per cent of worldwide gross domestic product. A majority of victims are poor pedestrians and bicyclists (World Bank, 2002a).

The Global Road Safety Partnership has focused much effort on such issues since its establishment in 1999 and the 'Decade of Action' continues efforts. Road safety initiatives are often categorised into one of the three areas of engineering, education and enforcement. Given the technical focus of this document, only the engineering aspect is considered.

Road safety is an underpinning principle for the management of road infrastructure and so cuts across all the other themes highlighted in this report. However, further issues that have been identified at this stage include:

- ***Traffic calming and safe urban street design***. Some experience[13] suggests that engineers responsible for design of high capacity roads in urban areas focus on speed humps as the only potential means of driving safer outcomes. However, there are a range of counter-measures that have been tested and developed in the developed world, and for which there is potential in LICs. Again, transferability and applicability to such contexts needs to be tested.
- ***Vulnerable road users***. With increased density of traffic and changes in the composition of the vehicle fleet, there are greater safety risks for vulnerable users. The provision of safe footways and crossings, for example, is often lacking in LICs despite these modes generally having a high modal share. In the UK, London has committed significant research effort to investigate safer ways of managing, for example, cyclists and pedestrians who are also using the road corridor (Transport for London, 2013). Similar initiatives are already being developed in countries such as Ethiopia[14].
- ***Road workforce safety***. As traffic levels increase, so the risk of accident to road workers working in 'live' traffic conditions increases. Considerable efforts have been made in the developed world to manage these risks with increased health and safety measures being put in place[15].
- ***Driver training***. Whilst possibly beyond the scope of 'technical' research, a strong element of education in road safety focuses on improving driver training. There will be specific driver training needs in LICs which could improve safety outcomes and which require technical input.

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13 Based on informal discussions with stakeholders in recent years at, for example, the 6th Africa Transportation Technology Transfer (T2) Conference at Gaborone, Botswana (March 2013) and the 2nd African Community Access Programme (AFCAP) Practitioner's Conference at Beira, Mozambique (July 2012).

14 UN Habitat and others funding of the Addis Ababa Sustainable Transport Solutions initiative.

15 See, for example, TRB (2013).

Technical Research Needs for Road Safety
• Development of safe road designs which address all (including vulnerable) road users • Advancing methods to address road worker safety in high trafficked environments • Focused driver training strategies for LICs

Traffic and transport services

- As LICs develop and grow, so there will be growth in motorised forms of transport. ***Predictions of growth*** and increase in the different types of vehicular traffic will need to be based on developing vehicle technologies (e.g. increasing availability of hybrid and electric vehicles) and considerations of fuel prices. There may be a need to target research at LICs to identify if there are specific aspects relevant in those contexts which might warrant different planning approaches to those adopted in the past (e.g. by example, developments in communications technology have allowed many LICs to skip steps in telecommunications infrastructure development that were required in the developed world, due to uptake of mobile phone technology and the associated networks). As well as impacting on the appropriate design, management and operation of infrastructure, research might also help to understand and predict the level of vehicle emissions and climate change impacts that might result from such growth.

- ***Interchange*** will be of increasing importance in LICs as urbanisation leads to the need to develop effective public transport that can cater for large numbers of movements. Furthermore, the regulation (of buses and taxis etc,) may not lead to effective integration of services. Public transport regulatory structures may impede the development of the sector.

- The ***costs of transport services*** in sub-Saharan Africa and some other LICs remain very high by international standards[16]. Because freight dominates long distance movement on trunk roads it is perhaps obvious that long freight rates and travel time, are perhaps the best indicators to the public of the efficiency of interurban transport. Better road construction and maintenance will only deal with part of the problem, the organisation and management of the freight transport industry is also crucial.

The issues that drive cost disparities are predominantly wider than technical issues, and include aspects such as fixed transport markets and competitiveness of the freight industry, regulation of the different transport operators (taxis, buses and freight), delays at border crossings and due to other (often security related) factors. Even if the causes are non-technical, it is considered essential that costs of freight transport services are monitored so that the issues can be better understood.

In terms of indicators, freight transport is not the only aspect which needs better understanding to drive improved road transport outcomes. A study is needed to properly focus on not only what long term indicators to adopt for high volume traffic, but also appropriate systematic sampling procedures. Traffic volumes, composition, freight and passenger tariffs and journey times, as well as road roughness are obvious indicators. But there may be others such as empty running, commercial ownership structure, annual utilisation and methods of freight consignment which might improve understanding of high transport tariffs, the lack of competition and the presence of cartels. Too often, the

16 See, for example, Teravaninthorn and Raballand (2009) and also Foster and Briceño-Garmendia, (2011).

challenges perceived are hampered by lack of appropriate data to establish the real issues and causes.

Technical Research Needs for Traffic and Transport Services
• Understand traffic growth (both by fleet composition and total volume) patterns to predict infrastructure requirements more precisely and to understand emissions and climate change impacts • Development of appropriate approaches to improve interchange between transport modes • Improvement in indicators to monitor freight transport and other issues affecting transport costs to understand initiatives that can be taken to reduce the cost of transport services

Road financing and fund allocation

Issues of financing and fund allocation are primarily of a non-technical nature. In recent years, various innovative approaches to ***road funding*** (use of road funds, involvement of private finance etc.) have been developed around the world. As technology develops, so the means by which road user charges (and tolls) are collected have also been explored. It is considered that such technical issues arising out of these developments will be a matter of transfer of advanced technologies (if appropriate) into the relevant local environment. There may be some aspects which merit technical research, but at this stage no specific aspects have been identified from the scan.

The issue of optimising ***fund allocation*** across different activities and operations is gaining considerable attention in many road agencies, as they seek to optimise use of funds across the numerous and different types of asset (pavement, structures, road furniture etc.). For example, the UK Highways Agency has invested considerable effort on this topic in recent years and it is a topic of wide discussion[17]. There may be lessons for consideration in LICs.

Technical Research Needs for Road Funding and Fund Allocation
• Improved approaches for fund allocation across road agency activities • Research on technical aspects related to tolling and road user charging in LICs

[17]See, for example, PIARC Committee 4.1 focus of activity (PIARC, 2011).

SECTION 4

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SECTION 5

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ANNEX A

Additional Research Strategies

Section 2 summarises the research and development strategies from organisations considered of most relevance for roads and transport services in LICs. However, it is also worth noting the experience from some other regional, cooperation organisations involved in road and transport research. The specific context of LICs may be different to the target countries of these organisations, but the themes identified give an indication of the challenges being faced worldwide.

Conference of European Directors of Roads

The Conference of European Directors of Roads (CEDR) was established in 2003 to address on-going research priorities of national road authorities in Europe. Its latest Transnational Road Research Call (Call 2013) has identified the needs structured as shown in **Error! Reference source not found.** (CEDR, 2013).

Theme	Sub-Themes
Ageing Infrastructure	Understanding risk factors Common cost breakdown framework High speed non-destructive condition assessment
Traffic Management	Incident management Implementation of Innovation in traffic management (usable solutions) Human factors in traffic management
Safety	Accident prediction models Stopping sight distance Safety review
Energy Efficiency	Materials and technology
Roads and Wildlife	Cost-efficient road management Cost-efficient mitigating strategies

Table Summary of Call 2013 from CEDR

European Commission

The European Commission issues research calls through its framework programme. The latest draft document describing its short to mid-term objectives is currently under consultation. The programme, known as Horizons 2020, has identified various areas for the framework to address. Areas relevant to technical aspects of roads and transport services are shown in
Table (European Union, 2013). It is noted that there is also a separate and wide ranging call on the further development and implementation of 'Green Vehicles'.

Topic	Sub-Topic
Road	MG.3.1-2014. Technologies for low emission powertrains MG.3.2-2014. Advanced bus concepts for increased efficiency MG.3.3-2014. Global competitiveness of automotive supply chain management MG.3.4-2014. Traffic safety analysis and integrated approach towards the safety of Vulnerable Road Users MG.3.5-2014. Cooperative ITS for safe, congestion-free and sustainable mobility MG.3.6-2015. Safe and connected automation in road transport
Urban mobility	MG.5.1-2014. Transforming the use of conventionally fuelled vehicles in urban areas

Topic	Sub-Topic
	MG.5.2-2014. Reducing impacts and costs of freight and service trips in urban areas MG.5.3-2014. Tackling urban road congestion MG.5.4-2015. Strengthening the knowledge and capacities of local authorities MG.5.5-2015. Demonstrating and testing innovative solutions for cleaner and better urban transport and mobility
Logistics	MG.6.1-2014. Fostering synergies alongside the supply chain (including e.commerce) MG.6.2-2014. De-stressing the supply chain MG.6.3-2015. Common communication and navigation platforms for pan-European logistics applications
Intelligent Transport Systems	MG.7.1-2014. Connectivity and information sharing for intelligent mobility MG.7.2-2014. Towards seamless mobility addressing fragmentation in ITS deployment in Europe
Infrastructure	MG.8.1-2014. Smarter design, construction and maintenance MG.8.2-2014. Next generation transport infrastructure: resource efficient, smarter and safer MG 8.3-2015 Facilitating market take up of innovative transport infrastructure solutions MG.8.4-2015. Smart governance, network resilience and streamlined delivery of infrastructure innovation

Table Summary of European Union draft framework for research and innovation

Forever Open Road

The Forum of European Highway Research Laboratories[18] (FEHRL) has initiated the Forever Open Road Programme (FEHRL, 2013) as the core of its Strategic European Road Research Programme V (SERRP V)1. The Forever Open Road Programme works towards developing a next generation of advanced and affordable roads that can be adopted both for maintaining the existing network and building new roads. This will enable future road operators to adopt emerging innovation, whilst overcoming the increasing constraints on capacity, sustainability, reliability and integration. The overall aim is to facilitate the future mobility needs of our 21st century society.

The programme identifies that the next generation of roads will require high levels of adaptation, automation and resilience. These three elements will define the next generation of road as follows:

- The Adaptable Road: focusing on ways to allow road operators to respond in a flexible manner to changes in road users demands and constraints
- The Automated Road: focusing on the full integration of intelligent communication technology applications between the user, the vehicle, traffic management services and the road operations
- The Resilient Road: focusing on ensuring service levels are maintained under extreme weather conditions

The programme aims to deliver against five key societal challenges which are:

- Decarbonisation – the challenge to reduce carbon emissions and consumption
- Reliability – the challenge to provide reliable transport to maximise capacity and reduce impacts from extreme weather events
- Safety and Security – the challenge to ensure transport is safe and secure

18 Includes representation from USA, Australia and South Africa.

- Liveability – the challenge to ensure transport impacts on living expectations (noise, natural habitat, air quality etc.)
- Cost – the challenge to deliver transport at lower cost