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THE IMPORTANCE OF ROAD MAINTENANCE

World Road Association

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STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

This report was developed as a special project by the World Road Association after this issue was identified as a priority by the Association's Executive Committee.

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THE IMPORTANCE OF ROAD MAINTENANCE

Road infrastructure provides a fundamental foundation to the performance of all national economies, delivering a wide range of economic and social benefits. Adequately maintaining road infrastructure is essential to preserve and enhance those benefits. The importance of maintenance needs to be recognised by decision makers, funded appropriately and well managed to ensure maximum value is achieved. Inadequate levels of investment or poor management of the road network will have serious consequences for economies and social well-being. This paper makes the case for the importance of road maintenance by drawing on robust evidence from around the world.

Roads are key national assets which underpin economic activity

Roads are significant national assets. Roads are the internationally dominant transport asset, comprising millions of kilometres across the world (e.g. the average length of public roads in OECD countries is more than 500,000 km). Roads are often the single largest publicly owned national asset. It is road maintenance that controls the depreciation in value and determines the impacts of the network on road users and society. Without proper maintenance the high value of any road network can be quickly eroded and road users and society can experience significant adverse impacts if a road network is in poor condition.

Road transport is a foundation for economic activity. Based purely on the value added by commercial transport services, a widely quoted measure is that road transport typically lies between 3% and 5% of GDP. However this ignores a number of other considerations (e.g. inputs of fuel and transport equipment and infrastructure) which, if taken into account, suggest the contribution of transport to GDP is more realistically between 10% and 20%. Data provided by the International Transport Forum (OECD countries plus other countries such as China, India and Russia) suggests that for all surface passenger transport, road transport accounts for 83% of passenger travel.

Ageing infrastructure requires increased road maintenance. The need for maintenance increases as road infrastructure ages, since it becomes more fragile, less resilient and journeys are more susceptible to disruption. There is a lag between building new roads and their need for maintenance. For countries with mature road networks, much of the road building happened in the second half of the twentieth century. Large structures such as bridges and overpasses typically have design lives around 100 years and so on many networks, the full realisation of the long term on-going maintenance need will not yet have been reached. For example, in 2011, 9% of Japan's 160,000 bridges were 50 years old or more and, at the current replacement rate, this will rise to 53% in 2031 as the bridge stock ages.

Traffic volumes continue to grow and drive an increased need for maintenance. As traffic levels grow, the need for maintenance is only increased. Even for many developed countries, where the long term rate of traffic growth has slowed, attempts to maximise capacity on congested networks and to maintain mobility at higher traffic flows have led to use of increasingly complex assets to ease traffic flow. Such assets require more frequent interventions on the network and drive increased maintenance costs. With the low rates of growth in network length in these countries, the expectation would therefore be that maintenance becomes a larger share of the total spend on the road infrastructure. However, there is evidence that this is not happening in the last years.

For example, for OECD countries, the ratio of maintenance to overall expenditure on roads was 33% in 2005 but had declined to 27% in 2011 while the age of the stock increases.

Impacts of road maintenance are diverse and must be understood

The impact of road maintenance is significant, providing safety, economic, environmental and social well-being benefits. The relative balance of the benefits (or the negative impacts when maintenance is inadequate) varies by network. A comprehensive framework for describing and evaluating the impacts of road maintenance is therefore required to communicate the message to decision-makers and to drive rational decision-making for maintenance planning. The paper shows how applying such a framework identifies the different balance of needs and impacts on different types of network.

Investing in maintenance at the right time saves significant future costs

Analyses typically establish that the annual cost of maintaining a road is a small fraction of the initial investment cost, usually some 2-3% for a major paved road and 5-6% for an unpaved rural road. Failing to make this rate of investment over the long life of the road risks losing the benefits for which a road was originally constructed.

A well-established principle which drives the need for maintenance is that spending money now saves future costs. As assets deteriorate, so the cost to restore their condition increases. Numerous studies have quantified this effect. For example, countries with low income economies typically under-invest, yet spend 50% more on the network, per kilometre, than higher income economies. Including the wider impacts amplifies the effect. The World Bank has shown that delayed road maintenance expenditure in Africa increases the total vehicle operating costs by between two and three times the savings in maintenance costs. The same effect of increases in indirect costs, higher than the reductions in maintenance funding, has also been shown for mature networks in developed countries.

The case for road maintenance - The firm evidence

Case studies from around the world are presented which establish the evidence base for the above themes. The case studies highlight the diversity of issues for consideration on national, local rural and urban road networks.

Evidence is also presented to highlight two important, cross-cutting themes. The first is that of climatic considerations, as the effects of climate change serve to re-emphasise this key concern. The second is that different terrains drive very different requirements for expertise and local practice, and the benefit of preventive maintenance (although universally applicable) is particularly emphasised by this consideration.

Maintenance investment must be properly managed

Evidence shows that adoption of sound asset management principles as the basis for technical and management decisions will improve road network performance. The paper does not provide detailed guidance but describes the importance of taking a long term view of road maintenance and focusing on:

- establishing appropriate levels of service for different parts of the road network based on social, environmental and economic need. Public demand for road maintenance should not be underestimated. Public opinion surveys in many OECD countries have shown that the public

becomes extremely concerned when maintenance is inadequate. In many developing countries, lack of adequate maintenance compromises access to basic services such as health and education;
- understanding the extent and nature of the network and the demands on its use by operating appropriate management systems;
- effective maintenance programming using robust and formal design and decision making processes, based on regular monitoring and reporting. Understanding of all direct and indirect costs of network operation and maintenance is needed, with appropriate use of prediction models as required;
- valuation of the assets and their depreciation, to demonstrate the investment needed to protect that value over the long term;
- audit and reporting of maintenance and management operations, to generate a cycle of continuous improvement.

To support a strong technical and management approach, there must also be robust institutional arrangements in place. Challenges that have been faced by road agencies in recent years show the essential points:

- funding for road maintenance must be justified and available at the right time. In the developing world, countries with well-financed (second generation) road funds have been shown to be better at capturing resources for road maintenance resources. In developed economies, competition for funding has been increased by the development of models showing the relationships between funding and consequence (e.g. in the health service and education). Road administrations must be able to provide the same sort of evidence;
- legislation for roads must be appropriate and enforced. Freight traffic is a major cause of asset deterioration and legislation must control the level of loading and be strictly enforced;
- appropriate resources must be in place. Recent years have seen significant shifts to outsourcing of highway management in many countries. Such approaches demand different skills in the road administration (e.g. supplier management and strategic expertise) and staff must be skilled in the management of suppliers who provide much of the technical expertise. The challenge is at its most extreme for management of local road networks, where organisational capacity building is essential to achieve sustainability of road maintenance;
- procurement approaches need to match the available resources. Countries which are committed to maintenance continue to innovate in this area to ensure that procurement delivers best value for money and is flexible to accommodate wider political and economic changes.

An imperative for road maintenance for future generations

Inadequate maintenance now affects not only the present generation but places undue financial burden on future generations. The paper provides robust evidence that maintenance at the right time saves increases in future costs. Avoiding the necessary investment and management now only further exacerbates the problem and can have far-reaching economic, social and environmental impacts.

FOREWORD

Modern transportation systems increasingly rely on roads and road transportation. Roads provide the foundation for economic activities and make substantial contributions to national GDP. The road system is generally the largest public national asset and must accommodate ever-growing traffic volumes, both of passengers and freight, under more demanding conditions to meet year-round needs, regardless of climate and location.

Because of their extended and ubiquitous role, roads have large impacts on the economy, on safety, on the environment and on social welfare, to name but a few. To sustain the quality of their services, road systems need to be adequately maintained in all of their components (pavements, bridges, signals, tunnels, lighting systems, ITS, etc.) and this requires large quantities of mostly public funds.

As road systems age, as their vulnerability to the effects of climate change increases, and as their relevance for each nation's well-being augments over time, there is a greater need for road maintenance. As a consequence, the share of road maintenance expenditures in national road budgets should increase over time, at the same time bringing with it a growing need to spend it wisely, effectively, transparently and getting the most value out of it.

Road authorities must ensure that the funds allocated to maintenance programs are spent effectively to save future investment costs and to obtain maximum value from these investments. For this purpose, modern road asset-management schemes and institutional strengthening of road authorities are becoming increasingly necessary.

The World Road Association has identified road maintenance as a key priority for road systems to keep meeting public expectations in all regions of the world.

This report is intended to make a persuasive case for appropriate levels of expenditure on road maintenance by demonstrating the economic and social benefits of road maintenance and, perhaps even more importantly, the negative economic and social impacts of inadequate levels of maintenance. The primary audience for this paper is senior road administration and public sector finance decision makers.

The report offers a comprehensive, summarized overview of the need for road maintenance in most countries. It provides a full view of the problem, of the need to address it systematically and consistently, and of the main building blocks required to implement institutional capabilities to manage it efficiently.

The report presents case studies that illustrate how countries have addressed certain problems or met maintenance-related challenges, and it also contains an up-to-date bibliography.

I trust that you will find this report valuable and useful to make the case of sustainable maintenance of our road networks for the sake of the current economy and in the interest of our children and subsequent generations.

Oscar de Buen Richkarday
President of the World Road Association

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1. ROADS ARE KEY NATIONAL ASSETS UNDERPINNING ECONOMIC ACTIVITY

1.1. ROADS ARE SIGNIFICANT NATIONAL ASSETS

Roads are the internationally dominant transport asset, comprising millions of kilometres across the world (e.g. the average length of public roads in OECD countries is more than 500,000 km). They are significant and highly valuable public assets. Even in a small country like New Zealand, the national highway network has a depreciated replacement cost of around €15 billion making it the single largest publicly owned national asset (New Zealand Transport Agency, 2012 and New Zealand Treasury, 2013). For this valuable asset, it is road maintenance that controls the depreciation in value and determines the impacts of the network on road users and society. Without proper maintenance the high value of any road network can be quickly eroded and road users and society can experience significant adverse impacts if a road network is in poor condition.

Comparisons with other sectors and organisations help to understand the size and importance of road networks. For example, the World Bank (Heggie and Vickers, 1998) noted that the Japan Highway Public Corporation managed assets roughly equal in value to those of General Motors, the Highways Agency in England was comparable with IBM and AT&T, while a relatively small road agency like the Roads Department in South Africa was similar to Northwest Airlines (now part of Delta Air Lines).

1.2. ROAD TRANSPORT IS A FOUNDATION FOR ECONOMIC ACTIVITY

The importance of transportation within the national economy tends to be substantially understated when based purely on the value-added by commercial transport services. The widely quoted measure is typically between 3% and 5% of Gross Domestic Product (GDP). However, when full account of related activity is considered, figures of around 15% are more realistic[1]. As said by the European Commission *'Transport is the lifeblood of the EU economy'* (European Commission, 2013).

Roads deliver more than just economic benefit. At the most fundamental level, roads provide access but not all benefits of access are easily translated into economic outcomes. In remote areas it has been recognised for many years (World Bank, 1992) that restricted rural access means:

- farmers are reluctant to grow a marketable surplus second crop because it cannot be sold or due to the difficulty and expense of transport significantly reducing the returns to labour;
- agricultural productivity is low and there is a lack of innovation because information and inputs do not reach farmers;
- school enrolment is low and absenteeism is high (often among teachers as well as children);
- standards of health care are low because clinics are hard to reach and health workers cannot travel easily;

[1] The widely quoted measure ignores inputs of fuel and transport equipment and infrastructure, as well as own account transport services and unpriced services by the household sector. A broader measure of transport-driven GDP is the most comprehensive measure of total GDP generated by all productive activities to support the transport function. On this measure the size of transport-driven GDP was estimated for the United States in 1997, to be 16.5% of GDP; that is 5.6 times as large as the alternative, often quoted, measure of 2.9% (Han and Fang, 2000).

- women's working days are long and arduous, largely owing to the time and effort required to reach water and fuel sources.

For developed networks, breaks in the network (e.g. due to landslips or bridge failures) can prevent, or severely disrupt access. If access is compromised due to lack of maintenance, then the economic and wider benefits of roads are lost.

1.3. AGEING INFRASTRUCTURE REQUIRES INCREASED ROAD MAINTENANCE

The need for maintenance increases as road infrastructure ages, since it becomes more fragile, less resilient and journeys are more susceptible to disruption. There is a lag between building new roads and their need for maintenance. For countries with mature road networks, much of the road building happened in the second half of the twentieth century. Large structures such as bridges and overpasses typically have design lives around 100 years and so on many networks, the full realisation of the long term on-going maintenance need will not yet have been reached. For example, in 2011, 9% of Japan's 160,000 bridges were 50 years old or more and, at the current replacement rate, this will rise to 53% in 2031 as the bridge stock ages (Kikuwawa, 2013).

1.4. TRAFFIC VOLUMES CONTINUE TO GROW AND DRIVE AN INCREASED NEED FOR MAINTENANCE

For European Union countries (EU 27), in 2011, roads account for 72% of freight transport, rail 17%, inland waterways 6% and pipelines 5% (by total tonne-km) (European Union, 2013)[2]. For surface passenger transport, road transport accounts for 83% of passenger travel while rail accounts for 17%. On a worldwide basis the middle income and developing countries are much more heavily dependent on road transport so these road transport figures are likely to be underestimates. As traffic levels grow, the need for maintenance is only increased.

Following the 2008 global financial crisis and the collapse of world trade in 2008 and 2009, most regions have been recovering since 2010 although with a weak growth in developed economies. However, between 1990 and 2011, inland freight has experienced an increase of over 60% in EU and OECD countries mainly related to road transport.

While presently for developed economies, the long term rate of traffic growth has slowed, attempts to maximise capacity on congested networks and to maintain mobility at higher traffic flows lead to use of increasingly complex approaches to manage traffic. Assets related to intelligent transport systems (ITS) have relatively short operational lives, requiring more frequent intervention and increased maintenance costs.

Low rates of growth in network length for most countries in the developed world should lead to an expectation that maintenance becomes a larger share of the total spend on road infrastructure. However, there is evidence that the converse has happened in the last decade: for example, for OECD countries, it was 33% in 2005 but had declined to 27% in 2011 (International Transport Forum, 2013)[3]. This calls for a change as the age of the road stock increases.

[2] A few countries have a higher share of rail freight; USA, Russia and China represent over 80% of the total world rail freight.
[3] The proportion of road maintenance to total road spending has historically fluctuated between 25% and 35% of the total for most networks.

2. IMPACTS OF ROAD MAINTENANCE ARE DIVERSE

2.1. FRAMING THE IMPACTS TO TELL A COMPREHENSIVE STORY

Too often, decision makers are left unaware of the importance of road maintenance because justification for funding is based only on a narrow range of considerations and is not described in terms of the impacts on users and wider society. But maintenance often offers some of the best returns for investment in the transport sector. For example, recent plans for renewal and expansion of USA's infrastructure (Department of the Treasury, 2012) quoted earlier economists: *'some types of highway investment still seem highly desirable, such as plain old maintenance'*.

The high desirability of maintenance investment is due to the breadth of road maintenance[4] activity and its diverse impacts. Hence it is essential that a comprehensive framework is adopted to articulate the full range of social, environmental and economic benefits. Different frameworks are adopted by agencies for assessing the impacts of transport projects (e.g. Department for Transport [2013a], Transport Scotland [2013] and Federal Highway Administration [2013]). In developing countries, processes may be less formalised and need to match development agency requirements[5]. However, there are reasons for maintenance that appear in some way in all contexts:

- safety and security impacts,
- environmental impacts,
- economic impacts,
- integration (with wider transport and government policy) impacts,
- accessibility and social inclusion impacts.

Key issues that drive consideration of each criterion are summarised in *table 1, following page*. In the more specific context of the developing world, the impacts could be framed to support specific objectives such as the Millennium Development Goals (International Development Committee, 2011), as shown in *table 2, following page*.

2.2. QUANTIFIED IMPACTS TELL ONLY PART OF THE STORY

Justification for road maintenance funding is also often promoted based only on the *quantifiable* monetised impacts. Such approaches narrow the argument and ignore the real, if unquantified, impacts that might result but can only be described in *qualitative* terms.

For example, there are concerns about the impact of insufficient maintenance on local residents' security in urban contexts, and more widely with regard to health benefits, on a local population, if pedestrian and cycling access deteriorates to a poor standard (Parkman et al, 2012). Public outcry due to the effects of inadequate maintenance (e.g. restricted access for heavy vehicles across a deteriorated bridge) has created major concerns for funders and meant that the predicted quantified economic impact is only one of the considerations for decision-makers[6].

[4] See *Appendix A, page 31* for further explanation of the diversity of road maintenance.
[5] For example, the World Bank adopts a consistent approach to appraisal of investments (Belli et al, 1998).
[6] See *Appendix A, page 31* for further discussion on the challenge of quantification.

TABLE 1 - FACTORS WHICH DRIVE THE IMPORTANCE OF ROAD MAINTENANCE	
Criteria	**Comment**
Safety	
Accidents	A significant factor (often able to be costed), accidents may increase due to asset deterioration or occur due to sudden events (e.g. asset collapse).
Security	Relevant mainly in urban areas, reduced maintenance can increase perceived or real levels of crime and deter people from travel (e.g. the elderly).
Environment	
Air quality	Global (CO_2) air quality, usually more significant than local air quality, can be costed. Vehicle emissions are affected by road quality and traffic speeds.
Noise and vibration	Degradation of the riding quality of the pavement induces a significant increase in noise level generated by road traffic which is now a main concern in urban areas .
Soil and water quality	Not often significantly affected by maintenance but includes, for example, run-off concerns and impacts of quarry and borrow pit operations.
Biodiversity and habitats	Particularly for sensitive environmental areas and control of noxious or exotic plants for the benefit of the local environment.
Landscape and amenity	The public places significant value on the appearance and upkeep of public spaces and quality of life is promoted by well-maintained urban and rural roads.
Economic	
Vehicle operating costs	The dominant quantifiable factor for networks where conditions of some roads may be poor (i.e. above levels of around 5 IRI) and with minimum traffic levels, costs arise from increased fuel, parts consumption and vehicle maintenance.
Travel time	Failure of road assets and undertaking roadworks both cause disruption. For networks where journey time reliability is a significant consideration, travel time costs can be a key driver of maintenance requirements and a significant quantifiable factor.
Wider benefits	Wider economic benefits of roads such as sustaining local business, tourism or agriculture may be compromised if appropriate levels of access are not maintained.
Integration	
Physical and policy integration	Wider government policy initiatives such as health and physical well-being may be affected as lack of maintenance can deter activity (e.g. less cycling and walking).
Accessibility	
Community and social	Remote communities are affected if limited funding skews maintenance to higher trafficked roads. Specific social groups may be more affected by reduced road maintenance (e.g. if access for the disabled is compromised).

Source: Developed from Parkman et al (2012)

TABLE 2 - INFLUENCE OF ROAD MAINTENANCE ON THE MILLENNIUM DEVELOPMENT GOALS	
Goal	**Road maintenance contribution**
1. Eradicate extreme poverty	Efficient regional transport is necessary for trade and roads are necessary for rural economic growth.
2. Achieve universal primary education	Quality of access on village roads affects school enrolment and attendance.
3. Gender equality in education	Girls attendance at schools is significantly increased by safer roads.
4. Reduce child mortality	Adequate access to health services is supported by appropriately maintained roads.
5. Reduce maternal mortality	
6. Combat HIV/AIDS, malaria and other diseases	
7. Ensure environmental sustainability	Timely road maintenance saves long term costs and reduces materials consumption.
8. Develop a global partnership for development	Sharing best practice for road maintenance requires investment.

Source: International Development Committee (2011)

2.3. ROAD MAINTENANCE AFFECTS GOVERNMENT ACCOUNTS

Another perspective on the impact of road maintenance is given by reporting of government accounts. If inadequate funding for road maintenance occurs over an extended period, road assets deteriorate so that the asset value decreases. If this occurs the government has to *"write down"* the asset, which becomes a very public disclosure that the government has not provided adequate funding for road maintenance.

3. INVESTING NOW PRESERVES THE BENEFITS AND SAVES FUTURE COST

3.1. NOT SPENDING ON MAINTENANCE WASTES PAST INVESTMENT

It is usual practice to undertake a socio-economic investment appraisal when considering the possibility of new road infrastructure. Such appraisals include not only the costs of the new construction for the road authority, but the long term whole of life costs of maintaining and operating the new asset and the economic costs and impacts for society (e.g. accidents and travel time of road users). Investment is considered worthwhile if the benefits to society outweigh the costs to government.

Analyses have established that, over the life of the road, the annual maintenance cost is a small fraction of the initial investment cost, usually some 2-3% for a major paved road and 5-6% for an unpaved rural road (Dongges et al, 2007). This further demonstrates the case for road maintenance; without maintenance, the benefits to society are lost over time, yet the costs of appropriate maintenance are small compared with the overall cost to the road authority.

3.2. SPENDING ON MAINTENANCE NOW SAVES SIGNIFICANT FUTURE COSTS

A key principle of road maintenance is that spending money now saves future costs. As assets deteriorate, so the cost to restore their condition increases and as the condition gets worse, so the costs to society usually become more significant. The concept is well established and is shown in *figure 1.*

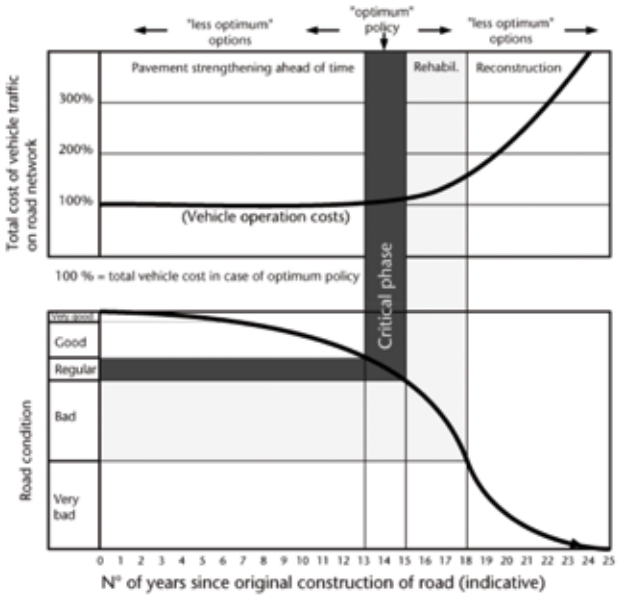

Figure 1 - The variation of costs with time (Source: World Bank, 2012)

A wide range of evidence supports this principle. The World Bank (Heggie and Vickers, 1998) reported that for Africa, every dollar of delayed road maintenance expenditure increased vehicle operating costs by between two and three dollars. It also reported that for Latin America and the Caribbean, the extra costs due to insufficient maintenance per year amounted to €1.2 billion and for India, €2.9 billion per year of reduced vehicle operating costs would be realised by improved maintenance.

More recent evidence comes from a study of the state of Africa's roads by the African Development Bank *(Box 1)*.

Box 1 - Impact of delaying road maintenance on Africa's road network

Paradoxically, low-income countries spend 50% more per kilometre [on road maintenance] overall than do middle-income countries, while countries with established road agencies and fuel levies seem to spend somewhat less than those without. The explanation is a pronounced capital bias in road spending, with investment accounting for two-thirds of total spending in the [resource-rich and] low-income countries, particularly those without adequate institutional mechanisms for funding road maintenance. Middle-income countries and those with high fuel levies tend to spend more on maintenance without incurring higher road expenditure overall. This finding clearly shows that timely attention to maintenance reduces the expenditure needed to sustain the road system in the long term.

Source: Foster and Briceño-Garmendia (2011)

4. ROAD MAINTENANCE: BENEFITS IN ALL CONTEXTS

4.1. STRATEGIC NATIONAL AND INTERNATIONAL NETWORKS

National and international road networks differ from other networks in a number of ways that impact on their need for maintenance, how maintenance is undertaken and the effects of lack of maintenance. The principal aspects of strategic networks that affect the benefits provided by road maintenance are:

- such roads represent a small proportion of the total network length but carry more traffic than local roads and usually with a higher proportion of freight traffic;
- multi-lane roads require more complex traffic management arrangements when undertaking maintenance;
- higher vehicle speeds affect levels of safety, deterioration of the assets, the need for more road features (e.g. vehicle restraint systems) and traffic management during maintenance works;
- maintenance works costs are often significantly higher due to the limited working hours (e.g. at night), the restricted road space available for the works and the more extensive traffic management during the works;
- road carriageway structure is likely to be thicker, based on established design methods and built using modern materials, rather than evolving from earlier tracks by the accumulation over many years of multiple thin treatments;
- asset condition data is collected using more structured survey regimes with data records stored in information systems enabling more advanced analyses of future performance;
- on developed networks, greater use of driver information and traffic control systems, which are often shorter life assets, require more routine maintenance and more frequent replacement than other assets.

In addition, strategic networks (or parts of them) may be funded under private finance arrangements with performance criteria for the pavement condition over a long concession period.

Within the road network, it is common practice to distinguish different classes of road with different levels of service and different priorities for maintenance interventions. In Scotland, after some years of deteriorating condition on the motorway network and concerns over its future performance, that part of the network was given a higher maintenance priority (i.e. a bigger share of the budget) than other parts of their network. This led to an improved condition of the motorway network and higher returns from the maintenance spend.

A study in Uganda (Ministry of Works and Transport, 2013), into the funding needs for the road network recommended that extra funding be dedicated to increasing the proportion of paved roads in good or fair condition from 74% to 89%. To achieve this, a higher priority has been given to routine and periodic maintenance programmes and the rehabilitation of roads in poor condition, where rehabilitation provides clear economic benefit. The programme was justified on the basis of an increase in the asset value of the network rather than the impacts of the poor condition on road users and other stakeholders.

Nevertheless, the benefits of reduced vehicle operating costs alone often demonstrate the significant value of timely road maintenance, as shown in *box 2*.

Box 2 - The impact of road maintenance on vehicle operating costs

In Morocco, an analysis of maintenance spend showed that an increase in maintenance budget, in part funded by a separate levy on fuel, would increase the proportion of paved roads in good condition by 16% over 8 years. That study was based on the effects on total transport costs (goods and passengers), evaluated using the HDM-4 software to assess the impacts of different budget levels. It showed a real increase in maintenance budget of € 2,650 m over 20 years could achieve savings in total transport costs of € 7,500 m compared to that achieved with the current maintenance budget. (Mesnard, 2013).

Even on relatively smooth networks with high traffic levels, the main quantifiable impact of cuts in maintenance budgets may be seen in increased vehicle operating costs. From the study on the Scottish strategic network (Parkman et al, 2012), a real cut in the maintenance budget of € 310 m over 20 years predicted an increase in vehicle operating costs of €440m whilst the net change in costs of other impacts (e.g. travel time, CO_2 emissions and safety) was estimated to be only € 3.5 m over the same period.

A study of the main roads in the network in the Kyrgyz Republic has also shown a reduction in the total transport cost over 20 years of € 2,100 m for an increase in maintenance budget of only € 320 m more than the cost of a 'worst first' strategy. The 'worst first' strategy would only fund routine maintenance and delay further spending until full reconstruction is required. (World Bank, 2012).

4.2. RURAL LOCAL ROAD NETWORKS

In most countries, local rural roads account for the majority of the road network by length. For example, although definitions vary, they are reported to account for 54% of the road length in the UK, 60% in India and 80% in China. Worldwide, unpaved roads account for about 40% of the total classified network of about 34 million kilometres.

All over the world rural road networks face a range of challenges in competing for maintenance funding. Inevitably higher trafficked, strategic and main roads attract the most significant share of funding from Road Funds and Central Government, with rural roads being more dependent on funding from more precarious Local Government sources. Reports of insufficient maintenance for rural roads are widespread. In a study of seven Asian countries, maintenance funding was found to meet only 25% of national requirements, and a much lower percentage for rural roads (Donnges et al, 2007). Yet regular maintenance is required to ensure vehicle accessibility, lower transport costs and an economically attractive environment to ensure rural investment and development.

Box 3 - An example from Tanzania

In 2011 there were 58,037 km of Local Government roads, of which 90% were rural and 10% urban. The network comprised 78% earth roads, 21% gravel roads and 1% paved roads. The condition assessment was 22% Good, 34% Fair and 44% Poor. In 2010, the approved budget was 45% of the assessed maintenance need. In 2010/11 the total maintenance undertaken covered 16,177 km including 10,973 km of routine maintenance, 3,861 km of spot improvements and 1,342 km of periodic maintenance. So overall, only 28% of Local Government roads received any kind of maintenance.

Source: Roads Fund Board (2011)

For gravel roads there is an immediate direct effect of grading (or blading) maintenance on ride quality (road roughness) and hence on transport costs. This is shown by *figure 2*, using the road planning model HDM-4 (HDMGlobal, 2014). Using Ethiopian data, for 100 vehicles per day, *figure 2* shows a significant decrease of total transport costs up to 7 gradings per year. However, for most countries it is rare for rural roads to be graded more than twice per year, which is very significantly below the economic optimum.

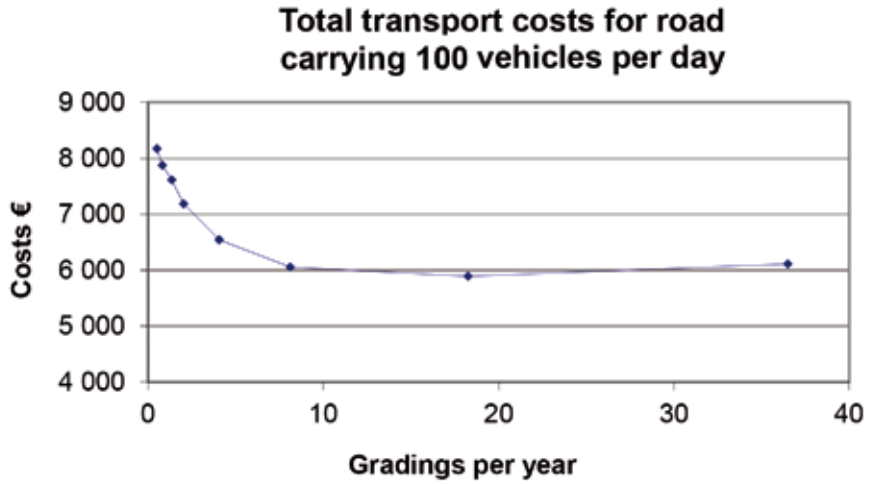

Figure 2 - Effect of grading frequency on total transport costs

Increased vehicle operating costs due to lack of maintenance on the rural road network is also an issue for the developed world. In the Scottish study cited in *box 2, previous page*, the effect of reductions to the current maintenance allocation was shown to have a greater impact for the local road network than for the strategic road network, due to the lower standards of local roads. The study showed that for every € 1 saved in government spend on road maintenance, there would be a disbenefit on local roads of € 1.67 and on strategic roads of € 1.12.

There are also wider economic impacts than those from vehicle operating costs. High road roughness levels damage a range of commodities, such as fruit and vegetables, during transportation and reduce their value at the market.

For many parts of the world poorly maintained roads are subject to varying degrees of closure during the wet season. Any period of heavy rain for more than a few hours can have very detrimental effects on the social and economic life of the communities affected. Problems of access to hospitals and clinics (particularly expectant mothers) are a particular concern. The wet season is also the period when people are most at risk from diseases like malaria and because food stocks are low before the harvest. Children can be prevented from going to school if a local stream or river is too high to cross. Commodities, such as milk, that quickly deteriorate will be spoilt if a delivery truck gets bogged down in mud. Similarly, organisations will be deterred from investing in a location that has serious access problems, and this will have major effects on development. *Box 4* gives an example from Australia.

Box 4 - Effect of lack of local roads maintenance on rural roads in Australia

A report prepared for the Australian Rural Roads Group argued that investment in rural roads in Australia is seriously underfunded (by up to € 1.9 billion per annum) and this has a range of adverse effects. The allocation for periodic maintenance for unsealed rural roads was less than a quarter of the requirement and roads were closed when wet. It argued that the 10% weight restrictions on heavy livestock vehicle movements in New South Wales (because of the poor state of road and bridge assets) had a major impact on the competitiveness of the meat industry, reducing export sales by 12% from rural New South Wales.

Source: Australian Rural Roads Group (2010)

Road maintenance in itself contributes to economic activity and targeted maintenance initiatives can be used to deliver wider social benefits. Whilst this principle is applicable in general for all road networks, it has been particularly true in the case of rural road networks, through innovative local community programmes. For example, *box 5* describes experience from Latin America of targeted network maintenance programmes to achieve such objectives.

Box 5 - Cooperatives in Latin America

In the late 1980s many countries in Latin America started to outsource routine maintenance, as part of an overall reform process to foster the use of the private sector. The majority of routine maintenance is now undertaken by private contractors. Colombia was one of the countries that spearheaded the reform process. It also pioneered the creation of micro-enterprises. The Ministry of Transport, with the United Nations Development Programme and the International Labour Office, initiated a programme to form cooperative micro-enterprises to improve the maintenance of the national road network and to create jobs for the people with little or no formal education or training who live alongside the roads. The system was, and still is, highly successful and serves as a model for many other countries in Latin America. Cooperative micro-enterprises have since been established in Venezuela, Honduras, Ecuador and Bolivia, while single-owner micro-enterprises are more common in Guatemala and Peru.

Source: Zietlow (2005)

4.3. URBAN ROAD NETWORKS

As of 2010 half of the world's population lives in a city and the number of urban residents is growing by nearly 60 million every year. By 2030, 60% will live in a city, and by 2050, this

proportion will increase to 70% with a total of 6.4 billion people (WHO, 2014). Increases in population in urban areas will have a large impact on the provision and maintenance of urban transport and road networks.

There are three significant distinguishing factors for the maintenance of urban networks:

- high traffic density, often resulting in congestion,
- difficulty of integrating road designs as well as traffic into a physically constrained environment,
- catering for the needs of a wide range of different types of road user.

It is common for road users to experience congestion in urban environments, particularly at peak hours of travel. For example in the United States (Parry, 2008), it was quoted that in 2005 the average traveller across the 437 largest urban areas lost 38 hours to traffic delays and the annual costs of congestion, including wasted fuel was estimated at € 56 billion.

It is impossible for an urban environment to be congestion free but it can be managed through road management policies such as providing adequate public transport to reduce journey times and user costs or implementing road pricing. This in turn makes the journeys more reliable and helps meet user needs, this can be only achieved by efficient infrastructure maintenance in order to minimize traffic disruption.

Electronic messaging, managing and signalling systems (ITS) have short design lives and as technology advances there are opportunities for frequent review and upgrade, which are calls on maintenance funds.

On urban networks, roads are commonly shared with utility companies running the electricity, water, sewerage and telephone lines under the road network. Maintenance of such utilities requires the road to be excavated and patched which can impact on the road quality and structural integrity. Coordination of all those who work in the road corridor is a necessity in order to minimize costs and disturbances.

There is also a wide range of users of urban roads that includes passenger cars, freight, buses, trams, bicycles, motorcycles and pedestrians. It has been shown that reduced upkeep of local footways and walkways, usually part of the urban road maintenance budget, serves as a deterrent to pedestrians and leads to severance of suburban communities (Commission for Architecture and the Built Environment, 2007).

Transport organisations for urban networks must meet the increasing pressures to maintain road networks in good condition and to cope with the need for increased capacity as urbanisation increases. Several local authorities in the UK (e.g. London Borough of Hounslow [2012]) have opted to commit to the long term cost of maintenance by securing private investment to fund initial road infrastructure renewals. In return, the private operator commits to and is paid for on-going maintenance over the life of a concession. To justify such commitments, the expected value to the local economy and residents needs to be demonstrated *(Box 6)*.

Box 6 - Cost benefit of maintenance for an urban network

In October 2010, the London Borough of Hounslow was advised by the Department for Transport that there would be an approximate 30% decrease in the government grant, which would require reductions in road maintenance activity. Despite this decrease, it was agreed that the Private Finance Initiative (PFI) procurement route remained affordable, provided value for money and that the range of benefits exceeded the costs. Over the core investment period of 25 years, by considering elimination of the maintenance backlog in comparison to continuing with the status quo, a benefit cost ratio (BCR) of 5.74 was shown. BCRs between 2 and 4 are considered as providing "high value for money" by the Department for Transport. Implementing the investment is expected to lead to benefits which include energy savings (33%), reduction in personal injury accidents (12%), reduction in crime due to street lighting improvements (20%) and reduction in accident claims (25%).

Source: London Borough of Hounslow (2012)

4.4. THE INCREASING IMPACT OF CLIMATE ON ROAD MAINTENANCE

The nature of the operations and impacts of road maintenance are heavily dependent on local climate. Extremely cold winters, high intensity rainfall leading to flooding and high tropical temperatures all drive significantly different requirements for maintenance. As road assets age and as the impacts of more extreme weather due to climate change increase, road networks will become increasingly less resilient if road maintenance is not adequate. Sustainable maintenance should be a prerequisite to the consideration of adaptation measures.

The significance of the direct economic impact of extreme weather is shown by the monetary cost of repairing or rebuilding damaged infrastructure *(Box 7)*.

Box 7 - Extreme weather events - induced costs for transport

Based on a European Commission Joint Research Centre Scientific and Policy report, the total economic cost due to the impact on transport of extreme weather events is € 2.25 billion annually of which impacts on road transport represent 80% (€ 1.81 billion per year). For road transport, out of the € 1.81 billion, 46% of the impact is due to rain and floods, 42% winter conditions, 9% storms and the remaining 3% due to heat and drought.

Source: Nemry and Damirel (2012)

In countries with cold climates, winter maintenance activities such as snow ploughing and de-icing is essential to ensure the safety and accessibility of the road network. The USA spends € 1.7 billion annually to keep highways clear of snow and ice while more than € 0.7 billion is spent annually in Canada (Akin et al 2013). In the UK, which has relatively mild winters (by comparison, for example, with Scandinavia and parts of Asia and America), winter maintenance is still shown to be extremely worthwhile and important in supporting the economy and society *(Box 8, following page)*.

Box 8 - How worthwhile is winter maintenance?

After a number of harsh winters in England and Wales, a winter resilience review was commissioned for the Department for Transport, to look at the economic benefits of winter maintenance in terms of:

- *lost economic output if people cannot get to work,*
- *personal time lost due to travel delays and lost journeys,*
- *additional road vehicle collisions,*
- *personal and health service costs of slips, trips and falls causing personal injury.*

Analysis showed on average there was an annual benefit of around € 1.2 billion from adequate winter maintenance funding during a 'hard' winter in England. The cost to highway authorities in England of providing winter service has been estimated to be around € 190 million per year. This analysis suggests benefit cost ratios of between 5 and 10.

Source: Quarmby, Smith, & Green (2010)

Drainage maintenance becomes more important as the frequency of high intensity rainfall increases. Effective timing of drainage maintenance before, during and after the wet season and around very heavy rainfall events helps alleviate failures and degradation. In sub-Saharan African countries, drainage channels are frequently not cleared before the rainy season which results in sections of roads being washed away leading to more extensive and expensive emergency repairs (European Court of Auditors, 2012).

Box 9 describes recent experience from Eastern Europe.

Box 9 - Recent experiences of flood events from Central and Eastern Europe

The increasingly variable climate in Europe has seen rising numbers of extreme flood events in the last decades (e.g. in the Danube, Odra and Elbe river basins). There is evidence that the most deadly floods are those with short lead times – flash floods - which in Central and Eastern Europe have mostly a spatially limited character and can occur far away from major rivers. Climate change predictions indicate that Europe is likely to see more flash floods in future.

Prediction systems for flood events require cross-sector collaboration, one of the key players being the road authority. Travel on some flooded roads is unsafe and the public needs road warnings. Drainage needs to be adequate to cope. Response after any event needs to be efficient and effective to enable transport to get back to normal as quickly as possible. All these aspects need to be included in the road maintenance task.

Developed from: Associated Programme on Flood Management (2007)

Extreme high temperature also impact on road maintenance. Bridges suffer due to the increased thermal stress on expansion joints, asphalt road surfacings may deform prematurely and chip seals can become slick with flowing bitumen causing major disruption and frustration to traffic (besides requiring repair). This is a major concern, for example, in countries such as Australia where 90% of the rural sealed roads are of light bituminous construction (Taylor et al 2010).

In summary, with predicted increases in extreme weather patterns around the world, there is an increasing need for road networks to be made more resilient by adopting appropriate road maintenance initiatives.

4.5. THE SIGNIFICANCE OF PREVENTIVE MAINTENANCE

All maintenance can be described as preventive, because the aim is to save future costs. However, in many countries, the term preventive maintenance is adopted to mean maintenance work which is intended to reduce the probability of failure or the degradation of the asset. Preventive maintenance is increasingly important with the effect of changes in climate *(Section 4.4, page 17)* but it is also particularly relevant to roads in challenging terrains.

Landslides make headline news when they sever access on road networks and incur high costs to restore the road. *Box 10* gives some examples of the significance of landslides.

Box 10 - Uncertainty of landslides and pro-active road maintenance

Managing road networks susceptible to landslides is about understanding the associated risks and hazards. Significant monitoring and surveillance operations and expertise are warranted where the consequences of the risks are serious. A recent study for Lao PDR reported (Hearn et al, 2008):

"Although the risk posed by landslides to mountain roads in Lao appears to be relatively low when compared to some other countries in the Asian region, there are both technical and economic justifications for the development of an enhanced slope management programme. An evaluation of landslide costs in engineering terms concludes that the economic justification for investment is marginal. However, when the costs of traffic delays are taken into account the case for increased investment in enhanced slope management becomes strengthened."

Such analyses take no account of the social or political impacts arising from lost access. The on-going provision of access is often non-negotiable, so the issue is reduced to simply choosing the lowest whole life cost option to keep the route open.

On the national road network in Scotland, analyses were carried out for a site where the risk of landslides are on-going and occur from time to time. The access provided by the route is strategic and if not available, requires diversions of around 80 km using the current network. Of the three preferred options for providing continued access, the 'maintenance' option provided a Benefit Cost Ratio of 0.43. Whilst this, being less than unity, represents a poor return, it nevertheless is a much better return than either of the two 'new construction' options that were considered, being between 4 and 10 times more favourable. The message is: if access is essential, then the maintenance option represents best value – by quite a margin. (Jacobs, 2013).

For areas prone to earthquakes, there are mitigating maintenance actions which are important and if taken in advance, can reduce the level of damage and the resulting accidents and loss of life, and facilitate recovery of the activity. *Box 11, following page* gives some examples.

Box 11 - Importance of preventive maintenance in seismic areas

The Northridge earthquake in Los Angeles in 1994 registered 6.7 on the Richter scale and caused severe damage and disruption, claiming 57 lives. A review of the event and its impact on highway structures was later carried out (Cooper et al, 1994). With regard to implications of the importance of maintenance of existing bridges, it noted: "Retrofitting [of existing structures using the maintenance budget] improves earthquake resistance….. Although retrofitting is not foolproof, it once again reduced structural failure and damage". The report demonstrated the importance of a long term maintenance approach by recommending that "road authorities should:

- *re-evaluate the retrofit prioritisation scheme based on lessons learned from this event;*
- *develop and train teams with damage evaluation experience prior to the disaster. Experienced, technically balanced, post-disaster response teams make a difference in facilitating recovery. For example, Caltrans uses a two-person team comprised of a bridge designer and a maintenance engineer to quickly evaluate the severity of damage and make a rapid preliminary assessment of needs in order to reopen a bridge. Typically, hundreds of bridges will have to be evaluated following a moderate earthquake. Preparedness training for these teams is essential."*

Similar conclusions have been drawn from the 2011 earthquake in Christchurch, New Zealand (Wood, 2012) and Great Japan East Japan Earthquake of the same year (Ministry of Land Infrastructure, Transport and Tourism, 2013). The message is that earthquakes cannot be avoided but the impact of seismic events can be mitigated by giving due regard to the importance of maintenance and operations in advance.

5. MAINTENANCE INVESTMENT MUST BE PROPERLY MANAGED

5.1. THE CASE FOR ASSET MANAGEMENT

If road maintenance is to be both effective and sustainable, then there is a range of technical, managerial and institutional factors that need to be in place. Clear evidence has emerged of an international consensus on the need for adopting an asset management approach. Recent years have seen consistent recommendations from the International Transport Forum (Crist et al, 2013), the American Association of State Highway and Transportation Officials (AASHTO, 2011), the International Infrastructure Management Manual (IIMM, 2011) and the international standard ISO 55000 (International Standards Organisation, 2014).

The overall aim of asset management can be stated as *'to optimise the service level delivered by infrastructure over its life-cycle'* (Crist et al, 2013). The key aspects which underpin all approaches to asset management, based on evidence from case studies, show the real benefits of adopting an asset management approach. *Figure 3* shows an overview of the asset management approach and provides the structure for the remainder of this section.

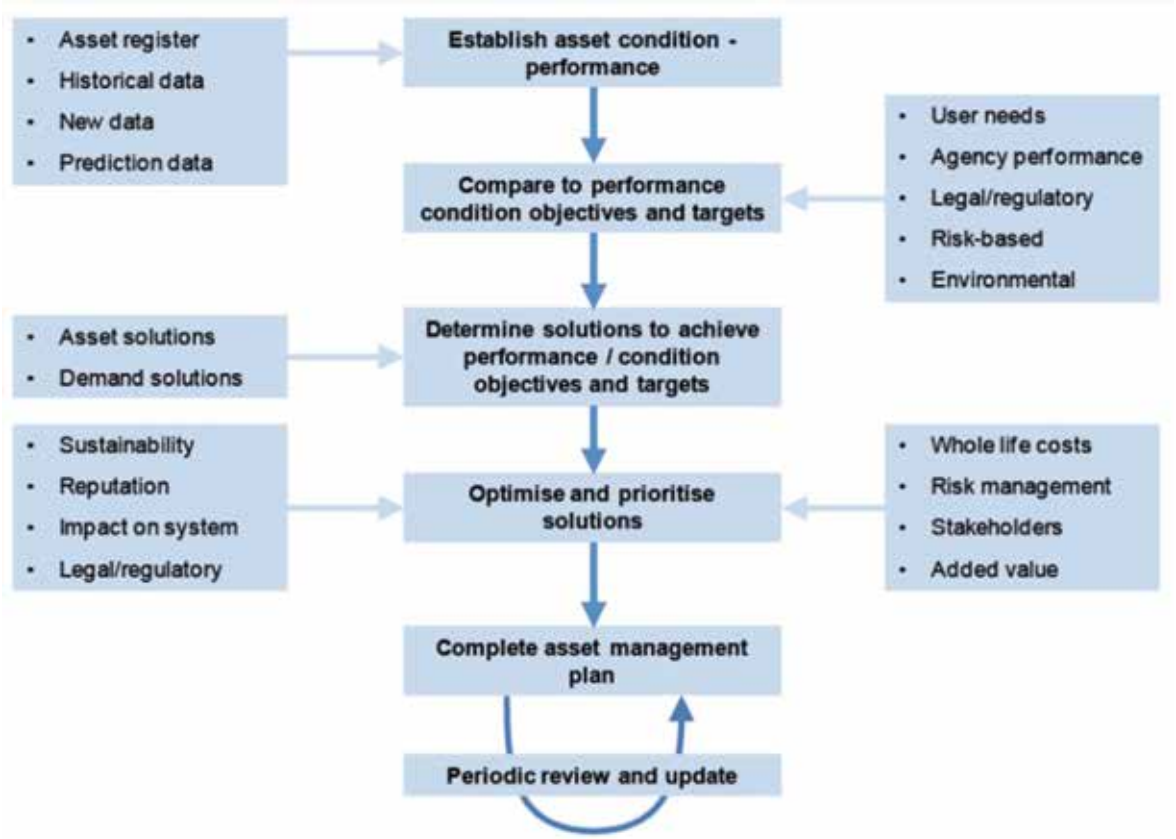

Figure 3 - The asset management approach (Crist et al, 2013)

Establish and manage appropriate levels of service

The social, environmental and economic benefits of road transport should drive the approach to setting levels of service. Account should also be taken of public opinion which is strongly in favour of effective and appropriate road maintenance. *Box 12* shows evidence that the public values maintenance even more than new road construction.

Box 12 - What does the public really want – maintenance or new construction?

In Canada, the user satisfaction survey for the province of Nova Scotia showed that poor road maintenance was the issue of most concern to road users, ahead of such issues as the provision of new passing lanes, and opposition to toll roads (Mills, 2010).

In UK, during the 2010 national election campaign, the RAC Foundation asked people their highest transport priorities of an incoming government. Top at 58% was "condition of roads and pavements"; next at 46% was "curbing the cost of driving"; public transport fares came lower down; and bottom at 3% was "developing a new high speed railway" (RAC Foundation, 2010). Surveys carried out on the national and local council road networks suggest a similar high desire of the public for appropriate road maintenance (HMEP, 2012).

Road authorities need to establish clear service requirements so that maintenance funds are invested where road users and the public need them most. International reviews (see Federal Highway Administration [FHWA], 2011 and Ward et al, 2012) report the importance of setting different service levels for different parts of the network. In the USA, the FHWA (FHWA, 2009) is developing different service levels depending on the use of the paved road network and, for example, Norway has three maintenance hierarchies that are determined primarily by level of traffic.

Know the asset and its level of use

Proper knowledge of the extent of the road asset, its performance and condition, and the level and type of use (i.e. traffic volumes and road users) is essential to enable rational decision-making. Numerous authorities have reported the benefit of improved decision-making that resulted from initiatives to improve road asset information.

For example, Namibia embarked on a major road information system initiative in 2000 and has reported significant improvements in its decision-making as a result (Namibian Roads Authority, 2009). The Bavarian Road Administration has highlighted some innovative condition and performance reporting techniques which have driven improved decision-making based on a more focused understanding of their assets (Bavarian Building Authority, 2011).

Programme based on robust planning processes and good risk management

Figure 1, page 11 shows the need for maintenance at the right time. The rate of deterioration, timing and options for renewal treatments and other operational requirements vary depending on the specific type of asset and its context. There is a need for:

- detailed understanding of the life cycles of each asset type, based on measured conditions and performance and prediction models for future behaviour, using tools such as HDM-4 (HDMGlobal, 2014);
- detailed understanding of the risks. Measuring the condition and performance of assets only identifies one aspect of the maintenance decision. All decisions are related to the level of risk which the road administration can tolerate. An asset in poor condition may not need immediate maintenance if there is limited risk of further deterioration in the foreseeable future and if failure of the asset would have limited impact on road users. For road users, the most important risk is road safety, but a road authority must also consider other risks (e.g. capacity, reputational risk etc). *Box 13, following page* gives an example of a risk management approach adopted by the Netherlands;
- maintenance and operational requirements need to be considered at design stage. Decisions made when an asset is first built can have significant consequences on future costs to the road user and road authority;
- appropriate operations management processes. Road networks require logistics planning and advanced real-time monitoring to enable efficient network operation. For example, incident management on highly trafficked networks where, for example, ineffective incident response may lead to unnecessary impacts on road users in terms of delays or accidents.

Box 13 - Accounting for the full impact of maintenance

In the Netherlands, analyses of maintenance spend consider the technical aspects of Reliability, Availability, Maintainability and Safety, and the non-technical aspects of Security, Health, Environment, Economics and Politics. This RAMS-SHEEP process is used to show the predicted performance of the network and indicate effects of changes in maintenance funding. It enables the Government (i.e. politicians) to include user and stakeholder needs and risks in decisions on funding levels.

However, care must be taken when using such approaches to ensure the measure of performance, often summarised by an overall performance indicator, does not hide significant changes in only a few aspects and therefore wrongly directs how maintenance budgets should be spent. In the Netherlands this risk is managed by a Service Level Agreement between the Ministry and the road authority, Rijkswaterstaat, which ensures it manages the network to meet strategic targets for spending that meet the interests of the road users and other stakeholders.

Source: Rijkswaterstaat (2009)

Understand the value of the asset

Section 1.1 identified the importance of the road network and its value and *Section 2.3, page 11* showed how it affects Government accounting. Understanding the depreciation in the value of the asset provides the link to the financial decision-making process. The rate of depreciation is directly related to the ageing or deterioration of the road asset and the level of maintenance undertaken on the network.

Strive for continual improvement

Asset management best practice points to the value of embedding asset management as a culture within road authorities. Asset management is not just about implementing systems and processes through a one-off improvement project or initiative. The implementation should be seen only as a first step and the long term benefits will be realised by continuous development and refinement of such systems and processes. Regular audit and review of the process challenge the organisation and promote that continual improvement.

5.2. THE NEED FOR WIDER INSTITUTIONAL SUPPORT

In 1998, the World Bank published a seminal report on the case for reform of road management (Heggie and Vickers, 1998). It had a strong focus on road maintenance, drew on experience from both the developed and developing world, and adopted wider lessons from commercial industry and the financial sector. It identified the need for four basic building blocks without which the asset management approach, summarised in *Section 5.1, page 20*, will not be successful:

- maintain steady financing,
- establish ownership with the active participation of road users,
- clearly assign responsibility,
- promote commercial management.

Progress has been made on these objectives in many places (e.g. Foster et al, 2011). Experience since then, specifically in relation to road *maintenance*, suggests four key lessons.

Funding must be stable and available at the right time

Road funding processes and the impact of slow disbursement of funds resulting in late or even lack of funds within the budget cycle have been well reported internationally (e.g. United Nations [2005]). Even when funding is sufficient, if it is confirmed or delivered too late in the year, opportunity to carry out maintenance work may be missed. It may also be impossible to spend at the required rate due to resourcing issues.

In England, with reference to the Highways Agency's management of the national highway network, the Department for Transport recently reported: *"Without a clear picture of its future resources, the Agency has not been able to plan how to manage its network efficiently in the future. This in turn has undermined the ability of its supply chain to invest in its own capability, limiting their ability to create jobs and drive down prices."* (Department for Transport, 2013b).

The use of road funds to assist with addressing such issues can deliver improvements but requires significant institutional and management support. In the developing world, countries with well-financed (second generation) road funds have been shown to be better at capturing resources for road maintenance. Road tolling is another option which has been adopted successfully in many countries but is only applicable for parts of the network. Any institutional changes need to consider how funding is raised, how it is administered and by whom.

Legislation must complement the road maintenance task

Legislation for roads must be appropriate and enforced. In a number of developing countries, overloading of trucks is the main cause of deterioration of the roads; with enforcement of legislation by public authorities often lagging behind. In a wider example, Japan has recently amended its legislation to ensure adequate implementation of road maintenance. The law obliges road authorities to conduct inspections of roads to identify maintenance requirements. Additionally, the amendment enables central government to provide technical assistance to local governments

Legislation in the technical areas is not the only regulatory requirement to ensure road maintenance delivers value for money. For example, corruption has been shown to have significant negative influence on road maintenance by increasing the cost of services (Snaith and Khan, 2008).

Appropriate resources must be in place

Recent years have seen significant shifts to outsourcing of highway management in many countries. Such approaches demand different skills in the road authority (i.e. client expertise) and staff must be skilled in the management of suppliers who provide much of the technical expertise. There is an emerging concern that institutional memory has been lost in many organisations as a result of such changes. The challenge is at its most extreme for management of local road networks, where organisational capacity building is essential to achieve sustainability of road maintenance.

Over the last two decades, in developing countries, a range of initiatives have brought management of local road networks closer to the population. The purpose has been to increase accountability and responsiveness, and to provide opportunities for wider local participation but these initiatives have met with varying degrees of success. The main problems encountered have been inadequate transfer of funding to the local level coupled with a lack of staff capacity and other resources.

Often, institutional procedures have proved too complex and lower levels of government have lacked experience and proper legal authority to manage the appropriate level of road maintenance. There is a need to ensure local road networks not only have the necessary funding, but also that staff have proper capacity and legal authority to undertake management of the network without a constantly volatile institutional approach (Stiedl and Robinson, 2000).

Procurement approaches must drive best value

Procurement approaches need to match the available resources and drive best value. Countries which are committed to maintenance continue to innovate in this area to ensure procurement delivers best value for money and is flexible to accommodate wider political and economic drivers *(Box 14)*.

Box 14 - Long term performance based contracts in Australia and New Zealand

New Zealand introduced long term, performance based contracts for road maintenance in the late 1990s. At the time, the benefits in terms of reduced maintenance costs of such new approaches had only been identified in a few examples from around the world, most notably Sydney, Australia, where savings of 30% had been quoted (Frost and Lithgow, 1996). Significant research has been undertaken since, as New Zealand and Australian state road agencies strive to deliver better value.

In 2013, New Zealand commenced procurement of the first set of contracts under its latest maintenance contract specification. Queensland and New South Wales also embarked on new approaches. The new contracts resemble earlier performance based contracts in many ways, but with some significant developments to ensure that the balance of risk, the payment mechanisms and the performance incentives align with current objectives (e.g. see New Zealand Transport Agency, 2013).

Similar such initiatives have continued elsewhere in the developed and developing world.

6. PRESERVING VALUE FOR FUTURE GENERATIONS

Maintenance now has benefits not only for the present generation; inadequate maintenance also impacts on the financial burden on future generations. Evidence that maintenance at the right time saves increases in future costs has been quoted and shows that avoiding the necessary investment and management now exacerbates the problem for the future.

Box 15, following page shows that even with knowledge of asset performance and the problems existing on the network, lessons are not easily learnt. The importance of maintenance is clear and must not be ignored.

Box 15 - What happens when things go wrong?

Six years after a Minneapolis bridge collapse that killed 13 people and drew attention to the state of bridges in the USA in 2007, media attention is still highlighting the challenge. Reports in 2013 are unforgiving:

There has been minimal improvement and insufficient funding to repair and replace ageing spans. The collapse of the Interstate Highway 5 in Washington State shined the spotlight once again on troubled bridges. In 2012, the Federal Highway Administration said 67,000 — 11% — of the nation's 607,000 bridges were structurally deficient. That means the bridges are not unsafe but must be closely monitored and inspected or repaired. That percentage is little changed since 2007 when 12% of the nation's bridges were listed as structurally deficient and the I-35 bridge collapsed in Minneapolis.

In the wake of that accident, States closed bridges, reduced weight limits or made immediate repairs. All bridges designed like the one that fell were inspected. Some States, conducted broader reviews to identify bridges needing the most work. Others installed high-tech sensors to record the deterioration of bridges.

Funding repairs and replacements continues to be a problem, especially because bridges are getting older, says Andrew Herrmann, an engineer and past president of the American Society of Civil Engineers. The average bridge in the USA is 42 years old, Herrmann says. "As bridges get older, we're going to see more problems, State departments of transportation are going to make hard decisions about what bridges to maintain, what bridges to replace and what bridges to close. We are going to see more closed bridges."

Source: USA Today, 2013

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APPENDIX A - THE DIVERSITY OF MAINTENANCE AND ITS IMPACTS

A.1. ROAD MAINTENANCE OPERATIONS

Road maintenance is more than pothole patching and resurfacing. There are a number of other operations which need to be sustained and assets that need to be maintained for a road network to provide an appropriate on-going level of service:

- structures such as bridges, tunnels and drains need to be kept structurally sound and operational;
- slopes and embankments need to be kept safe from sudden and potentially catastrophic collapse;
- the wider road corridor needs to be kept safe and managed to meet public demand. Activities include, for example, vegetation control to maintain sightlines for safety, mending boundary fences or noise barriers and managing adjacent pedestrian paths and cycle-tracks;
- assets such as streetlights, traffic signals, traffic signs, line-marking and safety barriers support the safe and efficient operation of traffic and must be maintained. In more advanced situations, use of Intelligent Transport Systems (ITS) to manage traffic operations depends on a range of information technology assets operating on the network;
- to ensure appropriate day-to-day operation as well as long term planning, a wide range of management support activities (e.g. asset condition monitoring and inspection, traffic monitoring and provision of support office staff and facilities) are required.

A.2. THE DIFFERENCES DRIVING MAINTENANCE REQUIREMENTS

There are similarities from country to country, and across networks, in the issues driving the importance of road maintenance. However, understanding the specific context of any road network is important so that the precise benefits and impacts are understood and managed. Diversity arises from:

- ***Network type.*** Road networks range from strategic national routes to minor local roads and serve a wide variety of strategic needs.
- ***Environment.*** Both the climatic variation (extreme winter to tropical etc) and range of terrain types (from mountainous to flat coastal etc) will drive very different impacts on users and wider society.
- ***Population density.*** Maintenance on remote rural networks has very different impacts to maintenance in densely populated urban areas.
- ***Different users and affected parties.*** Freight and passenger transport serves a variety of purposes and cyclists, pedestrians and other non-motorised transport lead to different considerations. However, it is not only road users who are affected: adjacent residents, landowners and businesses are all impacted by road maintenance.

A.3. QUALITATIVE AND QUANTITATIVE IMPACTS ARE IMPORTANT

The objective for any road authority is to minimise costs and derive maximum benefit (Robinson et al, 1998). Given the diversity of road maintenance activities and the range of their impact, it is important to understand the relative significance of each and the most important impacts to consider for a given network.

Costs to be considered include the direct costs to the government or owner of the road network.

These may be realised as payments to contractors for maintenance operations, payments to privately financed road operators, or payments directly by the road authority if it operates its own maintenance teams or funds for specific activities directly (e.g. payment of energy bills for street-lighting).

Road users are directly impacted by road maintenance and these impacts can often be costed:

- ***Safety.*** Maintenance can reduce the occurrence (or likely occurrence) of accidents to road users or road workers.
- ***Travel time.*** Maintenance ensures that journeys can continue (e.g. clearing a landslip from a blocked road) or results in faster journeys if, for example, the road has deteriorated to a condition such that vehicle speeds are reduced. Such considerations need to be balanced against disruptions which may be caused to road users by carrying out the road maintenance itself.
- ***Vehicle operating costs.*** Maintenance of road surfaces provides a smoother ride which result in lower fuel consumption and less vehicle wear and tear.

In order to value the impacts, robust predictions of performance and impacts are needed and these are often a challenge to derive. For example, road signs are renewed to maintain safe driving and road use, but it is difficult to establish precise estimates of the increases in accidents that will result if maintenance is not carried out. There are other impacts on road users which it is difficult, if not impossible, to value. For example, graffiti removal and vegetation control help to improve the appearance of the network but placing a monetary value on this benefit is not straightforward.

More difficult to quantify are the indirect impacts of road maintenance to wider society. Some direct impacts result in wider society (indirect) costs which can be quantified. For example, vehicle operation results in fuel consumption and generation of vehicle emissions. Impacts of road maintenance on vehicle operating costs will also therefore have implications for global CO_2 and greenhouse gas levels.

There are also other, wider impacts to be considered. For example, if street-lighting is not maintained in urban areas, residents may feel less secure due to the potential of increase in crime (Parkman et al, 2012). If local road access is compromised due to lack of maintenance, then goods or crops may not be able to make it to market in time and economic and agricultural activity is suppressed.

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