International Transport Forum

Policies to Extend the Life of Road Assets

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Research Report
2018

The International Transport Forum

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Cite this work as: ITF (2018), "Polices to Extend the Life of Road Assets", *ITF Research Reports*, OECD Publishing, Paris.

Acknowledgements

In July 2017, the International Transport Forum (ITF) convened more than 25 distinguished international experts to form a Working Group "Policies to extend the life of road assets". The group, which assembled renowned practitioners and academics from areas including road operators, civil and vehicle engineering, and transport policy, was tasked to provide advice and practical examples of successfully implementing policy measures to extend the lives of road structures

The Working Group was chaired by Loes Aarts, Senior Advisor Freight Transport at the Dutch Ministry of Infrastructure and Water Management, facilitated by Katja Schechtner, Advisor Innovation and Technology of the ITF and brought knowledge from 17 countries to provide insights on one of the most discussed issues in the road transport sector.

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The Working Group would like to thank Jan Helmer, Rijkswaterstaat, Ministry of Infrastructure and Water Management, The Netherlands for providing valuable insights for our work. We are grateful to Inge Vierth, VTI, Sweden; Francois Combes and François Toutlemonde, IFSTTAR, France; Niels Groenen, Agentschap Wegen en Verkeer, Belgium; Thibault Prevost, Ministère de la Transition écologique et solidaire, France; Andrzej Maciejewski, General Directorate for National Roads and Motorways, Poland and Dejan Makovšek and Stephen Perkins, International Transport Forum, for serving as internal reviewers of our work.

Furthermore the Working Group would like to thank Maja Piecyk for organising the second Work Group Meeting at Cambridge University, Raimonds Arionietis, ITF, for facilitating it and SANRAL SA for hosting the third Working Group Meeting in Cape Town, particularly Steph Bredenhann and Paul Nordengen for facilitating the invitation and Nathan Zhivov, formerly of the International Transport Forum, for helping to bring this group together.

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Executive summary

What we did

This report presents policy options for extending the life of road assets by mitigating deterioration caused by trucks. Beyond traditional engineering responses, it considers the role of trucks in road asset deterioration from a broader, demand-oriented perspective. The report contributes to developing a new policy framework for maintaining and managing road assets in a cost-effective way and to meet road freight transport demand on a sustainable basis.

Transport agencies in both developed and developing economies acknowledge the problems they face with ageing infrastructure and understand the mechanisms that cause deterioration. However, budgetary constraints and competition for scarce public resources often inhibit or delay maintenance activities. Simultaneously, the demand for road freight transport continues to rise and become more complex. These trends are likely to continue, making proactive asset management ever more difficult. In this context, digitalisation offers new opportunities to prolong asset life through a better and close to real-time understanding of the structure of demand and the impact of truck traffic on pavements and bridges.

The insights and policy options presented in this report build on the collective knowledge of the Working Group on Policies to Extend the Life of Road Assets convened by the International Transport Forum. The group included 27 renowned practitioners and academics from 17 countries with expertise in asset management, traffic management, vehicle dynamics, logistics and economics, truck operations, and transport regulation and compliance.

What we found

Transport agencies plan, design, build, operate, and maintain their infrastructure assets, notably pavements and bridges, to serve transport demand and sustain healthy economies. Road agencies strive to contain costs by extending the life of assets and protecting them from deterioration caused by trucks. However, designing and implementing policies that are effective and extend the life of road assets in practice is not straightforward.

A new policy framework for maintaining and managing road assets in a cost-effective way and meeting road freight transport demand on a sustainable basis is needed. This framework should encompass policies of three types:

Demand-responsive policies: Prolonging road asset life requires better alignment of infrastructure maintenance and management actions with current and future road freight transport demand. This means better utilising financial, human, and technological resources to plan, design, inspect, and maintain road infrastructure and adopting more proactive and systematic approaches to asset management.

Policies that regulate demand: Road infrastructure protection is a common objective of truck regulation and enforcement. However, the pursuit of regulatory compliance typically occurs outside the civil engineering domain and without a clear understanding of the complexities of asset management. The policies in this category aim to close this knowledge gap.

Policies that influence demand: Policies in this category have seldom been considered as opportunities to extend the life of road assets. These policies aim to purposefully influence real-time and longer-term road freight transport decisions and behaviours. Their gradual and careful integration into asset management strategies increases the number of options the standard toolkit for road managers.

Regardless of the type of policy considered—responding, regulating or influencing—, a fuller understanding is necessary of current and future road freight transport demand, of the trucks that serve this demand, and of the mechanisms by which their utilisation of transport infrastructure deteriorates road assets. Simply put: trucks matter for pavements and bridges.

The digitalisation of asset management and logistics, together with increasing vehicle and infrastructure connectivity, can provide the data to support a comprehensive approach. In fact, this opportunity has motivated many transport agencies to consider data itself as an asset that requires attention and careful management.

Successful implementation of new approaches requires regular and meaningful stakeholder consultation. Challenging policy goals are more likely to be achieved when there is effective collaboration amongst policy makers, infrastructure owners, the freight transport industry, and experts in relevant knowledge domains such as pavements, bridges, vehicle technology, regulations, traffic management, and logistics.

What we recommend

Introduce a proactive approach for the maintenance of road assets

A proactive approach for the maintenance of road assets is critical to ensure a robust network and efficient cost management vis-a-vis increased road use by trucks and climate change impacts. Improved interaction between road managers and policy makers will raise awareness of the consequences of delayed or postponed decisions and the need to invest in long-term databases to provide insight into these risks.

Build a proactive, data-driven approach to the maintenance of road assets

Modelling the development of traffic demand and anticipating growing demands on the network provides valuable planning support for pavement and bridge maintenance. It can be translated into improvements in traffic safety, road capacity, accessibility and user mobility as well as higher ride quality and comfort.

Strive for continuous professionalisation in road asset management

Establishing development plans and backing these up with sufficient resources will go a long way to ensure continuous professionalisation. The future-proofing of road asset management systems should include a) planning approaches to respond to variations in user requirements; b) explicit consideration of risk in asset management; c) access to data from advanced ICT systems and d) effective governance arrangements for cross-jurisdictional alignment.

Move from managing the assets to cross-asset management

For road organisations that have mastered asset management practices for individual assets (such as a road section or a bridge) or groups of assets, the next challenge is to apply and harmonise practices across all assets to support users' door-to-door trips.

Adopt regulatory frameworks that treat the use of road assets as an economic input

Measuring the use of road assets in terms of economic utility will increase the productivity of road freight transport. This could include 1) assessing the full breadth of economic costs and benefits that can be derived; 2) identifying opportunities to reduce pavement and bridge wear through regulatory frameworks; 3) adopting performance-based standards to vehicle design to enable innovation and 4) adopting intelligent access policies that allow specific types of transports to travel on restricted parts of the network.

Implement infrastructure pricing for trucks to improve cost recovery

Cost recovery for infrastructure could include adopting (incremental) charging based on distance travelled and/or mass carried from operators whose truck combinations increase road asset wear. It could also make use of regulatory or financial incentives to encourage operators to use road-friendly vehicles and share data.

Better understand the reasons for non-compliance with truck weight limits

A good understanding of the reasons for non-compliance with permissible weight limits for trucks allows selecting the right approach for an effective compliance framework. This requires collecting evidence on the current level of non-compliance. It also requires ensuring that compliance management frameworks are outcome-focused and that the design of regulatory frameworks supports the compliance strategy

Focus on positive incentives for efficiency in regulatory and compliance frameworks

Innovative approaches to regulatory design and compliance will implement the carrot and stick method. To provide incentives for transport operators to comply with regulations, measures might include mechanisms for accreditation and self-regulation, state-of-the-art approaches to manage vehicle weight, as well as the use of telematics and related intelligent technologies.

Develop use cases and business models for the digital infrastructure of truck traffic management

While the development of digital infrastructure comes with uncertainties, different use cases will help to identify the digital infrastructure requirements for effective truck traffic management.

Create incentives for the logistics sector to implement truck traffic management

There are many potential benefits that encourage logistics providers to adopt systematic truck traffic management. These include fewer road works, wider access to areas or objects with limited access, shorter travel times and higher delivery time reliability. Reaping such benefits will also increase the willingness of the logistics sector to share vehicle and/or company data, which in turn could be used to reduce the cost of implementing truck traffic management strategies.

Improve awareness of the mutual impact that policies have on the environmental performance of road freight transport and extending the lifespan of road assets

Infrastructure should be considered as one of the foundations of a sustainable freight transport system, as it is a key enabler of environmentally and socially responsible freight activity. Measures designed to improve the environmental performance of road freight transport can often contribute to a longer life span of road assets. Where this is not the case, a multi-modal, cross-function and multi-stakeholder approach enables a reasonable social trade-off assessment to be made.

Focus on creating a comprehensive regulatory environment rather than on individual measures

Policies aimed at extending the life of road assets are best supported by bundles of appropriate measures. These include cross-modal infrastructure investments, performance-based standards and coherent pricing structures for infrastructure use that encourage shippers, forwarders and carriers to reduce the number of trucks and the number of kilometres driven.

Reader’s guide

AASHTO: American Association of State Highway and Transportation Officials

AI: Artificial Intelligence

AMS: Asset Management System

B-Double: A medium-sized articulated truck consisting of a towing vehicle and two semi-trailers

BIM: Building Information Modelling

BMS: Bridge Management System

CBA: Cost-Benefit-Analysis

CEDR: Conference of European Directors of Roads

CAO: Cross-Asset Optimisation

Consolidation Centre : Logistics facility where deliveries from multiple suppliers are consolidated into fewer larger loads for the delivery to the location or area it serves.

Deflectometer: In-motion pavement deflection measurement system where both loading and deflection acquisition systems are moving together

e-CMR: An electronic version of the consignment note used under the CMR Convention (Convention relative au contrat de transport international de Marchandises par route) when transporting goods by road. The CMR-document is a standardized document for cross-border transport of cargo by road, based on UN recommendations for uniform international rules and in force in the European Union.

HCM: Highway Capacity Manual

HCT: High Capacity Transport

HCV: High Capacity Vehicle

HDM: Highway Development and Management

Hub-and-spoke distribution systems: Centralised logistics system, where the central ‘hub’ receives goods from local depots (‘spokes’), sorts and consolidates the products, and sends them to local depots for final distribution.

IAP: Intelligent Access Program

KPI: Key Performance Indicator

Last mile: Last mile or last kilometre refers to the final leg in the distribution network that deliver goods to the end customer’s location, e.g. home.

LCV: Longer Combination Vehicle

LHV: Longer Heavier Vehicle

LOS: Level of Service

Mobility-as-a-service: Software-based mobility solution for businesses that allows for choosing the right option, scheduling and paying for that option.

NRA: National Road Authority

OBW: On-Board Weighing

PBS: Performance Based Standards

PIARC: World Road Association

PMS: Pavement Management System

RCM: Reliability-Centred Maintenance

RFS: Road Friendly Suspensions

Road wear and road damage: Road asset wear occurs when trucks carrying either normal or abnormal loads comply with the maximum axle and total load limits considered in the design process. In contrast, damage is inflicted by normal or abnormal loads which exceed permissible maximum limits.

Rutting: Deficiency in transverse evenness of pavement surface/structure

TAMP: Transportation Asset Management Plan

Truck: The report considers a truck as any on-road, heavy vehicle whose primary purpose is to carry freight in response to the demand for road freight transport

TSDD: Traffic Speed Deflectometer Device

TUE: Twenty-foot Equivalent Container Unit

V2I: Vehicle-to-Infrastructure Communication

I2V: Infrastructure-to-Vehicle Communication

V2V: Vehicle-to-Vehicle Communication

WIM: Weigh-in-Motion

CHAPTER 1

Introduction

The purpose of this report is to provide policy options that can help to mitigate the deterioration of road infrastructure assets that is caused by trucks. Transportation agencies around the world face the challenge of providing and maintaining road assets that meet rising demand for road freight transport while simultaneously dealing with constrained budgets. The policy options presented in this report offer opportunities to sustain or improve the robustness of road assets, stabilise infrastructure budgetary requirements, and enable road assets to support healthy economies.

The report targets those involved in developing policies and making decisions concerning road infrastructure assets, truck regulation and compliance, truck traffic management and freight planning.

The policies aim to extend the life of two classes of road infrastructure assets: pavements and bridges. Other road asset classes, such as tunnels and traffic control equipment, are beyond the scope of this work. Acknowledging that the definition of a truck varies widely, the report considers a truck as any on-road, heavy vehicle whose primary purpose is to carry freight in response to the demand for road freight transport.

Road infrastructure asset life depends on numerous design, construction, maintenance, environmental, and operational factors. Within these factors, the use of road assets by trucks plays a substantial role (OECD Road Transport Research Programme 1998; ITF 2011). The interaction between trucks and road assets is complex, not only because of the wide range of trucking activity, types and configurations, loads, and physical and operating characteristics, but also because the condition of the asset influences the dynamic loads imposed by trucks using it. Consequently, the effective design and management of road assets relies on an understanding of how these characteristics and interactions influence asset life. Research and development efforts principally within the civil engineering domain continue to enhance this understanding.

Despite the importance of these ongoing efforts, as a policy-level document, this report considers the role of trucks in road asset deterioration from a broader, demand-oriented perspective. By doing so, the report contributes to a more comprehensive view of how to maintain and manage road assets—a view which encompasses policies that respond to current and projected freight transport demand, policies that regulate the demand for truck transportation, and policies that influence the magnitude and nature of road freight transport demand.

Figure 1.1 conceptually illustrates the relationship between the demand for road transport and road asset deterioration. As shown in Figure 1.1(a), the movement of people and freight comprise the total demand for road transport. While freight transport demand represents a minority share of this demand (when measured in terms of the total distance travelled on a network), the trucks that serve this demand cause a disproportionately high share of road asset deterioration. A similar relationship is evident when considering the demand for road freight transport, as shown in Figure 1.1(b). Here, trucks carrying abnormal loads cause a relatively high proportion of road asset deterioration compared to trucks carrying normal loads, even though they serve a relatively small proportion of total road freight transport demand.

Figure 1.1: The relationship between road transport demand and the deterioration of road assets.

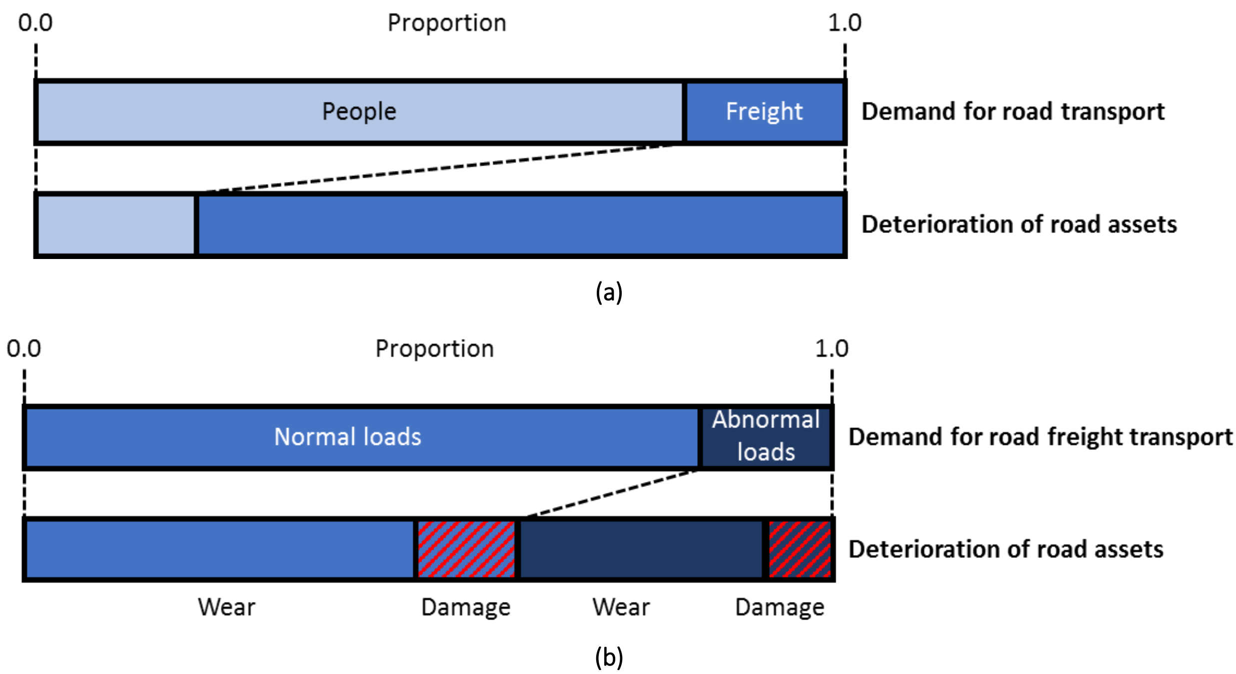


Figure 1.1b also conceptually illustrates the distinction between two components of road asset deterioration: 'wear' and 'damage'. Road assets are designed to wear. Road asset wear occurs when trucks carrying either normal or abnormal loads comply with the maximum axle and total load limits considered in the design process. In contrast, damage (depicted conceptually with the red hatching in the diagram) is inflicted by normal or abnormal loads which exceed permissible maximum limits. While such occurrences may be relatively infrequent, they have the potential to be responsible for a disproportionately high share of road asset deterioration and maintenance costs.

Motivation for this report

The policy options presented in this report are motivated by

- the problem of ageing infrastructure and constrained budgets;
- the rising and changing demand for road freight transport;
- opportunities and challenges regarding the use of data to support asset management decisions.

Ageing infrastructure and constrained budgets

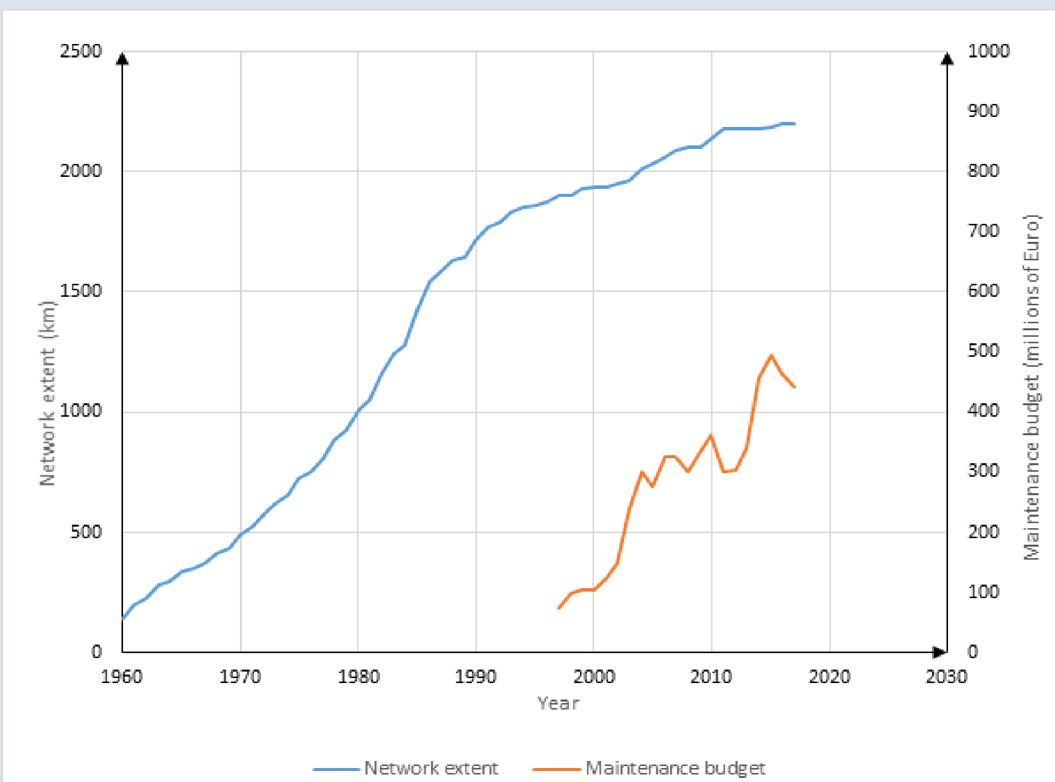
According to the World Economic Forum (2014), annual investments in transportation infrastructure continue to fall short of infrastructure needs, resulting in a persistent and growing asset maintenance and renewal backlog. This backlog is evident in both developed and developing economies.

In developed economies, including OECD countries, major investments through the 1960s to 1980s facilitated considerable road network expansion. As this expansion occurred, transport agencies struggled to allocate sufficient and timely resources to maintain this infrastructure, resulting in a deferment of asset maintenance and renewal expenditures. Box 1 illustrates the Austrian experience with this reality. Funding allocations for capital road infrastructure projects also face increased scrutiny amidst more stringent environmental regulations, rising social expectations, and physically-constrained urban spaces. Utilising private sector resources is now common but private financing alone cannot resolve what is ultimately a funding problem (ITF, 2018).

Box 1.1: Road network expansion and maintenance budgets in Austria.

As shown in Figure 1.2, Austria's network of motorways and expressways expanded considerably between the 1960s and the 1980s but has since experienced more moderate growth. In response to the deterioration of this infrastructure, the Austrian road operator ASFINAG has accelerated its road maintenance budget since 2000. The graph reveals the relationship and time lag between network expansion and maintenance budget requirements.

Figure 1.2: Time lag between road network expansion and maintenance expenditures



Source: ASFINAG, (2018).

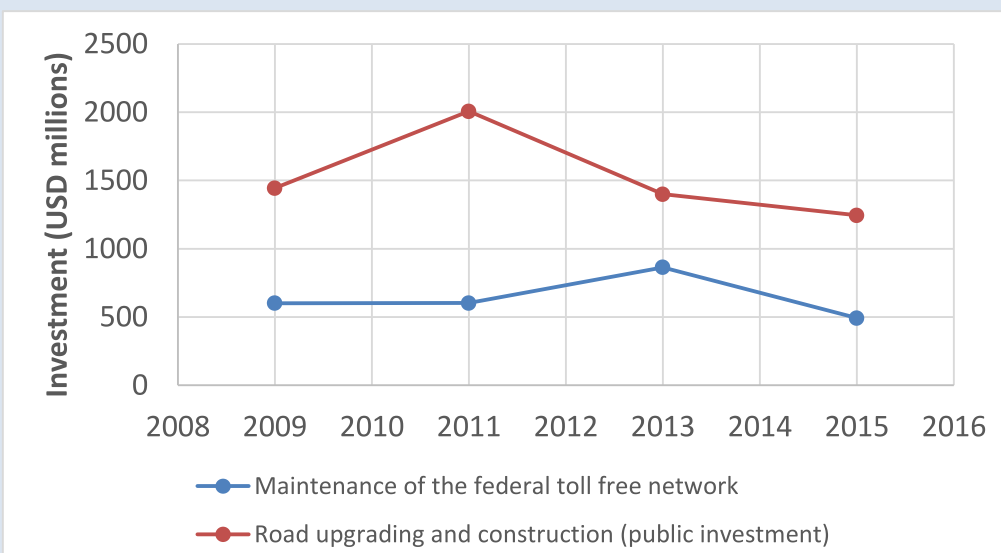
In developing economies, investment in new infrastructure is needed to propel economies forward alongside growing populations, industrialisation, and globalisation. In addition, existing assets require maintenance and rehabilitation. Box 2 illustrates the competitive nature of resource allocation for capital road projects and road maintenance in Mexico. Countries that invest in new infrastructure now, however, are likely to face infrastructure maintenance challenges in the coming decades, unless they invest in and implement proactive strategies to mitigate their maintenance expenditure needs in the future.

Box 1.2: Competitive resource allocation for capital road projects and road maintenance in Mexico.

With a total length of nearly 45 000 km, the Mexican federal toll-free road network represents one of the most important assets owned by the Mexican state. This network comprises primary and secondary roads stretching throughout the country. One of the biggest challenges faced by the authorities responsible for this network is the uncertainty of the budget necessary for maintaining it, which, in recent years, has had annual fluctuations as high as 42%. For the most part, the federal government allocates this budget amongst competing needs on an annual basis. Consequently, each year, network managers must work hard to justify the case for road maintenance expenditures.

Simultaneously, there is a need for Mexico to expand its national road network and upgrade existing roads to increase its competitiveness and the proportion of its population that benefit from good levels of accessibility. In this regard, in recent years, the federal government has invested from 1.6 to 3.2 times more on road upgrading and construction compared to the maintenance of the federal toll-free network (see Figure 1.3).

Figure 1.3: Annual federal investment in Mexico's toll-free road network.



Source: pending question to Mexico expert (as of 26 September 2018).

Consequently, whether now or in the future, all countries face the reality that road infrastructure ages and the budgets available to fund new projects and maintain existing road assets are constrained. Policies directed at extending the life of road assets help infrastructure owners to cope with this reality.

Rising and changing demand for road freight transport

The provision of road infrastructure underpins the economic and social well-being of a region, yet many countries struggle to provide sufficient infrastructure capacity to meet projected demands for road freight transport. While asset owners cannot ignore that increasing infrastructure capacity accelerates road freight transport demands, infrastructure providers do face infrastructure investment gaps.

According to 'baseline' predictions described in an Outlook on transportation trends by the International Transport Forum (ITF 2017), the global demand for road freight transport will experience a compound annual growth rate of 3.2% for the period between 2015 and 2030 and 2.8% for the period between 2015 and 2050. Even though the rates of growth vary between regions, policy makers around the world need to pay more attention to the long-term impact of trucks on road infrastructure.

While overall growth in demand for road freight transport is broadly accepted, the dimensions of this demand in the future are more difficult to characterise. Consequently, the effective management of road assets must consider not only overall growth in demand, but also the changing nature of this demand. The following points illustrate this complexity.

- **The geographic distribution of freight demand will continue to evolve.** Generally speaking, developing economies will experience more rapid growth than developed economies. Infrastructure capacity constraints will be experienced at key freight hubs (e.g., ports, distribution centres), in urban areas, and within inland networks. It is therefore important to target infrastructure investments at locations and regions likely to experience growth in freight demand.
- **The modal distribution of demand is complex.** Numerous economic drivers (e.g., price, service), commodity-related factors (e.g., commodity density, value), and geographic characteristics (e.g., distance between origin and destination, network density) influence a shipper's mode choice. Understanding how these factors affect the use of road infrastructure will enable policy actions that extend the life of road assets.
- **Truck transportation demand is multi-dimensional.** Trucks carry a wide range of commodities (from dense aggregates to high-value, time-sensitive products) over varying distances (from short intra-urban trips to long intercity trips) using different truck configurations. Understanding these dimensions influences how assets can be effectively managed to meet road freight transport demands.
- **Novel logistics trends continue to emerge.** These include the development of inland ports, hub-and-spoke distribution systems, on-line shopping and small package delivery, all of which place new and different emphases on where infrastructure investments are most urgent. Should government invest in urban or rural assets? Should government make an investment to increase the load capacity of a bridge (thereby enabling heavier vehicles) or to improve the travel time reliability of truck trips to and from an airport (thereby enabling more efficient deliveries of small package freight)? Effective consideration of these questions helps to ensure that the investments made in road assets today will meet future truck transportation demands.
- **Road freight transport is becoming more automated.** The automation of road freight transport and the digitalisation of logistics systems influence how road assets deteriorate and offer new ways to manage this influence. For example, truck platooning may offer an ability to decrease truck headways (thereby reducing operational capacity requirements), but this may exacerbate pavement rutting (if all trucks in a platoon follow the same track) and may increase the

likelihood that multiple trucks simultaneously impose loads on a bridge span (thereby increasing a bridge's structural capacity requirement). Simultaneous consideration of these issues gives rise to new asset management challenges and opportunities.

Understanding road freight transport demand is critical for mitigating the deterioration of road assets caused by trucks. This understanding enables policy makers charged with managing road assets to develop policies that are responsive to current and future road freight transport demand and that appropriately regulate and influence this demand.

Data-driven road infrastructure provision and data as an asset

The collection, verification, and analysis of good-quality data and the digitalisation and application of information comprise the foundation for managing ageing road infrastructure in the context of ever-changing demand. For example, pavement and bridge management systems rely on a well-defined strategy supported by physical condition data, current and future truck traffic and loading data, climate data, and treatment-related data to guide infrastructure investment decisions. Data and information technology needs will intensify as agencies seek to become more proactive, systematic, and strategic in the management of their road assets.

The importance of data within the provision and maintenance of road assets has motivated many transportation agencies to consider data itself as an asset. This emerging perspective creates both opportunities and challenges. New technologies and more advanced computational capabilities enable the collection, processing, and storage of more data than ever before. However, translating these data into useable information that supports effective and timely decisions remains elusive. Technical and institutional challenges occur when attempting to integrate data across diverse platforms. Increasing quantities of data do not always coincide with improved data quality. Privacy concerns pose barriers for data sharing and use. Questions remain about what, where, and when measurements should be made, the thresholds that trigger actions, and the types of actions that should be taken. More determined efforts to manage data are needed to overcome these challenges and enable these data to be used more effectively to manage physical road assets.

Approach, scope, and structure of the report

- This report approaches the development of policy options from a systems perspective—a perspective that acknowledges the complex and interactive nature of various influencing factors, identifies possible trade-offs between alternative courses of action, and highlights issues that policy and decision makers should consider. To provide structure within this perspective, the report presents policy options within three demand-oriented categories. **Demand-responsive policies:** Policies within this category aim to better align the planning, maintenance, and management of road assets with the current and projected use of these assets by trucks. As illustrated in Figure 1.4, these policies are foundational and enabling for subsequent policies that aim to regulate and influence road freight transport demand. Traditionally, the management of road assets occurs within the domain of civil engineering. Within this context, considerable improvements have been made in better utilising financial, human, and technological resources to plan, design, inspect, and maintain road infrastructure. Indeed, current practice has evolved from the concept of reactively managing one's assets (often within a single asset class) to the more holistic concept of asset management throughout the asset's lifecycle and across asset classes. Chapters 2 and 3 of this report discuss these topics in further detail and develop policy options within a demand-responsive context. Asset deterioration related to construction methods, materials, and environmental exposure is beyond the scope of this report.

- **Policies that regulate demand:** Policies within this category focus on developing more effective regulation of truck transportation—including the management of restricted access to specific parts of the road network—and ways to improve compliance with these regulations. While infrastructure protection is commonly cited as a reason for establishing and enforcing regulations, the pursuit of regulatory compliance typically occurs outside the asset management domain. Chapter 4 discusses these topics in further detail, focusing on policy options that concern regulations about vehicle design, infrastructure capacity, the interaction of trucks and infrastructure, risk management, and infrastructure cost-recovery. Chapter 5 presents contemporary compliance management strategies and discusses how these strategies could be used to manage road assets.
- **Policies that influence demand:** Policies within this category attempt to influence transport and logistics behaviours—both in real-time and in the longer term—and thereby slow down the process of deterioration of road assets by trucks. As new technologies emerge, opportunities arise to more purposefully direct truck transportation to avoid undue wear and damage of road assets. To our knowledge, these policies have seldom been thoroughly considered as opportunities to extend the life of road assets. Chapter 6 of this report discusses policies for actively managing truck traffic and Chapter 7 presents policy options to prolong asset life by influencing road freight transport demand.

These three core options are visualised in Figure 8.1 in the summary provided in chapter 8.

While these categories offer a useful structure to the policies presented in this report and portray a broadening of perspectives from traditional civil engineering approaches to more demand-oriented strategies, we acknowledge that the progression between these topics is not strictly linear. Moreover, the categories are not entirely independent, as certain policies contain elements from more than one category.

Each of the subsequent chapters comprises a problem statement and an overview of current knowledge and practice, with the exception of chapter 7 that has a different layout, but is based on the same essence. Stemming from this, each chapter recommends policy options and offers conclusions. Each chapter also contains case studies that highlight best practices and unique issues faced in various countries around the world. The final chapter of the report summarises key conclusions and recommendations.

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CHAPTER 2

Applying a pro-active and data-driven approach to maintenance of infrastructure

Problem statement

Road authorities and policymakers face complex choices throughout the lifecycle of road infrastructure. Planning, design, construction, operation, maintenance, rehabilitation and more expansion of infrastructure than ever are long-lasting processes affected by increasing population and traffic loads and changing climate. Under such circumstances future needs are difficult to perceive. As discussed in the previous chapter, a significant increase in road freight movements is expected in coming decades. This translates into a growth in truck traffic that consequently contributes to wear and damage of road assets. This is even further intensified by trucks that exceed the legal load limits: load limits that were the bases at the design stage of road assets. The percentage of overloaded trucks varies per country depending on enforcement policies, road class, truck type etc. but it may reach as high as 30% of the total volume of truck traffic. While it is challenging to determine the exact consequences of overloading, some research studies suggest that with 20% of vehicles overloaded pavement service life may be reduced by 50% (Rys, Judycki, Jaskula 2015).

The complexity of maintaining road assets and the relation to ensuring safety and meeting anticipated mobility demand is often underestimated. Long development times, data gaps, lack of knowledge and experience and administrative framework conditions can complicate the management of maintenance work. Forever-open infrastructure is taken for granted, while the availability of infrastructure, without major interventions, can be in contradiction with the demands of increasing transport.

Despite many advances in the areas of quality of damage recognition and its assessment and of selection of appropriate maintenance planning, in today's road administrations this is often still geared by the most accurate possible detection of recognisable distress. In this classical reactive approach the already occurring damages are the drivers for the maintenance actions. Taking action reactively could have significant unfavourable consequences for the owner, users and environment. In other words, any maintenance actions in this approach are, by definition, performed on damaged infrastructure which typically corresponds to sub-optimal cost to benefit analysis for the owner, uncomfortable and unsafe driving conditions for the users and finally increased emissions for the environment. Old, heavily loaded and already damaged road networks often cause resource bottlenecks in particular as they require heavy and time-consuming maintenance actions which affect other maintenance operations and influence traffic safety and mobility. Such an approach is not sustainable and should be avoided by network administrators in order to mitigate financial and environmental burdens for future users and indeed generations. Thus there is an urgent need to replace a traditional reactive approach with a proactive approach to maintenance.

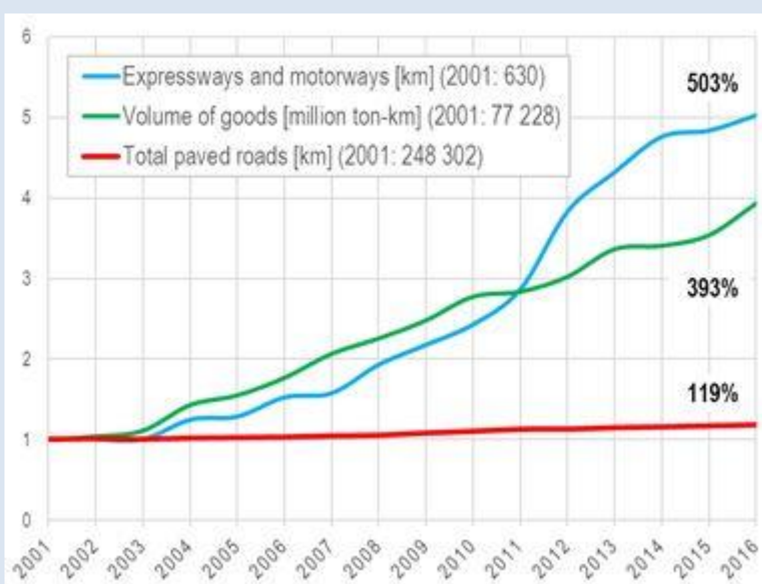
Overview of knowledge and practice

Today's typical reactive approach towards maintenance of pavements and bridges is based on regular surveys of asset condition. Such studies should ensure early and accurate detection of recognisable distress due to normal wear and tear. Normal wear and tear includes the impact of the passage of thousands of regular vehicles, and damage caused by regular weather patterns, degradation of materials over time and damage from extreme events, such as earthquakes, flooding, collisions between vehicles or passage of extreme loads. Maintenance approaches are usually integrated into evaluation and management systems, typically in form of pavement management systems (PMS), bridge management systems (BMS) or, in some countries asset management systems (AMS) decision-support platforms.

Box 2.1. Increase in traffic volume and road network in Poland

Poland is an example of a diversified road network. Since the early 2000's there has been a tremendous expansion of expressways and motorways at a national network level. Secondary and local network have also expanded but to a much lesser degree. At the same time, the volume of goods moving across the Polish road network has increased significantly reaching one of the highest levels among all European countries. These developments create a maintenance challenge for road administrations due to expected further growth in freight movements and associated wear and damage to road infrastructure. In order to manage road network under such variable conditions and still provide appropriate level of service (LOS), road administrators must reach beyond traditional reactive strategy and introduce, at least partially, proactive strategy for newer networks while maintaining and closing gap with the reactive strategy for older networks. This mind shift is necessary to avoid problems with ageing infrastructure like many developed countries are facing nowadays.

Figure 2.1: Road network and traffic volume growth



Source: Central Statistical Office of Poland (2018).

Pavement maintenance

As distress mechanisms do not all develop at the same rate, the frequency of surveys for pavement condition assessment varies from once a year to every four or five years. The condition of the top-layer of pavements is monitored, preferably at traffic speeds to minimise traffic disturbances. Common characteristics used to calculate performance indicators are pavement longitude and transverse evenness or rutting (to ensure safety), skid resistance (to ensure safety in curves and on slopes), noise levels and surface deterioration such as cracking and stone loss. The recent tools (PIARC, 2018) and reports (Wright and Benbow, 2016; PIARC, 2016) provide state-of-the-art reviews of techniques for pavement condition assessment. Parameters of physical pavement condition are calculated from survey data. The condition parameter values are often displayed graphically, for example in special heat maps (a graphical representation of data where the individual values contained in a matrix are represented as colours) that indicate risk and time left to organise maintenance. Such maps give an overview of the current condition of the road network and provide the basis for planning of maintenance. The evaluation of a maintenance and renovation strategy for a certain road section is typically done with a cost-benefit analysis (CBA) of the maintenance strategy over the full analysis period (typically 5-30 years, sometimes even further). As an alternative, some countries use a simple decision-tree approach where maintenance activities are selected based on the current values of pavement condition parameters and other criteria such as road class, traffic level, and location. It should be emphasised that these approaches are fundamentally reactive since they do not proactively address future pavement deterioration and are based primarily on the current condition. They are also unable to properly account for future challenges such as shifts in traffic patterns on the network level and weather changes. Such reactive approaches, specifically in the context of increasing truck traffic, are not feasible and should be replaced with a proactive approach in which risks and uncertainties can be managed and addressed ahead of time.

Information and analysis on the condition of top-layer pavement is often complemented with the bearing capacity information of the whole pavement structure. Such information is typically collected less frequently, partly destructive (by taking cores) and at discrete locations. In the last decade, technological developments have allowed collection of information on bearing capacity more regularly and with non-destructive-techniques to traffic speed. An example of such a technique is the Traffic Speed Deflectometer Device (TSDD) with more than ten devices currently operating on different continents and in countries (i.e. Poland, Germany, the United Kingdom, Australia, Italy, China, the United States of America).

Bridge maintenance

Bridges are designed to last for 75 to 100, or even 120 years in comparison to 5 to 35 years for pavements. They are not supposed to fail, as this may cause loss of life. Thus most countries pursue bridge inspection practices, with regular visual inspections taking place every year or every second year and more thorough inspections every five or six years. Towards the end of their design lifetime, when optimal measures to extend their service life are sought, the tests and monitoring procedures on bridges get more frequent and complex. In those stages, the most beneficial monitoring techniques are measurements of actual traffic loading and of structural behaviour under traffic loading, to measure reserves that otherwise could not have been considered in the analysis. Various tests to assess characteristics and degradation processes of steel and concrete can also vastly improve the calculations. Recommending the optimal maintenance measures (from do nothing, to repair, reconstruction or replacement) requires adaptive inspections and test procedures and should include assessment of future risk on the safety and cost effectiveness of the proposed measures.

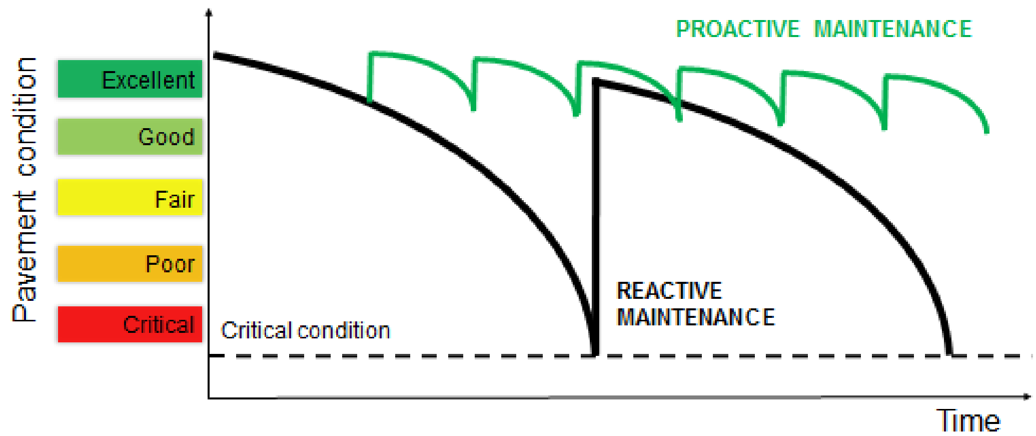
To determine their actual structural safety, the owners and operators of road networks should evaluate bridges against their specific situation related to actual capacity and loading. This raises questions of quantifying possible reserves in loading, in particular traffic, and behaviour of the structure (construction details). Unfortunately, today's practice with respect to bridge management and maintenance policies is often based on current condition (deterioration) only which results in unnecessary spending for strengthening and replacement of bridges. Instead, the infrastructure owners should benefit from collecting structural and traffic data, which, when associated with advanced assessment techniques and appropriate modelling and economic analyses, would spare many bridges the most severe rehabilitation measures and load restrictions. The important bridges with high traffic volumes are in some cases already monitored and proactively maintained in order to avoid major damage. If restoration is not possible, the bridge is replaced.

Proposed solutions for pavement and bridge maintenance

Today's predominantly reactive approach towards road maintenance planning should be replaced with a proactive approach that would integrate appropriate preventive measures to address future challenges and risks. In proactive maintenance strategy, damage growth is anticipated and often predicted so appropriate actions are taken ahead of time, even before any signs of damage are detectable (see Figure 2.2) (Zofka, 2018). This is especially needed now because of expected increase of road freight and consequently an unpredictable increase of trucks with abnormal loads that cause premature failures of road assets. Since this is a fairly new concept in road maintenance, it apparently requires additional knowledge and experience. There is a need for the advanced algorithms for stochastic forecasting of wear and capacity evolutions, and for relevant supporting information. This information goes beyond the existing databases used today as key inputs for decision making thatcontain data on traffic volumes and climate or damage inventories. In this context the digitalisation of the transport infrastructure sector, including machine learning, neural networks or artificial intelligence, will play a key role.

Proactive maintenance strategy is the ultimate goal but realistic transition scenarios consider co-existence of both proactive and reactive approaches, especially for the aged networks that may be beyond the critical point of preventive actions or where there are plans to allow longer and heavier vehicles. In the long term, proactive maintenance should become a standard practice since it supports effective network management, with lowest agency and social costs as well as the smallest environmental footprint.

Figure 2.2: Comparison of proactive vs. reactive maintenance



Source: Zofka (2018).

In contrast to traditional approaches, proactive maintenance is not yet a common practice, but this approach is gaining more and more interest among road administrations. This includes reliability or risk-based approaches to support condition assessment and maintenance management. Taking the risk as a key indicator into account, an optimised prioritisation can be achieved to ensure a desirable level of service. It is to be expected that these reliability-based approaches will enable the road infrastructure to be maintained or controlled via prioritisation and scenario building, whereby the available resources (budget, personnel) can be used optimally.

A risk analysis is comprised of the risk identification and the risk assessment, both for individual structures as well as for the interdependencies within the road network. Risk-based cost-benefit analysis should not only account for direct agency costs but must also include various social and environmental aspects. Reliability analysis and stochastic elements allows addressing future uncertainties and challenges, thus maintenance activities can be planned with a proactive and justifiable approach.

Implementation of the proactive approach requires further research since the current management practices do not support all required features. While a proactive approach is new to road asset management, similar approaches exist in other industries. Therefore, technological knowledge transfer of the potential developments from other fields to the road maintenance sector is of importance.

A key challenge with regards to proactive maintenance is the availability of comprehensive and reliable databases for verification and validation of stochastic models. Necessary information is often missing and/or proper quality control mechanisms are not in place. Without reliable information and appropriate quality of data models predictions and further inputs into decision support algorithms are biased and may lead to negative feedback from the users. Setting good procedures now with self-assessment feedback loop based upon correct Key Performance Indicators (KPIs), will create a self-improving environment and motivate agencies to further improvements. This is particularly important when considering upcoming digital developments and artificial intelligence (AI) applications. In the near future, a concept of big data will become a reality in road asset management and then data becomes an asset by itself.

 POLICIES TO EXTEND THE LIFE OF ROAD ASSETS © OECD/ITF 2018

Box 2.2: Pavement preservation initiative in the United States

Since the early 1990s, Federal Highway Administration (FHWA) in the United States has been actively supporting the pavement preservation concept. At that time, FHWA noted that huge infrastructure investments done in the past few decades require more than just reactive maintenance. In order to alleviate compiling burden of aging infrastructure several initiatives were implemented including the National Centre for Pavement Preservation (NCPP) and numerous research projects. On the legislative side, the pavement preservation concept was placed in two recent federal acts, namely MAP-21 (Moving Ahead for Progress in the 21st Century) and FAST (Fixing America's Surface Transportation). This requires state Departments of Transport (DOTs) to include consideration of pavement preservation as part of their long-term business practices while seeking support from the federal government. FHWA and the federal government clearly recognise that pavement preservation will benefit the economy (by providing more effective management), lead to life extension of pavement assets, and will provide a sustainable solution to pavement maintenance.

Box 2.3: A German initiative to increase the reliability of transport infrastructures

The transport network in Germany is based on infrastructures that have been in use for a long time and which require continuous maintenance. The growing age of bridges and other civil engineering structures, combined with the rising loads during their period of use increases risks in terms of reliability. Previous maintenance strategies pursue a damage-based, reactive approach which, due to the size of the problem, is no longer able to guarantee the availability of transport infrastructures to the required extent on a long-term basis. The traditional procedures should therefore be supplemented by risk-based procedures and behaviour models, which also incorporate the damage that is not (yet) visible. In 2016, seven departmental research facilities and executive agencies of the Federal Ministry of Transport and Digital Infrastructure (BMVI) formed a Network of Experts. The objective of work is to focus on the reliability of infrastructure. This method permits a holistic view over the entire life cycle, and can take complete consideration of specific aspects for the structure, such as load-bearing capacity (utilisation level), usability, planned residual service life, possible changes of use (including adjusted traffic load models) as well as vulnerabilities at network and structure levels. This is the basis for evaluating infrastructures comprehensively, by developing and implementing the best maintenance strategies. The reliability-based approach should give road authorities access to well-founded, information-based statements on the reliability of the transport infrastructure combined with an optimised utilisation of the service life.

With respect to bridges, proactive maintenance starts with timely fixes of small defects which can quickly grow into major damages that are expensive to repair and seriously affect bridge capacity, which may result in lower permitted maximum vehicle weights and reduced transport efficiency. Typical examples are failed drainage pipes or waterproofing membranes that allow salted water to spill over the structure, which accelerates degradation processes of concrete and steel.

It has been stressed above how challenging it is to derive objective risk related decisions that support proactive maintenance. On bridges these decisions require reliable information on structural capacity and loading. Statistically relevant data in the area of bridge capacity, which changes (degrades) over time, is rarely available. Moreover, influence of measurable deterioration processes on reduction of capacity is difficult to correlate and is as a result not part of current practices. On the other hand, collecting actual traffic loads data by weigh-in-motion systems provides sufficient information to reliably model and predict evolution of traffic loading. This can not only keep deteriorated bridges in service, as their reduced capacity may still be well sufficient to carry the existing and forecasted traffic, but is also beneficial in the perspective of longer and heavier vehicles, whose influences (bending moments, shear forces and local stresses in case of fatigue of steel structures) can be incorporated in load modelling. Finally, monitoring the behaviour of bridges under heavy traffic often exhibits lower load effects than calculated with analytical models. In conclusion, following the evolution of structural condition, traffic loading and bridge behaviour under loading not only provides valuable information for proactive maintenance, but potentially allows heavier and longer vehicles to cross bridges.

Box 2.4: Life expectancy of bridges in Australia

With respect to bridges, the demand for more freight and thus longer and heavier vehicles raises certain issues. For example, the Australian B-double applies 47% more loading but it is carrying 58% more payload than a regular 5-axle semi-trailer, so it applies significantly less loading per tonne of payload moved. The positive effects extend to short span bridges as they are only loaded by one or two axle groups at a time.

With medium span bridges, loaded by one full vehicle per lane at a time, the situation gets more complicated. The B-double will apply 47% more load on the span than the semi-trailer, yet the resulting bending moments and shear forces increase far less due to the greater vehicle length. However, in cases of fatigue of steel, the bending shear stresses per tonne of payload will be higher for the B-double.

Box 2.5: Bridge assessment practice in Slovenia

In Slovenia traditional bridge inspections revealed that almost 20% of all bridges from the Slovenian national road network were in bad or unacceptable condition. These primarily old and deteriorated structures were constructed before the modern design codes and were lacking information about their design and construction details. The results of safety assessments showed that when considering realistic traffic loading on Slovenian roads, evaluated from extensive weigh-in-motion campaigns, 77% of questionable bridges were proven safe even when simple analytical tools were used and conservative assumptions about the material characteristics and bridge behaviour were made. Performing higher level of analysis on the remaining 23% of bridges, which included material tests and measurements of their behaviour under traffic loading (influence lines, load distribution and dynamic amplification), less than 5% of bridges that required the severe measures, first immediate bridge postings and then strengthening or replacements. Financial benefits of implementing such methodology, compared to using the traditional design rules for assessment, were estimated in tens of millions of Euros.

Analyses also demonstrated that most of these bridges could safely carry longer and heavier vehicles similar to the B-double from the Australian example in box 2.5.

Conclusion and recommended policy options

1. Introduce a step-by-step plan for a proactive approach for the maintenance of road assets as it has become critical to ensure a robust network and efficient cost management vis-a-vis increased road use by trucks and climate change impacts. To achieve this, the road asset owners and managers should:
    a. Create the foundations for proactive maintenance to ensure sustainable investments for the future. The competition for scarce financial resources should not be at the expense of research and developments that could make a significant contribution to solutions in the future.
    b. Improve interaction with policy makers in order to raise awareness of the consequences of delayed or postponed decisions and the need to invest in long-term data bases to provide insight into these risks and considering data as an asset when formulating budgetary needs.
    c. Introduce educational initiatives that focus on comprehensive reliability-centered maintenance (RCM) and include various risk-based elements into cost-benefit analyses such as technical, social and environmental aspects.

2. Build a proactive, data-driven approach to the maintenance of road assets which models development in demand and traffic and anticipates growing demands on the network. For trucks this will translate into a higher level of service (LOS), expressed in terms of traffic safety, road capacity, accessibility, user mobility and finally ride quality and comfort. To achieve this, the road asset owners and managers should:
    a. Follow one of the available guidelines with the implementation steps. They will start with the overall goals and proactive strategy of an agency. The next steps will analyse the gaps and suggest the necessary changes in the organisational architecture; in the transportation asset management plan (TAMP); and finally in required processes, tools and systems.
    b. Implement policies that promote cyclic data collection on road asset condition. Set up proper frameworks to enforce reliable quality assurance of processed data. Promote linkages between various data sources, such as construction, climate, weather and traffic data which is necessary for proactive maintenance. Follow developments in digital technology and support new concepts such as big data, smart data and artificial intelligence that in the near future will take a greater role in the decision support for maintenance planning.

Road maintenance on the basis of diverse damage detection technologies is a common practice worldwide, often based on typical reactive approaches. A remaining problem in traditional approaches is that the damages already occurring are the main drivers for the maintenance actions. This is a major reason for integrating preventive measures into maintenance planning which is a baseline feature of the proactive maintenance strategy. In this strategy, damage growth is anticipated and appropriate actions are taken ahead of time, even before any signs of damage are detectable. A particular challenge with regards to proactive maintenance is the availability of comprehensive and reliable databases. In the long term, proactive maintenance should become a standard practice because it optimally supports an effective network management that is able to meet changing circumstances.

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CHAPTER 3

Advancing asset management

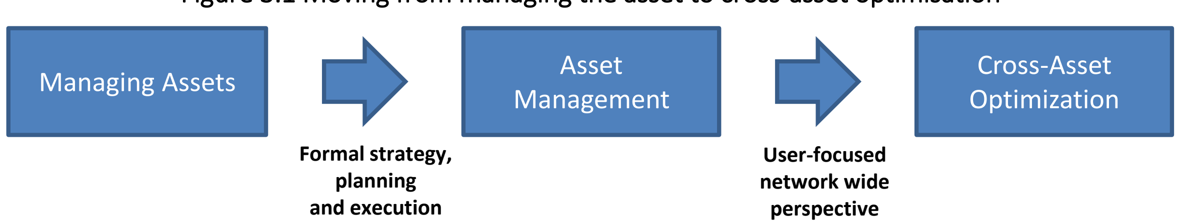
Problem statement

Of course, all road organisations manage their assets conscientiously, but they may not all use a formal asset management process to achieve the desired results. Maturity levels concerning asset management practice varies considerably among road organisations and although the appropriate levels of asset management differs between road organisations, one can argue that continuous improvement is important to extend the life of road assets. There is now a recognised and well-established asset management process employed successfully in many countries for motorways and other infrastructure, increasing the efficiency of resource utilisation and sustainably extending the lifetime of road assets.

The main direction of evolution is from "managing each asset" separately to systematic and formal asset management across the network. The asset management challenge for a road organisation transcends the level of the single asset. Road and other transport assets become increasingly interdependent at various geographical scales and are reliant on interregional and international passengers and, particularly, freight flows. These interdependencies are intensified by technological advances and requirements for improvement of capacity due to rapid urbanisation and the aging of infrastructure networks. Hence, there is an increased need to consider cross-asset optimisation (CAO) strategies in infrastructure planning.

Optimising maintenance cycles across assets (stretches of road, bridges, tunnels, electromechanical equipment, etc. is a complex task when considering different life cycles and risk levels. A lack of awareness or capabilities may result in different problems. Managing assets for subsystems may result in sub-optimality at the system level. Roads may be over- or under-dimensioned, because of a lack of knowledge of their usage pattern. The main planning objective can be expressed as achieving high standards of operational performance and enhanced accessibility across all regions in each country, through cross-modal cooperation and seamless network integration. Although national practices in asset management vary widely, systematic and explicit implementation of CAO practices has not yet taken place anywhere. It is worthwhile to look at the current practices which could support a system wide view on asset management and help to connect CAO to mainstream activities. Figure 3.1 shows the reasoning behind increasing maturity of asset management processes that is applied in this chapter.

Figure 3.1 Moving from managing the asset to cross-asset optimisation



In summary, there is a need for the development of asset management and CAO approaches to address opportunities for system-wide efficiencies and an improvement alignment between individual network components. With the rapid digitalisation of roadside and vehicle systems, many opportunities are now available to implement advanced monitoring and management systems, which can support system-wide effective and efficient asset management. Responding to these needs and anticipating the opportunities mentioned, this chapter takes a look at current and upcoming asset management practices including CAO. We discuss conditions that influence these practices using examples from different countries and continents.

Overview of knowledge and practice

The ISO 55000 standard defines asset management as follows: "Assets, and value realised from them, are the basis for any organisation delivering what it aims to do. (…) It involves the coordinated and optimised planning, asset selection, acquisition/development, utilisation, care (maintenance) and ultimate disposal or renewal of the appropriate assets and asset systems."

The World Road Association (PIARC) presented its new online manual on road asset management in 2017. This tool is aimed at national and international decision-makers in the field of road transport. The manual contains important information and data for a better understanding of all aspects of road asset management. It covers the topics of management, data and modelling, planning and application. It provides guidance on how to use the principles of asset management to achieve a more efficient approach of maintaining road infrastructures, and to support the implementation and ongoing development of road infrastructure asset management. The manual builds on advances in asset management techniques, including manuals from several countries. It also offers a wide range of recommendations, from the techniques available to appropriate organisational strategies and includes case studies of successful practical experience in implementing asset management.

The asset management framework presented in this manual focuses on infrastructure management for the entire lifetime of assets, including timely conservation measures and risk and risk management considerations, in the short- and long-term. At last, this management approach can also provide a better understanding of the contribution of road infrastructure to economic growth, better justify funding needs and better supporting communication with stakeholders on the needs of national and local road networks. The online manual is available at: https://road-asset.piarc.org/en.

In addition to the online-manual, PIARC is supporting the Highway Development and Management Software HDM-4. HDM-4 is a software package and related documentation that serves as a tool to analyse, plan, manage and evaluate road maintenance, road improvements and investment decisions. It is also used for road infrastructure programming, project analysis, and research and policy studies. Further information on HDM-4 and contact information is available at: http://www.hdmglobal.com.

Recently, the Conference of European Directors of Roads (CEDR) produced a report on a requirements specification for an integrated, effective management system for asset management, as specified by ISO standard 55001 (see CEDR, 2017 and the ARISE webpage on www.cedr.eu).

An important step in asset management is to combine the data of different assets and determine an optimal strategy and timing for maintenance work. On a project level this can be as simple as combining a major bridge maintenance and the structural maintenance of the pavement before and/or after the bridge, thus reducing both agency and social costs. To do cross-asset optimisation on a network level, more efficient tools are needed.

Over the last decade, European Road Authorities procured research to address this issue, first under the umbrella of Eranet Road and since 2012 via joint research calls organised by CEDR. Three research projects have addressed cross-asset optimisation in some way or another, most of the time resulting in a proof-of-concept.

The ASCAM project (Asset Service Condition Assessment Methodology) focused on the End User Service Levels safety, traffic delay/network availability, risk, cost and noise. Unpredictable risks were modelled with the Monte Carlo simulation. Three types of asset class were considered in the ASCAM model: pavements, structures and road equipment. The evaluation of risk is included but is revisited in more detail in later projects such as the Cross-Asset Risk Assessment (X ARA). However, ASCAM does describe the process of developing an EUSL-driven asset management system and the main steps to be taken.

PROCROSS addressed the challenge of how to optimise all maintenance activities across different sub-assets, to deliver the expectations and requirements of all stakeholders. The proof-of-concept model brought together data related to assets such as pavements, bridges, tunnels and noise barriers. A cost-benefit model was applied as the optimisation tool, in an iterative process, under a range of budget constraints. The optimisation analysis reflected top-down and bottom-up approaches.

The X ARA project (Cross-Asset-Risk-Assessment) developed a comprehensive risk assessment framework including a set of guidelines for the network level assessment of asset risks and impacts. The model takes into account high-level external variable factors affecting the different assets in an ageing road infrastructure, such as climate change, asset performance, funding/politics, demand (traffic), macro-economic and social factors. For each asset a risk matrix has to be developed based on the condition of the asset to calculate the risk for each maintenance section and for the total network.

In addition to the 2011 American Association of State Highway and Transportation Officials (AASHTO) Transportation Asset Management Guide, the U.S. Department of Transportation, the Federal Highway Administration has developed an approach to risk management called Risk-Based Transportation Asset Management. The NCHRP study of Maggiore et al. (2015) provides guidelines for resource allocation and impact assessment of investments across different types of transportation infrastructures assets. The effort included the inclusion into the guidelines of investment risk as a main parameter for decision making.

Conclusion and recommended policy options

Advancing asset management practice

The first main recommendation is that road organisations strive for continuous professionalisation in asset management using recognised maturity models, building development plans and backing these up with sufficient resources for development. The move for a road organisation towards systematic and formal asset management practice is not a trivial one; it is an organisational transition that requires major investments and time. Volker et al. (2011) present a maturity model for infrastructure asset management systems and explain the complexity of changes in strategy, planning and operational management practices, together with investments in hardware, software, institutions and even cultural aspects. There are several practical guides for organisations to transition towards asset management, as presented in the above section. They explain further how the basic requirements for asset management systems are evolving. Also they discuss the changing context of asset management, where serving the road user and managing its behaviour is becoming more important. They provide support for innovative, integrative approaches, recognising individual life cycles, interdependencies between assets and a need to cater for heterogeneous demand.

Cross-Asset Optimisation

The second main recommendation involves the extension of asset management across assets, towards cross-asset optimisation (CAO). For road organisations that have mastered asset management practices, integrating these practices across assets is the next challenge. CAO requires comprehensive and consistent information across the entire network and approaches to allocate investments and build maintenance programs at the network level. Also, prioritisation across a network is needed to allow projects to be bundled and economies to be achieved. Moreover, network level asset management should provide opportunities to maintain the network depending on actual user demands (volumes and quality requirements) -- all sections of the network have to respond to changes in door-to-door flows together. With CAO practices in place, programs can be aligned across an entire corridor or network, and one can also apply access policies that require a guaranteed service quality across a larger part of the system. This can open the door towards a joint optimisation of infrastructure demand and supply. The move to CAO transcends the responsibility of departments of a road organisation, and even the responsibilities of different organisations. Cross-jurisdictional governance, e.g. at corridor or network level, becomes a key component (we elaborate on this further below). Box 3.1. provides three examples of national planning or asset management approaches from different countries.

Box 3.1: Global examples of national system-wide approaches relating to asset life.

Standardised guidelines for infrastructure design: India's HCM

The paving of India's roads is developing quickly, by about 4% per year, but cannot keep up with the rapid motorisation (number of vehicles increasing at 11% per annum since 2001 (MoRTH, 2017). These growths need to be systematically and scientifically addressed in the overall planning system to cater for the future year conditions and dealt with proper transport policies leading to optimisation across assets at the national level. A recent development is the production of an indigenous highway capacity manual (Indo-HCM) provides standardised support for the design of road facilities ranging from single lane roads to multilane highways and expressways, roundabouts, signal controlled intersections and pedestrian facilities (CSIR-CRRI, 2017). This manual will be an extremely useful document in the hands of Highway Engineers, Planners and Policy/Decision Makers during road widening projects, maintenance of road infrastructure including assets and/or for traffic and transportation planning of a city. As it uses standards for measurement, analysis and design that can consistently be applied throughout the country, it can support the development of CAO.

Integrative transport planning: the case of Greece

In Greece, as in several countries worldwide, there is an increased need to establish an integrated strategic planning and a system-wide governance of road and other transport assets. This holistic system of transport asset planning and management should review current failures to coordinate relevant policies at different tiers of government and types of interrelated infrastructure investment (Tsekeris, 2014, 2016). As the country appears to exit the long-term persistent recession, it is projected to experience an international (transit) trade-led growth as the principal freight hub of Southeastern Europe. The main developments that will help to address the above challenges include:

- A National Transport Plan, which will provide a strategy for the sustainable development of the transport infrastructure and services by efficiently combining all modes over the next 20 years.

- A Logistics Business Park Network Development Plan, in conjunction with law bills about the institutionalisation, modernisation and diversification of the logistics industry.
- A Road Toll Agency, which will be responsible for distance-based electronic tolling of highway users and the collection of toll revenues, in conjunction with collecting, monitoring and processing road traffic and the implementation of the national Inteligent Transport Systems (ITS) strategy and architecture.

National economic value of assets in Japan

The main social issue in Japan is a declining and aging population. This also affects infrastructure maintenance and management,. It has required Japan to become more efficient with a limited budget. Furthermore, Japan is faced with a high risk of natural disasters, also affecting its industries' supply chains. In the infrastructure management plans, economic damage assessment of natural disasters has also become important. To deal with these challenges, it became necessary to consider full and network wide economic effects of infrastructure management. The latest research integrates economic damage assessment with conventional traffic demand forecasting models and economic models (Koike and Miyamoto, 2017). It helps to assess the contribution of local network disruptions to regional development, as well as individual infrastructure improvements. It is possible to locate critical assets and to evaluate the broader contribution of maintenance management for each road link.

Critical capabilities for the future

Supporting the above two main recommendations – the introduction of formal asset management practices and the extension towards cross-asset management – are a number of capabilities that are critical to make asset management future proof. These are outlined below.

Planning to respond to variations in user requirements

More information is needed about the expected future growth of freight flows and about their differentiation, combining geographical (location, direction of flows) and functional (user/weight classes) segmentations. Opportunities for a differentiated design of maintenance schedules will arise as deterioration and risk of failure will be predicted more accurately and priorities will be easier to set. More robust maintenance plans can be made for larger infrastructure objects that are the backbones of major corridors, if the critical links (a combination of state and loads) are addressed. Eventually, a more pro-active approach could be taken towards users of the network by smart access incentives (special provisions for heavy trucks, like parallel lanes or services, or load-dependent pricing) or access regulation (limiting access to certain roads for certain groups during times of the year) combined with a refined classification of road types depending on maintenance cost considerations. In the longer term future the development of automated highways, smart hub facilities and driverless trucks and fleets, will also affect demand and load patterns. New access management policies may be needed for new classes of vehicles when planning considers the differences between user classes and adapts asset management decisions for user groups. A primary understanding of how demand patterns will evolve and what can be done to influence them will be especially important.

Risk identification and integration

In view of the unfavourable age structure of transport infrastructures in many highly developed countries and the limited budgetary resources, additional efforts are needed to optimise and coordinate maintenance, upgrading and, if necessary, replacement. As the existing tools and methods are of limited use, there is a need for further development of infrastructure asset management with the aim of ensuring the reliability of infrastructures and of prioritising and using existing resources in a highly efficient manner.

Commonly used assessment procedures and repair strategies for existing structures are deterministic and based on the assessment of visible damages. In many cases a damage-based, reactive approach is still being pursued which is no longer able to ensure the long-term availability of the transport infrastructure to the required extent. For the future, these established methods must be supplemented by risk-based procedures and behavioural models.

It will only be possible to take a holistic view of the infrastructure life-cycle by implementing these approaches since object-specific aspects such as load capacity, planned remaining service life, possible changes in use as well as vulnerabilities at network and object level can be taken into account. Risk-based approaches make it possible to assess infrastructures comprehensively and thus achieve better maintenance and expansion development strategies. The risk- or reliability-based assessment of the structures forms the basis for a higher reliability of the transport infrastructure and, as a consequence, enables the optimal exploitation of the service life, since besides the damage-oriented condition assessment further relevant criteria are included in the assessment.

Optimal use of information technology

Digital progress can also bring significant improvements and further develop asset management systems. This applies in particular to the development direction from Big Data via Smart Data to Artificial Intelligence (AI).

Information about road infrastructure can very quickly take the dimensions of big data, i.e. that they exceed the possibilities of conventional evaluation tools due to their data volume. However, increasing the amount of available data is not an advantage in itself. Valuable input can only be generated for asset management when intelligent algorithms are applied. Big data turns into smart data. Artificial intelligence will increasingly be used to generate smart data, e.g. through machine learning, neural networks or other advanced approaches. In doing so, the number of possible sources of relevant data for asset management will increase, in addition to traditional data from the infrastructure area, e.g. through data from vehicle fleets or special sensor networks.

Although the potential of these developments is huge, their useful application in the area of asset management does not come by itself, but must be explicitly promoted. An example of this is BIM (Building Information Modelling). BIM refers to a collaborative working methodology that uses digital models of a building to consistently record and manage information and data relevant to its life cycle. This information is exchanged between the participants of the project in a transparent manner or is passed on for further processing. BIM could also be very valuable for asset management. However, today's developments are more focused on design and visualisation. Here it is important to consider the necessity of a later asset management already during the model development.

Data-driven policies are very suitable for synchronising and diminishing the gap between plans, designs and underlying objectives in road infrastructure management (ITF, 2017). Such programs as the e-CMR allow the implementation of more targeted and flexible regulatory frameworks, based on data-led market-based, vehicle-based and driver-based rules, and more efficient enforcement mechanisms based on quantifiable activity and performance indicators. By and large, new technology systems such as those related to vehicle automation, routing as a service and freight-matching platforms will directly influence the legal and regulatory frameworks of road freight transport, allowing safer operations and improved privacy protection, safety and security of data handling by the diverse actors without discrimination between them, increasing the firm revenues and reducing operating costs.

Governance approaches for cross-jurisdictional alignment

New highway governance-models are internationally required to address the increasing uncertainty around construction and maintenance costs under severe budget constraints and lending liquidity problems. In addition, the growing interdependencies of road and other infrastructure assets at various geographical scales necessitate cooperation, harmonisation and enforcement of legislative and regulatory frameworks, and shared use of appropriate technologies and best practices. In this way, possible conflicts among local-national and supra-national planning objectives and practices can be circumvented and potential sources of planning system inefficiencies and failures can be treated. There are several cases around the world of effective cross-jurisdictional coordination, within and outside the sphere of road asset management.

Box 3.2: Examples of system-wide road asset governance models and tools

United Kingdom

Highways England (est. 2015) is a government owned company responsible for managing the English strategic road network, empowered with a strong governance model that is customer-centric and accountable for its capital and maintenance decisions. It has the mandate to develop a 25-year plan, along with certain funding arrangements on a five-year basis.

Australia

VicRoads is a statutory authority in Victoria that has the full range of responsibilities from planning to delivery. The Roads and Maritime Services (RMS) in New South Wales is a corporatised delivery agency, involving annual budget allocations and commercial revenues (Bowditch et al., 2017).The Intelligent Access Program (IAP) is a national program developed by the national government and all States' and Territories' road agencies to facilitate the planning, management and collection and storage of data on heavy-goods vehicle transport. As in the case of VicRoads, sub regional governments can take joint initiatives to ensure the long-term financial capacity to meet the full costs of running their (corporatised) roads. Regional agencies such as the Roads and Maritime Services in Australia can put forward accountability standards to ensure that infrastructure assets deliver services which meet future customer needs for the benefit of the local economy and community.

The Netherlands

Coordination of planning and maintenance across jurisdictional boundaries in the Netherlands is a centuries' old practice for flood prevention. This experience can be of value for cross asset management and particularly useful for (vertical) alignment of investments to needs and of (horizontal) alignment between asset types. In order to avoid mismatched maintenance cycles for assets with different life cycles and risk levels, every trimester, all advised maintenance measures are collected in one, centrally accessible programming system This system supports finding the optimal work package by helping to integrate the optima of each object category with respect to different policy goals and future needs.

Corridor management

In several parts of the world, corridors that cross regions, countries or continents (e.g. the Maputo Corridor Logistics initiative in South-Africa, the Trans-European Network's Corridors, the Chinese One

Belt One Road Program) have developed new co-operative governance models, and in some cases even new institutions, to align infrastructure developments along a corridor. The focus of these co-operatives are on improving accessibility through infrastructure development and on operational logistic performance (services, customs, road safety) – but, interestingly, much less on asset management.

Coordination of technologies, policies and regulatory measures across jurisdictions is important for the functioning of a road network. It helps to mobilise resources, address changing requirements and ensure appropriate funding and acceptable service levels for different user groups, throughout the life cycle of the network. Note that cooperative mechanisms are not only useful for cross asset management – consider the challenges posed by climate change, which can only be tackled through alignment with water management boards.

Extend asset management across assets, towards cross-asset optimisation (CAO). For road organisations that have mastered asset management practices for individual assets (a road section or a bridge) or groups of assets (e.g. bridges, and roads), the next challenge is to harmonise and apply practices across all assets to support door-to-door trips.

This chapter introduced asset management as a well institutionalised approach, which provides systematic guidance for asset life extension. If indeed implemented this way, it facilitates the optimisation of resources to achieve required levels of accessibility and network performance. Today, formal and systematic asset management is not widely practiced, however. At the same time, the approach is becoming very well documented, including detailed guidance for road organisations on how to transition towards professional asset management. The main recommendation of this chapter is that road organisations need to invest sufficient resources to operate according to advanced asset management principles, and to further develop a continuous learning process. A second recommendation is that this practice is extended to include cross-asset optimisation. This way investments can be allocated towards those parts of the system that give the highest benefit to overall accessibility and performance. Important supporting conditions that should be kept in mind and developed to create a future-proof asset management system include (1) planning approaches to respond to variations in user requirements; (2) the consideration of risk in asset management; (3) access to advanced ICT systems and (4) advanced governance schemes for cross-jurisdictional alignment.
Internationally countries should be striving for continuous professionalisation of asset management, building development plans and backing these up with sufficient resources for development. Establish the elements of a future-proof asset management system including: 1) planning approaches to respond to variations of user requirements, 2) explicit consideration of risk in asset management, 3) access to data from advanced Information and communications technology (ICT) systems and 4) effective governance arrangements for cross-jurisdictional alignment.

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CHAPTER 4

Supportive regulatory frameworks for trucks

Problem statement

Policies to extend the life of road assets are often viewed as being in competition with truck access policies, and more broadly, in competition with regulatory frameworks for the management of trucks on road networks. Trucks are widely recognised as contributing to the ‘consumption’ of road assets at a much greater level than most other vehicle types.

The projected growth in freight volumes means that there will be sustained increases in the tonne-kilometres (t-kms) of freight moved by trucks. This forecast, coupled with fiscal constraints that impact on road asset maintenance and capital investment programmes, means alternative approaches need to be included to complement conventional options considered by policy makers and road asset managers. The 'do nothing' approach is not sustainable. The result will be an ongoing increase in the volume of truck traffic, and the potential for increased wear of road infrastructure.

Although every jurisdiction has a regulatory framework for controlling the size, weight and configuration of trucks, not all frameworks are capable of enabling different truck configurations, nor enabling the appropriate relationship with infrastructure capacity limitations. In addition, not all road infrastructure is suitable for all vehicle configurations. So there needs to be a match between vehicle configuration and access provisions to the road network.

Overview of knowledge and practice

Regulations to manage the interaction between truck design and infrastructure

In most jurisdictions, size and weight regulations have historically focussed on protecting road infrastructure from damage, rather than optimising the use and consumption of infrastructure. These regulations have typically been prescriptive and have evolved over time, with a series of incremental changes, rather than having an overall, strategic focus. There are examples in many regions where changes within these traditional regulatory frameworks have been introduced that are intended to reduce infrastructure wear per tonne of freight moved, while providing transport operators with economic gains.

Many regions have introduced higher productivity vehicles (under various names) to meet the growing freight task. By catering for increases in weight or cubic capacity, higher productivity vehicles have the potential to improve the productivity of freight movements, reducing fuel consumption, unit labour costs and reducing the number of truck trips.

Box 4.1: Longer combination vehicles and road-friendly suspensions

In Canada, longer combination vehicles (LCVs) are higher-productivity combinations that consist of a tractor and two or three trailers or semi-trailers with a combined length greater than 27.5m. LCVs have been operating in Canada for nearly 50 years. In this time, the development and application of LCV regulations in Canada has evolved considerably as regulators respond to increasing demand for LCV travel while simultaneously striving to achieve the objectives of safety, productivity, infrastructure protection, and environmental sustainability. The following image presents the three most common LCV configurations in Canada.

Figure 4.1: Most common LCV configurations in Canada

LCV configuration	Diagram of a typically-configured LCV	Axle configurations
Turnpike double		3-S2-3, 3-S2-4 (shown), 3-S2-5, others
Rocky Mountain double		3-S2-2 (shown), others
Triple trailer combination		2-S1-2-2 (shown), 3-S1-2-2, others

Source: Wood and Regehr (2017).

In Europe and Australia, road-friendly suspensions (RFS) provide additional load carrying capacity with the expectation of no increase in pavement wear. In the United Kingdom and in a number of other European countries, additional load capacity is provided for using a three-axle tractor, as opposed to a two-axle tractor for container movements (International Transport Forum, 2015).

It should be noted that some changes have been detrimental to pavement wear, such as the use of wide single tyres, which provide gains in transport efficiency through lower weight and reduced rolling resistance, but have been shown to generate increased pavement wear.

Not all jurisdictions have taken advantage of the opportunities to improve pavement wear performance of existing vehicle combinations. However, the extent to which the traditional regulatory framework can respond to the growing demand for road freight transport is limited. The additional capacity that flexible regulation can achieve through authorising high productivity vehicles for use in the right circumstances needs to be exploited.

An effective regulatory framework for trucks should set out to balance what are often competing objectives between productivity, safety and road asset preservation by reducing the growth in individual vehicle movements, while accommodating an increase in t-km transported.

State-of-the-art regulatory frameworks give consideration to five inter-related dimensions:

- Truck design.
- Infrastructure capacity.

- Management of the interaction of trucks and infrastructure.
- Regulations to manage truck safety and risks.
- Regulations to recover costs of road infrastructure consumption.

Individually or collectively, each of these approaches represents an ability to 're-engineer' the use of road assets – and an ability to deliver significant productivity gains through truck access policy – without defaulting to traditional engineering options/investments in road assets.

A brief overview of each of these inter-related dimensions are presented as follows.

Truck design

Truck design encompasses the dimensions, weights and configuration of vehicles, and may also encompass axle layout, tyre configuration (dual or single) and widths and suspension design.

Of all the design parameters, truck axle and axle group weights as well as overall weight have the most significant impact on the life of road assets. Pavement wear is primarily related to axle and axle group weight. The specifics of this relationship depend on both the type of pavement structure and the type of pavement wear and thus jurisdictions should consider what the applicable relationship is for their circumstances. For bridges and related structures, the loading applied depends on the span length spans. It will often involve more than one axle group simultaneously and for longer spans may involve multiple vehicles.

There are opportunities to reduce pavement wear through alternative vehicle configurations (as distinct from comparatively simple modifications to existing truck designs). This can be achieved through changes in prescriptive vehicle design requirements, or through Performance-Based Standards (PBS) approaches to truck design.

The basic principle of PBS is matching the right vehicles to the right roads. PBS has been implemented in Australia, Canada, and New Zealand, and is under trial in South Africa and Sweden. PBS focusses on the performance outcomes of vehicle operations. Innovative truck designs can be developed to meet requirements of specific transport tasks while still complying with a defined set of infrastructure and safety performance standards. Their vehicles do not usually generate additional road wear compared to conventional trucks, as they typically operate with the same maximum axle loads as conventional trucks but have more axle groups to carry a higher payload. In most cases, the payload makes up a higher proportion of their total weight and thus they generate less pavement wear per tonne of payload moved. The key measure is pavement wear per tonne of payload moved.

Box 4.2: Performance-Based Standards in Sweden and South Africa

Sweden

A project "Performance Based Standards for High Capacity Transports in Sweden" started at the end of 2013 to investigate applicability of PBS in Sweden. The project was completed in 2017 (Kharrazi, Bruzelius and Sandberg, 2017).

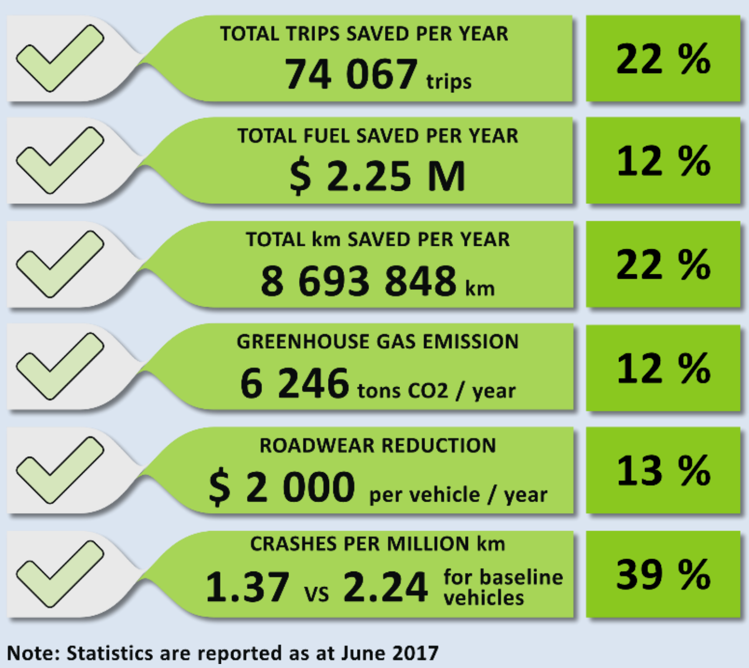
To introduce HCT vehicles in Sweden, the existing regulations need to be modified and a proper way of regulating HCT vehicles and their access to the road network should be developed to ensure that a certified HCT vehicle would not have negative effects on traffic safety, infrastructure and the environment. One approach is to use performance based standards (PBS) for regulating trucks access to the road network. A PBS project included addressing the three domains of safety, infrastructure and environment. A primary focus has been on safety and manoeuvrability.

One of the main objective of the PBS project was to investigate the applicability of PBS in Sweden with attention to winter road conditions. Thus, the safety aspects related to winter conditions were investigated, resulting in proposals for safe performance levels.

South Africa

South Africa embarked on a PBS pilot project in 2004. The first two PBS vehicles were commissioned at the end of 2007 in the timber industry. The pilot project is largely based on the Australian PBS scheme. The certification in terms of the Road Transport Management System (RTMS) accreditation scheme is a prerequisite for operators who wish to participate in the pilot project. As of June 2017, data for over 100 million kilometres of PBS truck travel had been collected. The number of PBS vehicles at that point had increased to 245. Monitoring results are summarised in Figure 4.2.

Figure 4.2: Results of Performance-Based Standards truck travel after 100 million km operations



Source: Nordengen, De Saxe, Berman, Steenkamp and Deiss (2018).

Infrastructure capacity

Infrastructure capacity relates to structural capacity and geometric capacity. The structural and geometric capacity of road infrastructure can vary significantly, and all infrastructure may not be suitable for all truck designs. Both the structural capacity and the geometric capacity of the infrastructure directly influence the extent to which new truck designs can be introduced. Infrastructure capacity, particularly of bridges and structures, may influence the maximum weights of combinations of axles based on their spacing and the maximum overall weights of trucks. For longer span bridges, multiple vehicles may load the bridge simultaneously and there may be a need for measures to control inter-vehicle spacing or other traffic management strategies.

It is also important to note that different parts of the road network may be managed by several different entities, which means that assessments and approvals may need to involve multiple stakeholders. This is particularly the case with local municipalities. There should be structured processes and procedures to assess and evaluate the suitability of infrastructure to accommodate different truck designs, which involve all relevant infrastructure managers.

There are opportunities to assess infrastructure based on broad categories, which would enable the establishment of effective networks. This avoids the challenge of performing bespoke assessments for individual truck design and/or access entitlements to the road network. For example, the Australian PBS system defines four levels of access with different pass or fail criteria for each level. If a route is assessed as being suitable for a given level, then all vehicles that achieve the performance standards for that level can be granted access.

Managing the interaction between truck design and infrastructure

A key factor with regards to the interaction between truck design and infrastructure relates to structural capacity and life. Each jurisdiction holds a pavement design guide, assumptions about the relationship between axle loads, weights and the pavement wear which results from these interactions. Infrastructure has a design life that is based on an expected level of traffic loading (including the number of axle passes and a distribution for axle loads). Underpinning this design process is a model of the relationship between axle loads and the consumption of pavement life/amount of pavement wear. These models can differ based on the type of pavement construction and the type of pavement wear.

Regulatory frameworks need to be cognisant of the load versus pavement wear model(s), which is applicable to each jurisdiction. The models for pavements differ significantly from the models for bridges. Underpinning bridge design is the need to take into account vehicle axle spacings and weights, and the size of the bridge spans. Each jurisdiction will have a bridge design code which specifies the level of loading that bridges are required to be able to withstand. These parameters need to be taken into account within any regulatory framework, and directly influence the life of the infrastructure.

Different truck designs have different on-road performance characteristics, which need to be assessed with reference to the infrastructure's capacity. This means that certain truck designs are only suitable to operate on designated parts of the road network. The performance of individual truck designs should be matched with the structural and geometric capacity of road infrastructure.

Further information about the monitoring of road and structure condition, and strategies to maintain the life of road infrastructure are presented in Chapter 2.

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Regulations to manage truck access and safety risks

The management of infrastructure and risks is crucial to the management of trucks and their interaction with infrastructure. In many regions, there is a tiered approach to the management of infrastructure and safety risks:

- General access – where trucks can operate on all parts of the road network.
- Restricted access – where trucks are approved to operate on specific parts of the road network.
- Intelligent access – where trucks are remotely monitored to provide assurance that infrastructure capacity and safety risks are being managed.

In simple terms, the intelligent access approach ensures that 'the right vehicle is on the right road'.

Intelligent access involves the use of remote monitoring of vehicles using telematics, to ensure that conditions of access are adhered to by drivers and operators, thereby ensuring that the 'right truck is on the right road'. Policymakers may elect to use intelligent access for trucks that could pose significant risks to infrastructure and safety if not operated in accordance with the conditions of their approvals. Telematics devices collect and generate data that can be used to improve compliance management outcomes.

Box 4.3: Intelligent access policies in Sweden

In a sequence of research projects, a proposal for an Intelligent Access Weight Control System has been developed. In 2009 it was observed that Australia was in the process of implementing intelligent access policies (IAP), which led to a research collaboration with Transport Certification Australia (TCA) in Australia for technology transfer. During 2013-16 an operational pilot of the IAP was performed in Sweden on High Capacity Transport vehicles.

Based on the experience from the IAP pilot, and requirements from stakeholders and from the EU and the Swedish legal environments, system specifications were proposed and published (Asp et al., 2016).The proposed system, called Intelligent Access and Control (ITK), uses already installed fleet management systems, where the on-board computer registers its GPS position every minute, axle loads, gross weight and identification of the prime mover and all vehicle modules, and reports to the back-end server of the telematics and fleet management service provider. Neither the driver nor the vehicle speed is reported. This information must be securely stored for one year and made available through a standardised interface at the back-end server for compliance inspections by the police and other enforcement agencies in a similar way as tachograph data are checked. After all identification parameters are taken away, the information must be sent to the Swedish National Road Administration for statistical purposes, e.g. calculating degree of regulatory compliance and maintenance planning. The two Fleet Management System (FMS) standard interfaces used are developed and supported by the European Automobile Manufacturers' Association (ACEA).

The differences compared to the Australian IAP system are that the ITK1 service provider (most often the vehicle manufacturer) and his hardware and software is not certified and does not produce Non-Compliance Reports. Instead the back-end server must be provided with a FMS-remote ACEA standard interface via which enforcement agencies (police and the transport agency) can download up to a one year history of actual routes and weights to compare with what is allowed.

Regulations to recover costs of road infrastructure consumption

Cost recovery models have been used to establish new or alternative funding mechanisms to fund the maintenance and investment in road assets, based on the utilisation of specific vehicle types. Road pricing reforms can establish improved links between the utilisation (consumption) of road assets, and investments to maintain and develop road assets (including tolling and toll roads).

With many different road pricing mechanisms already implemented globally, the purpose of this section is not to review established arrangements but rather to focus on mechanisms that can improve truck productivity and access.

Road pricing

Road pricing schemes can be introduced as a mechanism to

- manage demand for infrastructure;
- manage the supply of infrastructure;
- internalise external costs (such as congestion, noise, pollution).

There are three main models of road pricing schemes for policies to extend the life of road assets as discussed below.

Location-specific charging

Location specific charging typically involves a charge being applied at defined geographical location (i.e. cordons) to manage demand. Examples of location charging include:

- the London Congestion Charging Scheme;
- the Singapore Road Pricing Scheme.

Distance-based charging

New Zealand has operated a weight-distance Road User Charge regime for all diesel-powered vehicles and all trucks including trailers since 1977 (de Pont and Colgrave, 2008). The scheme is based on recovering the full cost of operating the road transport system from the users. The charging rates depend on the axle and tyre configurations as well as weight capacity and explicitly reflect the infrastructure wear attributable to the vehicles based on models of the relationships between infrastructure wear (both pavements and structures) and axle loads and vehicle weight. Thus the infrastructure costs are directly seen by the transport operator which thus influences their choice of optimum vehicle configuration for a particular freight task. Distance-based truck charging schemes are now operating in 15 European countries.

Incremental charging

Incremental charging provides a facility to require operators of trucks to pay an "incremental charge" to operate at mass levels higher than the current regulated limits. This concept can increase productivity by allowing transport operators to move the same amount of product with fewer trips. This could be beneficial on both major roads and for the first- or last-mile in the supply chain, where existing mass limits can have a significant impact on the efficiency of a supply chain.

For an incremental pricing scheme to operate, a base mass limit needs to be established, reflecting what operators pay for under established charging arrangements. Operators would then be charged an additional amount based on the extra road wear caused by carrying mass above the established mass limit.

An incremental charging framework was trialed in Australia a decade ago, but there have been no practical deployments to date – despite the availability and widespread use of telematics through the IAP and the National Telematics Framework.

Box 4.4: Road charging trial in Australia

Main Roads Western Australia (MRWA) tested the concept of charging a small number of transport companies for access to a particular area south of Perth. A trial was conducted for road trains of 36.5 metres to access the Kwinana Industrial Area, including the local government-managed Kwinana Beach Road. The trial enabled direct access from Kwinana for the movement of fuel and dangerous goods without having to use Kewdale as a staging area for road trains of 27.5 metres. The route selected for the trial started at the Kwinana Freeway and included Thomas Road, Rockingham Road and the first 460 metres of Kwinana Beach Road. The route was assessed as meeting the standards required for the trial vehicles.

MRWA worked with Transport Certification Australia (TCA) to implement a road user charging solution using vehicle telematics. The trial, which ran from 1 August 2016 to 31 May 2017, was limited to non-containerised freight transported by operators having access to a depot on Kwinana Beach Road.

Conclusion and recommended policy options

1. Adopt regulatory frameworks that treat the use (and consumption) of road assets as an economic input and measure the use of economic utility in order to improve productivity of road transport.
    a. Assess the full breadth of economic costs and benefits that can be derived. Avoid focusing only on the road asset costs, when there may be a wider range of benefits and costs to the community to be considered.
    b. Identify opportunities to reduce pavement wear through current regulatory frameworks. This could include the use of dual tyres and/or multi-axle groups. Incentives could include increased mass limits or reduced road user charges.
    c. Adopt a performance-based standards approach to vehicle design, which could enable the introduction of innovative truck combinations with lower road-wear characteristics.
    d. Adopt intelligent access policies (including the use of telematics and related intelligent technologies) which enable specific vehicle types and/or loads to travel on restricted parts of the network with suitable infrastructure capacity.
2. Implement infrastructure pricing to improve the recovery of costs and provide efficiency incentives by encouraging behavioural change in transport operators.

a. Adopt distance-based charging to improve the recovery of costs from users of road infrastructure.

b. Adopt incremental charging arrangements based on distance travelled and/or mass carried, from operators of higher productivity vehicles where these vehicles are deemed to increase road asset wear.

c. Use regulatory and financial incentives (in a voluntary policy environment) to encourage transport operators to:

    - use vehicle designs and configurations with lower road asset wear characteristics;
    - adopt higher productivity vehicles on infrastructure with suitable capacity (i.e. restricted or intelligent access);
    - adopt the use of telematics and related intelligent technologies;
    - share data with asset managers.

Significant benefits can be derived from regulatory frameworks that facilitate the interaction of vehicle design and infrastructure capability. Collaboration between vehicle designers, infrastructure managers, regulators, legislators and transport operators is critical to the success of any regulatory framework that will extend the life of road assets.

Adopting a cross-disciplinary approach contributes to balanced outcomes that are able to take into account all costs and benefits, and optimise the use of road infrastructure as an economic utility for the efficient and productive transport of goods.

Innovative approaches such as performance-based approaches to vehicle design, and the remote monitoring of vehicles with suitable capacity, can increase the productivity of road freight transport while managing road infrastructure risks.

The key challenge faced by policy makers (and legislatures) to create supportive regulatory frameworks for trucks is to avoid regulatory prescription and the imposition of barriers to innovation. Instead they should look to promote opportunities for road managers, regulators and the transport sector to collaboratively achieve outcomes which can advance policies to extend the life or road assets, while accommodating the forecast growth in road freight transport.

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CHAPTER 5

Achieving compliance with regulations

This chapter focusses primarily on approaches to achieving improved compliance with respect to weight regulations, as the level of weight compliance achieved has a significant effect on the life of road assets. This does not discount the importance of compliance with regulations which may improve (for example) traffic management or safety outcomes. Non-compliance with weight regulations also has implications for safety.

Achieving compliance with regulations is directly related to regulatory frameworks for trucks. It is important to assess the potential impact of improved enforcement policies and methods, and the consequences of these on the reduction of overloading occurrences and intensities, and from this the potential benefits for road assets.

One of the most efficient mitigation measures to limit the impact of trucks on existing infrastructure is to promote compliance of axle loads and gross vehicle weights in accordance with regulations. Overloading does induce additional wear and may cause damage to infrastructure. Current policies and methods of overload enforcement, mainly by static or low-speed weighing, in most of the world are generally inefficient. They require intensive use of human resources which is costly and not always available.

The extent to which non-compliance with regulatory requirements – in particular, axle group weight limits and gross weight limits – affects infrastructure damage should not be underestimated. The relationship between load and wear is not linear and higher loads have a disproportionately large impact on the life of road assets.

The level of overloading that occurs also influences the willingness of policy makers to introduce reforms to improve vehicle productivity. Although such reforms could enable increased weights to reduce the total number of vehicle movements for a given tonne-kilometre of freight, infrastructure managers need to have greater confidence that these higher weight limits will not be exceeded.

Overview of knowledge and practice

Monitoring of trucks by road authorities typically makes use of road-based systems and on-road enforcement personnel for compliance management and law enforcement purposes. Examples include:

- static weighbridges and road-side safety stations;
- weigh-in-Motion (WIM) sensors linked to Automatic Number Plate Recognition (ANPR) cameras (for monitoring both speed and overloading);
- intelligent access monitoring (see Chapter 4).

Traditional approaches focus on the detection of violations, and triggering enforcement based on observed breaches of regulations.

The traditional approach is inherently reactive. That is, it applies after the offence has been committed. This means that, in addition to the reactive nature of traditional approaches, it is limited by:

- a need for authorities to have personnel and systems in place to observe a breach;
- relying too heavily on enforcing the law rather than helping people to improve compliance;
- processing failures one by one, so that there is no mechanism for developing systemic solutions;
- focussing on the enforcement process, so that they sometimes fail to recognise that it is behavioural change that is being sought, not better prosecution or conviction rates (Sparrow 2000: p. 183).

An effective compliance framework for trucks should recognise the diversity of reasons why non-compliance occurs, employ multiple approaches to influence positive behaviour and compliance with regulations, and mitigate risks to infrastructure and safety.

Understanding why non-compliance occurs

Research has recognised that deterrence is not an objective quality but depends on how offenders know or understand the law and law enforcement practices. It is the perception of the law that is important, so that subjectivity becomes the focus of an understanding of the deterrence process.

An overview of the key reasons why non-compliance occurs (the understanding of which can influence the approaches taken by infrastructure managers/regulators to improve compliance) follows:

- Economic factors: Transport operators who maximise their load can gain a substantial competitive advantage over others who follow the rules.
- Opportunism: Opportunism may occur when a regulated party simply believes they can get away with not complying.
- Lack of knowledge or understanding of legal requirements: There is often a lack of understanding (or even awareness) about the law, its obligations, and how it applies to vehicle loading. However, rapid increases in the complexity and volume of new regulations can make this basic assumption unrealistic (OECD, 2000).
- Lack of ability: There may be a lack of ability to comply, which may be attributed to the lack of clarity in the law itself, or confusion due to the complex technical details of the law, or potentially to the lack of infrastructure necessary to support compliance.
- Lack of willingness: A lack of willingness to comply, which generally occurs with operators who perceive the law to have little substantive purpose in itself, or in its administrative processes.
- An open market with minimal barriers to entry: Compared with other sectors of the transport industry (such as air, rail and maritime) there are comparatively low barriers to entry for parties to enter the road transport sector. The minimal margins and competitive nature of the truck transport industry may lead to overloading.

Overview of traditional enforcement methods and technologies

Improved truck compliance with weight limits has the potential to extend the life of road assets. There are four broad categories of devices that are used for weighing vehicles and achieving improved compliance outcomes:

- Weighbridges
- Portable weigh scales
- Weigh-in-Motion
- On-board Weighing.

Weighbridges consist of a set of scales, usually mounted permanently between a steel weighing platform and a concrete foundation. The mechanism weighs the entire vehicle and its contents, sometimes axle group by axle group. The weighing sensors are normally the load cells. These devices may be located at the entrances of factories, quarries, dumps, warehouses etc., for commercial purposes or at the road-side where they are used for compliance and enforcement purposes.

Portable weigh scales are able to measure individual axle loads, but their accuracy is typically lower than that of weighbridges because the stop-and-go driving over them can cause considerable redistributions of the loading. Portable weigh scales are typically used by roadside enforcement personnel for random or targeted weighing activities.

Weigh-in-Motion (WIM) systems measure the dynamic axle loads of the vehicles passing at full highway speed under uncontrolled conditions and are used to calculate the best possible approximation of the static axle weights (COST 323, 2002). WIM systems typically deliver: axle loads, axle group loads, gross vehicle weight, number of axles, overall length of the vehicle, axle spacing, speed and vehicle classification. WIM systems can be used to screen trucks for compliance assessment at road-side weighbridges or vehicle inspection stations. WIM systems can also be used for direct law enforcement, subject to accuracy requirements being met.

On-board Weighing (OBW) systems are installed on vehicles to measure axle group weight, and the gross vehicle weight of combinations. The systems rely on three sensor technologies:

- Load cells, especially in steel-sprung suspensions.
- Air pressure transducers, in association with air suspension.
- Strain gauges.

OBW systems have the ability to be used by transport operators to manage their compliance with regulatory requirements. They also have the potential to be used for enforcement purposes by regulators, subject to accuracy requirements being met.

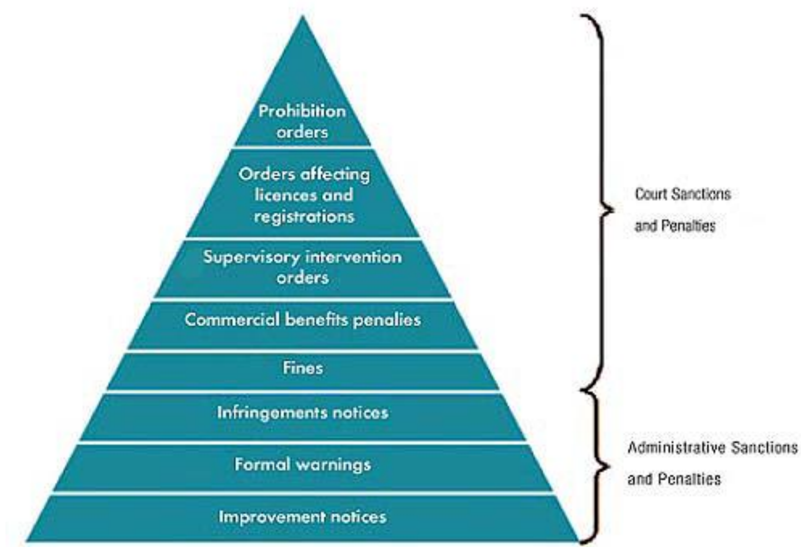
New approaches to achieve regulatory compliance

There are diverse approaches available to achieve compliance with regulations. The ‘enforcement pyramid’ below shows how different approaches can be adopted.

A more educative or persuasive strategy should be directed towards those who are inclined to comply but have made an inadvertent mistake or misinterpreted the rules and their implications. If the intervention fails to induce compliance then the regulator should invoke an escalated penalty and so on until the offender complies. If compliance is not achieved then the offender should be removed from the system.

In contrast, the full, punitive force of the law should be directed towards those who have actively decided not to comply. This group is characterised by a pattern of recidivism and a systemic 'culture of non-compliance'.

Figure 5.1 Hierarchy of Interventions



Source: (Leyden, P, McIntyre, K, Moore, B., 2004)

The pyramid allows for a holistic approach to compliance and its strategic enforcement by taking into account the many influences that can contribute to non-compliance. This approach also encourages industry to engage in a partnership approach to compliance. It emphasises the low-cost options for compliance – persuasion, partnership, education – and only when these less interventionist approaches do not succeed are sanctions and penalties required.

Alternative compliance management

The ability to influence positive behavioural outcomes can be achieved through alternative compliance approaches, which have been adopted in some regions. Transport operators may be certified through some form of accreditation scheme i.e. promotion of self-regulation/voluntary compliance. This is particularly relevant in many developing countries where non-compliance, not only in terms of overloading and speeding, but also driver and vehicle fitness, is widespread.

Examples of such accreditation schemes are ISO 39001:2012 Road Traffic Safety Management Systems (the primary focus is Road Traffic Safety – RTS), SANS 1395:2014 Road Transport Management Systems (RTMS) in South Africa and the National Heavy Vehicle Accreditation Scheme Scheme (NHVAS) in

Australia. Certification in terms of such accreditation schemes can be made a prerequisite for transport operators to own and operate high capacity vehicles.

Such accreditation schemes require periodic external audits to be conducted, during which the external auditor will check the company's policies and processes and verify whether such policies and processes are being implemented. Furthermore, where non-compliances have been detected, there must be evidence of corrective actions.

Box 5.1 Research into accreditation schemes and self-regulation

Walker (2012) found that research suggests that auditors play an important role in regulatory learning, enhancing both the compliance capability of firms as well as enhancing the enforcement options for regulators. The study shows that regulatory learning is central to the development of responsive compliance programmes.

Current trends in regulatory practice reveal an increasing reliance on process orientated models of regulation that draw on self-regulation, demands for accountability and assurances that public policy objectives are being pursued still remain. In this environment audits have emerged as a key accountability tool that allow organisations to report on practice, systems of operation and methods of control without requiring the State to step in and undertake their own inspection and assessment (Hutter, 2006). Audits are common elements of regulatory programmes that reflect New Public Management (NPM) ideals of autonomy, delegation and less direct involvement from the state (Blundell and Robinson, 2000). Audits enable the state to make judgments about the activity of others from a distance and this has allowed autonomous units to become more governable (Vincent-Jones, 2002:45). The growing preference for accountability and reporting through audits has led to what Power (1997) refers to as an 'audit explosion' where government institutions, private firms and professions have all become involved in accounting for their actions through audits.

How weight assurance can drive productivity reforms

Vehicle and axle weight data (obtained from WIM or OBW Systems) provide the ability to link weight information to other key pieces of information, including the configuration of the vehicle, its location and time of collection, and, when required, its speed. This means that weight information is not only more reliable and available, but contextually aligned with other key pieces of information, allowing for richer use.

The ability to access and use weight information is important in design, management and compliance for both pavements and bridges. Obtaining assurance through the accuracy and integrity of weight measurements presents new opportunities for all stakeholders. An example of new opportunities can be seen in the updated Australian Standard for bridge assessment (Standards Australia ,2017). The updated standard incorporates reduced traffic load factors for vehicles monitored through the Intelligent Access Program (IAP) and OBW for the Ultimate Limit State (ULS). By obtaining assurance in the weights of vehicles, the consequently reduced traffic load factors in bridge assessments achieves an increase in vehicle mass limits, while at the same time improving compliance.

Conclusion and recommended policy options

1. Understand the reasons why non-compliance occurs so that the right approach can be selected for an effective compliance framework.
    a. Establish an evidence-base of the current level of compliance and non-compliance.
    b. Ensure compliance management frameworks are outcome focussed, with the availability of different interventions and techniques to influence positive behavioural outcomes.
    c. Ensure compliance strategies are supported by the design of regulatory frameworks.

2. Move towards innovative approaches to regulatory design and compliance approaches which include a combination of 'carrots' and 'sticks' with the emphasis on positive incentives for efficiency.
    a. Introduce mechanisms for accreditation and self-regulation.
    b. Introduce contemporary approaches to manage the weight of vehicles (including in-road and on-vehicle technologies).
    c. Use telematics and related intelligent technologies as a way to manage compliance with regulations.
    d. Provide incentives for transport operators (and other parties in the supply chain) to comply with regulations (i.e. reward good behaviour).

Achieving compliance to loading regulations has a significant impact on the life of road assets. The inherent level of compliance observed in any regulated environment results from a number of inter-related factors and influences, which need to be considered in the context of a region's social and cultural norms.

Like any other regulated sector, achieving adherence to road transport regulations requires a strategic, cross-disciplinary, risk-based approach to deliver improved compliance outcomes. There is no single approach that guarantees results. However, all too often, the terms 'compliance management' and 'enforcement' are used interchangeably – despite enforcement being but one of a number of potential instruments available to improve compliance outcomes.

The use of these instruments will be guided by the inherent level of compliance, and the responsiveness of transport operators, drivers (and other parties along the supply chain) to comply with regulations. To this end, an understanding of the motivations for non-compliance is crucial, as are the appropriate responses to influence behavioural change.

The focus on changing behaviour needs to include a combination of carrots and sticks with the emphasis on carrots. An enforcement focussed regime (sticks) will usually catch only a small proportion of the non-compliant vehicles because of resource limitations. Much of the negative impact on infrastructure from non-compliance will still occur. Well-designed carrots are likely to achieve higher rates of compliance, so long as they are complemented with the ongoing use of sticks.

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CHAPTER 6

Truck traffic management

Problem Statement

Specific interactions between infrastructure and trucks can endanger road assets. The goal of (truck) traffic management is to influence traffic situations in a way that the overall wear and damage caused by truck traffic on road assets is reduced. In this chapter policy options are presented for traffic situations that strongly contribute to infrastructure wear: this mainly corresponds to trucks driving at the same time or at the same location, during critical conditions, for example in adverse weather conditions.

Managing truck traffic in a proactive way can help to extend the life of road assets. To achieve that, information must be retrieved about usage, for example by installing and using monitoring sensors. Traffic management decisions can then be proposed by experts, and implemented through communication means.

The problem is that the expected benefits corresponding to the costs are not known precisely and quantitatively, and therefore the communication around the positive motivations of truck traffic management is scarce, or non-existent.

To provide the context of the problem, various aspects are discussed below for managing traffic situations that are critical for road asset wear and damage caused by trucks and the needed knowledge for choosing between possible solutions.

Traffic use situations and traffic management solutions

Truck traffic management deals with the following types of damaging traffic situations, and adapted solutions:

- Road assets: Road and pavement, bridges etc.
- Traffic conditions: “Normal” traffic, specific loads in weight or in dimensions, platoons etc.
- Management style: Allocation of time or space, speed target, minimal distances between trucks target, lateral position etc..
- Incentives: Allocation of time slots (reduction of travel time), allocation of lanes (increase of driving quality), pricings, tolls, allowance of other types of traffic and/or loads, etc.

The issue is therefore to determine which traffic situation(s) are the most damaging for the road and asset network as a whole and to choose the best solution in terms of traffic management procedure and implementation means.

Data, information and knowledge

Dynamic traffic management is based on information collected in real time. The various possibilities for managing traffic depend on the type and amount of available information.

The information that is needed for the choice and the implementation of a given management procedure has to be defined in terms of nature, quantity and quality: for example, what element has to be monitored, how and for how long to decide of the choice in traffic management procedures? Experts or engineers in various domains, like structural engineering, traffic, vehicle dynamics, meteorology, etc., can answer these questions, i.e. determine which time series should be monitored, when and how.

Another challenge in the search for information is the adaptability and interoperability of the monitoring and measurement devices. This highlights the need for standardisation of the interoperability and communication languages, also in order to ensure (cyber-)security.

Indicators

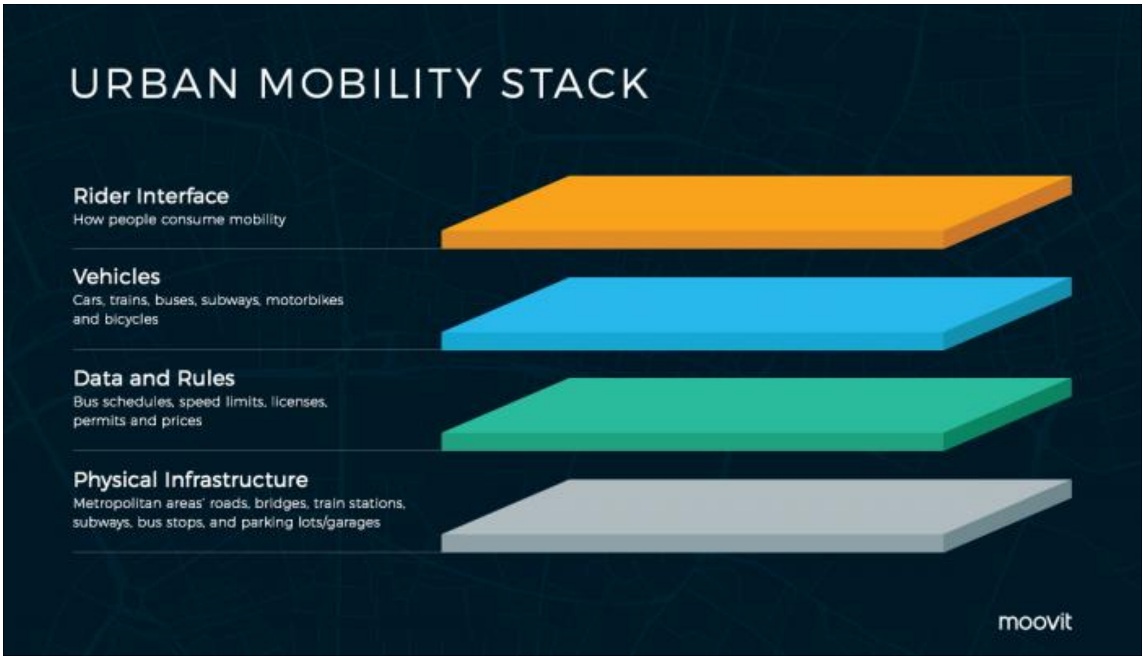
Assuming that data is available, objective limits or goals for the monitored objects are needed to take rational decisions: Key Performance Indicators (KPIs), either for traffic loading (Bridge Formula to limit the axle loads on bridges, Performance Based Standards (PBS) for various vehicle dynamic parameters, etc. and for road infrastructure (reliability indices, cumulated damage, residual lifetime etc.

Overview of knowledge and practice

The company Moovit who specialises in urban mobility data analytics, designed a model to visualise the different speeds in development between the components of the transportation system. It is a variant of existing similar ways of interpreting the transportation system. Moovit designed the model for urban mobility, but it applies equally to other forms of mobility. The model is used here as a framework for the different forms of traffic management that can be used to reduce the wear and damage to road assets caused by trucks.

The bottom layer is the physical infrastructure, which varies slowly in time. Further up in the model, the changes in the parts of the transportation system may go faster, like the digital infrastructure (data and rules like traffic management rules, see Figure 6.1.

Figure 6.1: Urban mobility stack

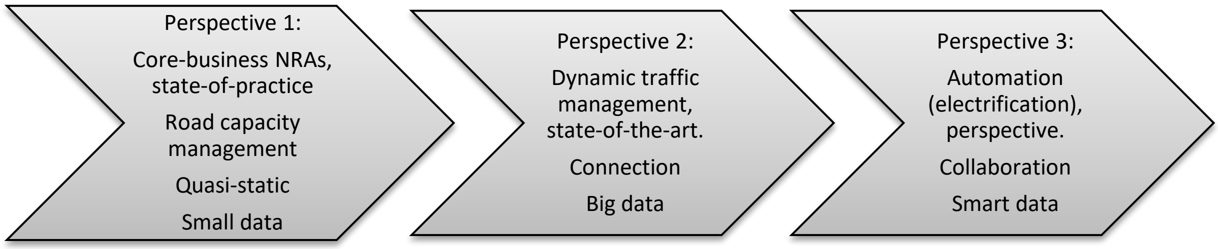


Source: Moovit (2018).

Based on this scheme, the various information exchanges can be distinguished, especially between infrastructure and vehicles. Their existence (or not) make it possible to define three types of dynamic management frameworks:

1. The first framework is **road capacity management**, which is widely applied nowadays: when lacking data or information and often only relying on expert knowledge, the principle is to reserve time slots or lanes for some given traffic.
2. When more data is available, real-time, **dynamic truck traffic management** through the monitoring of traffic and of road infrastructure is possible. In this case, dynamic communication with the traffic is needed, for example, through dynamic communication panels. This solution is well known nowadays, but generally not applied completely on-site.
3. Finally, when more data is available and more communication is possible, real-time management through **communication and collaboration between vehicles and infrastructure, such as vehicle-to-infrastructure or infrastructure-to-vehicle (V2I/I2V) or between vehicles (vehicle-to-vehicle V2V)** can be undertaken. In this case, to have this collaboration of traffic, adjustments for vehicles accepting to communicate may be proposed.

Figure 6.1: Three types of dynamic traffic management.



This corresponds to the traffic management procedures applied today, because of its simplicity. It should be noted that road-capacity management only needs few data (aggregated or small amount), or "expert" knowledge.

Road capacity management

Time or space-oriented traffic management

This type of traffic management allocates, in a (quasi-) static manner, slots in time or in space to a specific group of traffic users. This makes it possible to better distribute the heavy traffic on a given road stretch along time and space, thus decreasing the wear and damage it inflicts on this part on the road infrastructure, especially the bridges.

This can be a win-win situation as the wear and damage on the asset is decreased whereas there can be an incentive for the carriers or drivers: for example, specific carriers get allocated specific time slots and makes it possible for them to reduce the travel time needed on the same route. With this they can improve the delivery time reliability. The incentive could also be linked to pricing policies, which may take into account type of traffic or time of passage. The principle is the same for specific loads or types of truck traffic like platoons, where dedicated roads or lanes may be reserved or priority access may be granted. Several strategies could be combined to make them more effective. Moreover, this kind of traffic is not always possible because of economic or political pressure: indeed, some bodies like commercial chambers enforce for the traffic to be passing when arriving.

Box 6.1: Austrian national practice for according to time slots for different traffic users

Using time slots on motorways and expressways for standard traffic users (gross weight < 38.5 tonnes) is not common. However, time slots are used for abnormal loads or transports with bulky goods. These traffic users need a special permission to use the motorways and expressways in Austria. With this permission some restrictions can be generated: for example, abnormally high-load vehicles and vehicles with bulky goods are only allowed to travel at off-peak times or at night-time with an escort vehicle. Also, some speed limits have been set, especially for travelling over bridges.

Truck traffic management in extreme weather conditions

The principle is to adapt the traffic management strategy depending on the weather conditions, as these make the road and road assets less or more adapted for truck traffic.

Box 6.2: Different national truck traffic management procedures during freeze/thaw cycles

During low temperatures, the pavement can undergo freeze and thaw cycles which make the pavement more sensible to loadings. On the other hand, if frozen, the substrate is more much compact and able to support much higher loadings. This leads to different policies, depending on the country: in several Scandinavian countries (e.g. Sweden, Finland) heavier loads are allowed during cold temperature periods. For example, in Sweden, trucks with Central Tire Inflation (CTI) during thawing season are allowed higher weights, compared to trucks without CTI. On the other hand, in France, roads are closed to trucks during cold temperatures.

Another example of risky weather conditions is wind. It can lead to risks for trucks themselves and for bridges.

Box 6.3: The influence of wind and traffic management to reduce risks in France

Wind is a determining factor in the valley of the Millau viaduct in Aveyron, France. To avoid the consequences of "normal wind", this cable-stayed viaduct is equipped with 3 metre-high windbreaks to protect vehicles against gusts. But when winds reach a speed of 90 km/h, trucks and caravans must reduce their speed. At 110 km/h, they are prohibited from the viaduct, and beyond 140 km/h the viaduct is closed for all traffic. These measures are of course aimed at the security of the traffic itself, but by protecting the traffic the bridge itself is less prone to be submitted to an impact of a truck against a pylon, a cable or the windbreakers which would endanger the structure itself.

Dynamic (truck) traffic management

This second level of traffic management corresponds to an integrated and holistic vision of existing road infrastructure network with site-specific, real-time data, either on the loadings or on the structural response or both.

This type of situation may lead to big data issues, which means that rational indicators for application of traffic management have to be derived by technical experts. It should also be noted that this type of traffic management is only possible if appropriate digital infrastructure has been installed, which corresponds to a serious amount of investment. Therefore, this policy is only applied locally and partially nowadays.

Rational analysis of traffic management strategy

Several tools exist in order to analyse the impact of given decisions in dynamic traffic management on the induced lifetime of assets.

- Physical and mathematical tools for rational decision-making: Use of physical models and/or artificial intelligence (machine learning, neural networks) applied on (voluminous) data to develop a damage evolution model or update an existing physical model.
- Short term predictions: for example, predictions for the traffic loads or the weather conditions during the following hour, may lead to adapted traffic management procedures to minimise traffic wear and damage.

Rational space and time allocation for traffic

With this data and data-related models, the same measures of road capacity management may be applied in a data-driven way, leading to a smart management of the road asset. One advantage of this methodology is that it is possible to take into account the complex behaviour of trucks and truck drivers in a holistic way (without having to explain all relations mathematically). For example, when deciding the lane opening or closing for given types of traffic, one has to be aware that weights have of course an impact on road wear and damage, but it also changes the behaviour of trucks (depending on the geometry).

Conditions for application

Obviously, dynamic traffic management is only possible if dynamic communication means exist, as for example overhead signs. This represents a cost which cannot be underestimated. Application is therefore often not done for small, rural roads, but for motorways which, in any case, gather most high capacity transport with heavier loads.

Box 6.4: National practice for Austria according to dynamic communication

In urban areas, dynamic traffic signs are used to communicate with customers and influence the traffic in a positive way: speed harmonisation to extend the capacity and reduce congestion, speed adjustment in case of dangerous weather situations, no overtaking for trucks, warning message in case of congestion, accidents, etc.

Communication and/or collaboration between road assets and (truck) traffic

This collaboration must be highly dynamic and often proactive. To reach this goal, learning the patterns is possible through digitalisation of the needed input. The final goal is to achieve a rational optimum, knowing that there exist various strategies for application (PIARC, 2015).

This dynamic truck traffic management should be seen in relation with the concept of mobility-as-a-service. Instead of just ensuring that the road infrastructure can be used, service and quality of mobility are ensured, and a counterpart from the traffic can be expected, in monetary terms of course but also through collaboration with the system. This could lead to behavioural changes.

This level of dynamic traffic management can be associated with road automation and electrification.

Vehicle-to-infrastructure (V2I) and from infrastructure-to-vehicle (I2V) communication

Real-time communication from the vehicles to the infrastructure is possible, about the localisation, the loading and the speed.

The communication from the infrastructure to the vehicle may be some real-time feedback about their use of the road (loading, speed, induced wear and damage, loss in resistance capacity, etc.) and some guidelines for their driving.

This communication may or may not use side-board units. An integration of all this information is then made, either in these units or on a server: the assessment of the induced wear and damage, security assessment, choice of actions to influence the traffic, and a decision on traffic management procedures.

This could be a possible way to influence traffic users' choices and to change mobility patterns. For example, in France, many cities have now installed speed radars with real-time feedback (by dynamic traffic signs) of the speed to the vehicles. This has been proven to be quite effective.

Vehicle-to-vehicle communication (V2V)

Communication between vehicles makes it possible to act on the interaction between trucks, as for example platooning behaviour, headways and the number of trucks on a bridge. Using this information, the policy maker may then decide if he wants to take an active part in the work, or just use the technologies of private companies for his own purposes.

Box 6.5: Management of multiple truck passings on bridges in Australia

The identification of multiple vehicles travelling across bridges simultaneously is currently being implemented in Australia through telematics applications managed through the National Telematics Framework.

Telematics applications which deliver high-accuracy position, time and date records can be used to optimise the utilisation of bridges, and provide infrastructure managers an understanding of the likelihood of vehicles travelling across bridges at the same time.

Work is now underway in Australia to introduce real-time communication capabilities when more than one 'specified type of vehicle' (particular types of vehicles which represent risks to road infrastructure assets) approaches a particular bridge, structure or other road infrastructure asset. There is the opportunity to use real-time communication capabilities (such as V2V or V2I applications), which can alert drivers of these vehicles of another high-risk vehicle simultaneously approaching the asset.

Another example would be Northern Sweden where High Capacity Vehicles are not allowed to be closer than three minutes of headways, because of the weak ground. This is monitored in real-time, and communicated between vehicles. With this system, information is also sent about deer's that are seen on the road, to diminish the number of accidents.

Creation of digital infrastructure

All this data makes it possible to associate the physical infrastructure with a digital infrastructure: the digital infrastructure integrates the infrastructure-related data with the traffic data, for example by using a complete information and communications technology (ICT) system between trucks and infrastructure.

Communication with the drivers and/or the public can be done through various means, as for example web applications or internet pages. Service can be offered accordingly.

Again, it should be highlighted that digitalisation leads to automation. Standardisation is needed, for the data formats, the models and the services. In Australia, for example support systems were built to facilitate this standardisation: the consequent format is not mandatory, but using it allows it to provide other data to the partners (ports for example). In Europe, the most important project to work on the European standardisation may be the European Intelligent Transport Systems (ITS) platform Easyway (2018), that uses the e-FRAME ITS architecture in Europe (FRAME architecture, 2018).

This level of dynamic traffic management may be quite expensive and it may also be challenging to be enforced, especially in countries where this is not already the case (the majority of countries). Therefore, the uses cases (the different ways of road utilisation by different groups of road users on specific locations, for example long distance road freight transport on motorways and the related business models have to be developed and agreed on: to do that, the global benefit in terms of environment, less congestion and reduced wear and damage to the infrastructure, have to be taken into account.

Nevertheless, it should be noted again that several policies are possible. For example, the United States decided to get out of actively working on automation and instead concentrate only on ensuring the road is readable by autonomous vehicles. On the other side, in France, artificial intelligence (AI) has been decreed as a national project, with EUR 1.5 billion available for projects, focussed also on autonomous driving and the needed regulation and approval.

Conclusion and recommended policy options

The following recommendations are aimed at increasing the success of the introduction of truck traffic management strategies for a longer lifetime of road assets:

1. Use cases and business models should be developed to address the uncertainties associated with the development of digital infrastructure for truck traffic management. Within these use cases research can be done on what is required of digital infrastructure in order to achieve an effective implementation of truck traffic management.
2. Create benefits for the logistics sector (fewer road works, wider access to areas or objects with limited access, shorter travel times and higher delivery time reliability) of implementing truck traffic management. This will also increase the willingness to share in-vehicle and/or in-company data. Making use of this data could reduce the costs for truck traffic management strategies.

Traffic management is a means to decrease the wear and damage on road assets caused by trucks in order to extend the lifetime of road infrastructure. There are possibilities for truck traffic management strategies, even if the available budget for investments is limited (road capacity management). Beyond that, a cost-benefit analysis can show that investments in truck traffic management pay off.

Truck traffic management strategies are often introduced to limit the negative effects of truck traffic. A more positive approach is based on the interests involved in introducing truck traffic management for the logistics sector: fewer road works, wider access to areas or objects with limited access, less travel time and higher delivery time reliability. Starting with positive motivation, the willingness of the logistics sector to share data can increase. If companies are willing to share (in-car or in-company) data, fewer investments are needed in V2I and I2V applications.

Developments in needed digital infrastructure are going fast and the direction in which these are going is not yet fully clear. Therefore, use cases (the different ways of road utilisation by different groups of road users on specific locations, for example long distance road freight transport on motorways) and related business models have to be developed in which the global benefit in terms of environment, less congestion and reduced wear and damage to the infrastructure, is taken into account.

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CHAPTER 7

Modal shift and optimisation of freight transport systems

Problem statement

Demand for road freight transport is a consequence of economic activities related to the production and consumption of goods and services. More progressive governments recognise the need to develop freight transport policies that are sensitive to wider logistics and supply chain trends. Corporate freight transport demand and freight movement patterns stem from and are integral parts of a supply chain strategy. Therefore, to influence a company's behaviour, policy makers need to understand the dependencies between transport, logistics and the wider business environment (McKinnon, 2015).

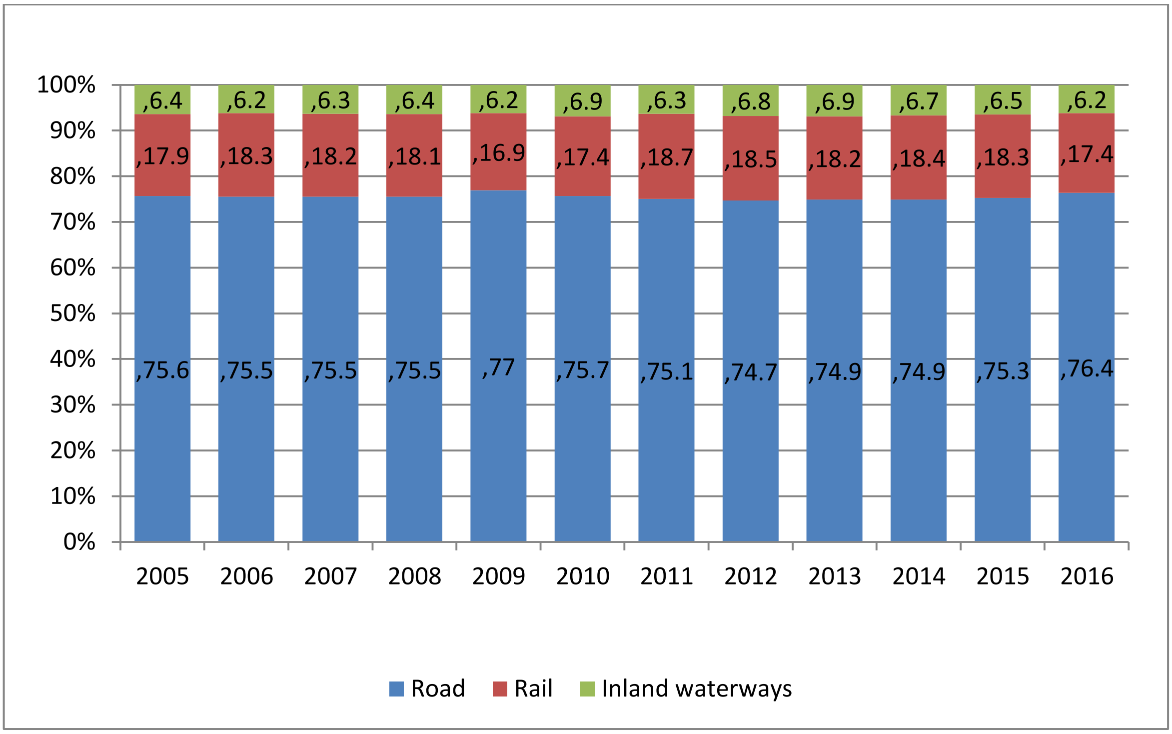
Policies that intervene in the use of trucks are usually motivated by objectives like the reduction of emissions or congestion. However, limiting the number of trucks, the number of kilometres driven by trucks and a more efficient use of trucks, can also contribute to a longer lifetime of road assets. Chapter 4 deals extensively with regulatory frameworks aimed at improving efficiency of truck use, so that fewer trucks are needed to transport the same amount of goods. This chapter therefore focuses on measures aimed at reducing the number of trucks and the number of kilometres driven by trucks.

Based on an assumption that the overall demand for freight transport is fixed, logistics interventions considered in this chapter focus on two ways of minimising the impact of trucks on road assets: i) trip avoidance: this can be achieved by shifting freight to alternative freight transport modes; and ii) reductions of trip length: this focuses on interventions that can impact the structure of supply chains. In addition, effective stakeholder management is necessary to support these logistics interventions. The following sub-sections further describe the problems addressed by these interventions.

Modal shift from road to alternative modes of freight transport

In the European Union, there has been little change in modal split during the past decade (Figure 7.1). In developing and emerging countries, the main trend has been a shift from rail to road transport. In the future, increasing digitalisation of logistics and transport, combined with scale increases of vehicles and consolidation of loads, is likely to add further to the increasing pressure on infrastructure systems. Overall, in the scenarios modelled by the ITF (2017), road freight transport is expected to increase globally by 34%-101% over the next 30 years. In many countries and regions, policies exist to encourage modal shift from road to alternative modes of transport. However, past experience suggests that a significant modal shift away from road is not likely to occur without significant investment in efficient rail and waterborne transport systems, including intermodal transhipment points, strong pricing incentives and an accompanying logistics reorganisation by shippers.

Figure 7.1: Modal split of inland freight modes in the European Union



Source: Eurostat (online data code tran_hv_frmod).

Note: % of total tonne-kilometres

Reducing trip length

It has been estimated that, on average, freight transport costs per tonne-kilometre (t-km) were 90% lower in 2004 than they were in 1890 (Glaeser and Kohlhase, 2004). Falling transportation costs, along with other supply chain developments such as technological advances in materials handling (including containerisation), transport infrastructure developments, economies of scale from centralisation of manufacturing and distribution, have led to significant increases in the distances freight travelled.

The average length of haul for road freight vehicle movements in the United States is reported to have increased from 272 miles in 1960 to 485 miles in 2001, an increase of approximately 80%. This can be partially attributed to the development of the Interstate highway system (Rodrigue, 2018). In Britain the average length of haul of individual road freight vehicle movements by heavy goods vehicles (HGVs) increased by 107% between 1965 and 2016 (Department for Transport, 2017a). Within Europe, the average length of haul increased by 1.5%-2.0% per annum from 1970 to 1996 and has been the main driver of the growth in road freight activity in Europe, which is responsible for two-thirds of the increase in t-km performed by road (McKinnon, 1999).

In urban areas affordable depots from which to operate last-mile deliveries have becoming increasingly difficult to find due to rising land values. These increases have forced many freight transport operators to relocate their central urban depots to less costly peripheral areas, which has led to the suburbanisation of warehousing and distribution facilities, often referred to as 'logistics sprawl' (Dablanc et al., 2014). This has had the effect of increasing stem mileages (the distance from the depot to the delivery catchment area and back), especially when delivering to inner and central urban areas, resulting in increased vehicle kilometres. In Paris, for example, the average distance from express parcel carriers' depots to the delivery area in the city increased from 6.3 km in 1974 to 18.1 km in 2010 (Andriankaja, 2014). Between 1998 and 2009, warehousing in Los Angeles sprawled considerably, with average distance to centre increasing by over 6 miles (Dablanc et al., 2014).

Advice, best practice and stakeholder engagement

Many freight operators, particularly from the small and medium-sized enterprise (SME) sector, do not have the knowledge and/or resources to improve their road freight transport operations in a way that minimises the amount of required truck movements, maximises vehicle utilisation and reduces the negative impact of trucks on the environment and transport infrastructure. It is also argued that increasing stakeholder engagement in the policy-making process may promote greater acceptance and ownership of proposed solutions and thus their successful implementation.

Overview of knowledge and practice

Modal shift from road to alternative modes of freight transport

The most recent White Paper on Transport for the European Union (EU) emphasises the importance of shifting freight that is transported 300 kilometres or more from road to rail and/or water (European Commission, 2011). Environmental and social benefits form the basis of these policies, but such a modal shift may also present opportunities to reduce road wear and prolong the life of road and bridge infrastructure. The Core Network Corridors programme under development across the EU focuses heavily on infrastructure enhancements to the rail and, to a lesser extent, waterborne transport networks (European Commission, 2014). The initiative to create a European rail network for competitive freight (European Commission, 2007) has been subsumed into the Core Network Corridors programme, while specific countries have separate initiatives. As an example, since 2007 the United Kingdom has had ring-fenced funding to develop a Strategic Rail Freight Network (DfT, 2009).

While the EU modal shift target focuses on the distance the freight travels, the nature of the consignment is another key variable affecting freight mode choice. Rail and waterborne transport are generally best suited to flows of bulk products, given the economies of scale resulting from the ability to move large quantities in a single train, barge or vessel; this particularly suits flows in the early and middle stages of supply chains, either raw materials or part-manufactured goods, together with sizable reverse flows of waste materials. On the other hand, the convenience and flexibility of road makes it particularly well suited for the movement of consumer goods towards the end of the supply chain.

Intermodal freight transport, whereby goods are typically moved in unit loads such as in containers, is a means by which the positive attributes of both road and rail/water are maximised. By combining road with other modes, the dominance of road freight for flows can be reduced compared with the alternative of road-only transport. There is some evidence of rail freight growth resulting from an expansion of intermodal activity. In the United Kingdom, for example, intermodal rail freight grew by 44% between 2006-07 and 2016-17 (Office of Rail and Road, 2017). The estimated rail share of container twenty-foot equivalent unit (TEU) throughput at the country's two largest container ports, Felixstowe and Southampton, increased from 19.5% to 22.3% and from 23.9% to 27.5% respectively between 2007 and 2015 (Woodburn, 2017). In the port of Gothenburg, the share of containers handled by rail increased from around 20% in 2000 to over 50% in 2016 (Port of Gothenburg, 2017). Across the

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European Union, around 16% of rail freight and 8% of inland waterway freight in 2015 consisted of intermodal unit loads. These percentages have generally been increasing (Eurostat, 2017).

It should be noted that, while switching freight from road to rail or water for trunk hauls is likely to lead to global reductions in road wear (due to a reduction in total road freight activity), localised increases in truck traffic in the vicinity of rail and water terminals may result in an increase in road wear when feeder road haulage activity to and from the terminals is concentrated.

There is also a concern within the rail industry that modal shift from road to rail may be reversed should there be a widespread introduction of longer heavier vehicles (LHVs) on the European road network (see, for example, UIC/CER/UNIFE, 2014). Such a move could erode the economies of scale benefits associated with rail freight (and possibly water freight, though perhaps less likely) by reducing the cost per tonne kilometre of road freight and improving road haulage efficiency relative to that of rail freight. While many bulk flows would be little threatened by LHVs, given rail's considerable advantages over road, the intermodal market may be particularly vulnerable as road and rail tend to compete directly for such traffic. However, Vierth et al. (2018) found that the increase in the maximum permissible vehicle weight for trucks in Sweden in 1990 and 1993 did not have any significant impact on modal split trends in the country. Recent research also suggests that LHVs play a complimentary rather than a competing role in the intermodal transport systems (Sanchez Rodrigues et al., 2015).

Box 7.1: Successful mode shift examples from Switzerland, Germany, the United Kingdom and Spain

In Switzerland, a package of modal shift measures led to a 29% decrease in the absolute number of trucks transiting the Alps from 2000 to 2014, despite an overall growth in the volume of Trans-Alpine traffic during the same period (FOT, 2016). It is estimated that had the policy intervention not been implemented, there would have been a 50% increase in the number of truck movements. The policy measures focused both on improving rail freight (e.g. investment in rail infrastructure enhancements) and influencing the cost of road haulage (e.g. introducing distance-based Heavy Goods Vehicle Charge (HGVC) on all roads in Switzerland, and increasing the maximum gross vehicle weight for trucks using rolling motorways to 44 tonnes, four more that is allowed on Swiss roads).

In Germany, a package of financial and regulatory measures aimed at both rail and road has been deemed to have contributed to an increase of more than 30% in the volume of rail freight activity between 2000 and 2012 (Directorate General for Internal Policies, 2015). Measures have included financial support for the development or enhancement of transhipment facilities, certain regulatory exemptions for trucks involved in intermodal movements (e.g. increasing the maximum gross vehicle weight from 40 to 44 tonnes), and the introduction of truck tolls on motorways and major trunk roads. On 1July 2018, the truck charging scheme was extended to cover all federal trunk roads.

In the UK, an increasing the loading gauge of the rail freight corridor serving the Port of Southampton to cater for high-cube containers on standard wagons, coincided with an increase in rail's share of port container throughput from 24% in 2007 to 29% in 2012 (Woodburn, 2013). Rail infrastructure investment at the Port of Barcelona led to its share of port container throughput increasing from 3-12% between 2008 and 2012 (Directorate General for Internal Policies, 2015).

The above examples show that modal shift policy is most successful where a comprehensive package of measures is implemented. This usually consists of investments in infrastructure for rail and waterborne transport, promotion of intermodal solutions and / or road charging.

Reducing trip length

Little has been done by policy makers to limit the increasing geographical length of product supply chains for fear of damaging national economies. Instead, national governments have typically encouraged it. Theoretically, it would be possible to reduce the distances travelled by trucks by reconfiguring the location of production and warehousing facilities in the supply chain, and reverting to greater use of local suppliers (McKinnon, 1999). However, in reality, given the economic benefits associated with the growing spatial geographies of supply chains in recent decades, this is unlikely to happen unless there are major increases in freight transport costs, reducing journey time reliability through road congestion, or a major reversal in trends towards international trade.

Unlike the increasing patterns of product supply chain length nationally and internationally which policy makers have not attempted to reduce, there have been some recent efforts at the urban level to influence these trends, given their potentially negative traffic and environmental impacts. These efforts have included considerations of how best to use the urban land-use planning system to protect and safeguard logistics land, as is currently being considered in London (Mayor of London, 2017). In addition, whilst these efforts have not directly sought to reduce individual vehicle trip lengths in urban areas, they have sought to consolidate the flow of products destined for urban areas at a physical depot so that vehicle load factors can be improved (and in some cases cleaner goods vehicles can be used for last-mile deliveries). This has had the effect of reducing the total number of vehicle journeys that need to make delivery journeys in the urban area, and thereby reduce average vehicle trip lengths (Allen et al., 2012b).

Box 7.2: Example of an urban freight consolidation centre in Monaco

The Monaco Consolidation Centre (MCC) was set up in 1989 when the local government decided to rationalise freight vehicle movements in Monaco. The MCC is a public managed service and is operated by a private company. The operating costs are 20% public and 80% private. Apart from the financial support, the principality of Monaco provides a free warehouse space to the MCC operator. It services both the retail and construction sectors and its use is compulsory for all trucks over 8.5 tonnes. Trucks under 8.5 tonnes may access Monaco only during specific time windows. Senders and recipients of goods are charged for deliveries, contributing towards the recovery of the MCC's operating costs.

The MCC has resulted in significant environmental benefits, and reductions in truck traffic translating into a 38% decrease in traffic congestion as well as a 42% reduction in space used by vehicles for delivery (Transport for London, 2016; SUCCESS, 2017).

Consolidation centres are facilities that perform this role and which are typically situated towards the edge of urban areas, so that road vehicles can deliver their loads at such centres without having to penetrate busy inner and central urban areas. Such facilities have been trialled and established in many European countries, and whilst most have attracted public subsidy, some have been operated on a commercial basis by the public sector. They have been used for the transhipment of a range of goods including retail, pharmaceutical and construction onto optimally loaded vehicles for final delivery.

Some micro-consolidation centres have also been tested and operated in inner urban areas to facilitate transhipment for retail and office deliveries in the busiest, most congested city centres. In these operations, bulk deliveries are typically made to the micro-consolidation centres overnight or very early in the morning while roads are uncongested, and then the last-mile deliveries take place from these centres during the daytime using clean vehicles (Allen et al., 2012; Browne et al., 2011). While a large proportion of consolidation centres still fail financially after the initial financial support from local authorities or research funding is withdrawn, there are also successful examples of such initiatives, particularly if other complimentary measures are introduced to maintain their economic viability.

Advice, best practice and stakeholder engagement

Some governments run advisory programs or stakeholder engagement initiatives that promote the adoption of best practice in the road freight transport sector. The focus of such undertakings varies, including a range of freight-related issues such as improving energy efficiency (e.g. the SmartWay program in the United States), servicing of city centres (e.g. Central London Freight Quality Partnership), and encouraging the uptake of low emission commercial vehicles (e.g. LoCity in London). Such initiatives provide cost-effective approaches of disseminating information to the industry (McKinnon, 2015), and could be a valuable option to support training and communication on issues related to fleet selection, optimum loading and advisory routing of trucks, inter-company collaboration and consolidation of loads to minimise the overall volume of traffic and reduce empty running of trucks, etc. Examples of existing advice and stakeholders' engagement initiatives are outlined below.

Guidance for the freight transport industry

Some governments or trade associations provide guidelines, reports and factsheets on a range of freight-related topics including vehicle selection, fleet management, fuel efficiency, developing skills, equipment and systems.

Box 7.3: Example of the UK

The UK Driver and Vehicle Standards Agency in its guide "Heavy Goods Vehicle Overloading: The Basics" explains how to avoid overloading trucks and what may happen to an overloaded vehicle (www.gov.uk/government/publications/hgv-overloading-the-basics).

While such publications may not be specifically focused on the impact of freight vehicles on infrastructure, advice provided is a valuable resource to companies wanting to improve their logistics operations.

Stakeholder engagement and public-private partnerships

There is an interaction between policy aimed at making the road freight transport more sustainable and infrastructure. If both are considered in conjunction, they can reinforce each other in order to deliver a more sustainable freight transport system, including a longer lifetime of infrastructure. Where there are trade-offs between different objectives, multi-stakeholder partnerships allow a more balanced approach to the development of relevant policies.

There are also examples of Freight Quality Partnerships (FQPs) with the primary purpose of alleviating the impact of freight on road infrastructure. These usually focus on sectors generating heavy freight and potentially oversized loads, such as quarrying and mining, construction, timber and forestry.

Box 7.4: Multi-stakeholder partnerships focussing on improving the sustainability of road freight

The Centre for Sustainable Road Freight

The Centre is a collaboration between Cambridge and Heriot-Watt Universities and organisations in the freight and logistics sectors. Its purpose is to research engineering and organisational solutions to make road freight economically, socially and environmentally sustainable. A vital feature of the Centre is its close links with the freight industry. Of the first five year's funding, GBP 4.4 million will come from the Engineering and Physical Sciences Research Council (EPSRC) and GBP 1.4 million from the industrial consortium. The consortium includes key freight operators such as John Lewis, Tesco, DHL and Wincanton, along with vehicle industry partners, including Volvo, Goodyear, Firestone among others, who help set the research agenda and spearhead the adoption of the results by the road freight industry. http://www.csrf.ac.uk/

Lean & Green Europe

Lean & Green Europe is the leading program for sustainable logistics in Europe. It encourages organisations to grow together towards a higher level of sustainability, by taking measures that not only generate cost savings, but also reduce environmental impact and lead to more efficient organisation of business and logistics processes. Lean & Green Europe is being implemented in the Netherlands by Connekt, the independent network for smart and sustainable mobility in Delft. http://lean-green.eu/

Smart Freight Centre

Smart Freight Centre (SFC) was established as a global non-profit organisation in 2013. Their vision is "Smart Freight"– a transformation to an efficient and environmentally sustainable global logistics sector. Their approach is business-centric because freight is a highly commercial sector. SFC mobilises business to reduce emissions and recognises leaders. Together with leading multinationals, partners across their global logistics supply chain and other key stakeholders the SFC work towards: Harmonised global frameworks for emissions calculation and reduction, starting with the Global Logistics Emissions Council (GLEC) Framework; Professionalised transport operators for fleet energy management, starting with Smart Transport Manager (STM) Training; and Connected business and stakeholders to accelerate action. SFC organises events, manages/advices on projects that are relevant to business, and advocates for smarter freight with government, initiatives and other players.

SFC's Smart Truck Fleet Management helps road freight operators find the right technologies and measures for trucks and fleet operations to help improve their operational efficiency. http://www.smartfreightcentre.org/

In the UK, for instance, the North Yorkshire Timber Freight Quality Partnership was set up with an aim "to support the contribution of the forestry and timber industries to the North Yorkshire economy by ensuring that timber industries can access the timber resource whilst seeking to minimise the impact on the public road network, on local communities and on the environment' (www.nypartnerships.org.uk/nytfqp). Its main outcomes are the voluntary timber route map and a good practice guidance document

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for timber extraction and haulage in North Yorkshire. A number of similar timber "Freight Quality Partnerships" operate also in Scotland and Wales.

Public consultations

Through the public consultation process, government agencies can get a better understanding of the impact of freight activities on current and future infrastructure needs. Collected evidence is then reviewed and used in the formulation of relevant policies.

The 2018 consultation by the United Kingdom National Infrastructure Commission (NIC), for example, was carried out to "provide recommendations on the changes required to infrastructure, regulation, industry practices, and the government's investment priorities in the freight sector, in order to deliver an efficient and low-carbon freight system over the coming 30 years". (www.nic.org.uk/news/evidence-sought-future-uks-freight-infrastructure).

Conclusion and recommended policy options

Even though examples of successful policy interventions directed at reducing the number of trucks and kilometres driven by trucks exist, the relatively stable high-level statistics on mode split and a limited voluntary uptake of measures such as urban consolidation centres shows that it is inherently difficult to modify freight operator's behaviour. As transport cost is often a relatively insignificant part of the total cost of goods and services, supply chain decisions can be primarily driven by various other elements such as labour costs or time pressures. To maximise the chances of a policy package being successful, policy makers need to be aware of this wider context shaping the way in which the shippers, freight forwarders and carriers operate. The main recommendations regarding policy options related to the content of this chapter are:

1. An integrated approach to policy making is needed. Infrastructure should be considered as one of the foundations of a sustainable freight transport system, as it is a key enabler of environmentally and socially responsible freight activity. Measures designed to improve the environmental performance of road freight transport can often contribute to a longer life span of road assets. Where this is not the case, a multi-modal, cross-function and multi-stakeholder approach enables a reasoned social trade-off assessment to be made.
2. The focus should be on creating a comprehensive regulatory environment, rather than on single measures. Policy aimed at extending the life of road assets is best supported by bundles of appropriate measures including cross-modal infrastructure investments, performance-based standards and coherent pricing structures for infrastructure use that encourage shippers, forwarders and carriers to reduce the number of trucks and the number of kilometres driven by them.

The governments developing policies aimed at minimising the impact of trucks on road assets face multiple challenges. Often decisions have to be traded-off against other priorities related to economic growth, impact on air pollution and Green House Gas (GHG) emissions, accessibility, safety and working standards, etc.

Policies focusing on mode shift are particularly relevant if significant reductions in road and bridge wear are to be achieved, as they offer a potential to remove large volumes of traffic from the road network. As the mode split in most developed countries has been relatively stable over the last decade, a further intensification of efforts seems to be necessary to encourage further uptake of rail and waterborne freight transport. In order to maximise the efficient use of different transport modes and their infrastructure, policies should address multiple stakeholders (e.g. shippers, forwarders, carriers and network operators) representing all modes, not just road.

There is also a pressing need to increase the collaboration between transport authorities responsible for the infrastructure related to different modes of transport to enable a better cost-benefit analysis of proposed solutions. There are a few examples of countries (e.g. Finland, Netherlands or Sweden) that have infrastructure authorities responsible for multiple transport modes. This allows a more integrated approach to policy making and decisions related to infrastructure investment, resulting in optimisation at the system rather than individual mode level.

However, care should be taken to ensure that a policy introduced by one country or region does not have any unintended consequences on the neighbouring localities. For instance, road pricing may result in better load utilisation and reduced freight traffic levels in the affected area. However, trucks operators will simply use alternative routes, often in order to save costs, resulting in increased road and bridge wear elsewhere.

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CHAPTER 8

Summary

Transport agencies around the world face the challenge of providing and managing road assets to meet a rising demand for road freight transport while simultaneously dealing with constrained budgets, competing governance priorities, and a changing climate. The policy options presented in this report offer opportunities to sustain or improve the robustness of road assets, stabilise infrastructure budgetary requirements, and enable road assets to support healthy economies. The options presented in consider how to mitigate the deterioration of road assets (pavements and bridges) from a demand-oriented perspective. This perspective acknowledges the complex mechanisms of road asset wear and damage, but aims to contribute new insights about how best to respond to current and projected freight transport demand, regulate the demand for truck transportation, and influence the magnitude and nature of freight transport demand. This final section presents the principal conclusions and recommendations of the report.

Trucks matter! Understanding road freight transport demand is critical for mitigating the wear of road assets caused by trucks. While the extent, nature, and rate of asset deterioration depends on construction and maintenance practices, materials, and environmental factors, there is a growing need to improve infrastructure performance by better responding to current and future truck transport demands.

Go beyond counting trucks! To a degree, current road infrastructure design and maintenance practices account for the number of trucks expected to use the asset over its life. To prolong asset life, however, more detailed information about road freight transport demand is needed, including:

- Geographic and modal distribution of freight transport demand.
- Interrelationships between commodities, trip distances, and truck configurations.
- New logistics trends, digitalisation, and automation within the truck transportation industry.

Consider data as an asset. The importance of data within asset management has motivated many transportation agencies to consider data itself as an asset. This emerging perspective creates both opportunities and challenges. More determined efforts to manage data are needed to overcome these challenges and enable these data to be used more effectively to manage physical road assets—in the long-term and in real-time.

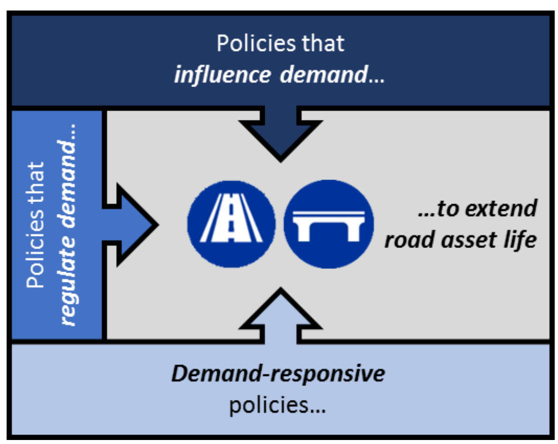
Don't be too late for the future. There is a need to involve infrastructure providers and asset managers early in the process of implementing new technologies and logistics systems. The life expectancy for bridges is 40 to 100 years and for pavements is 5 to 35. Adapting infrastructure design and maintenance practices takes time, so start early to facilitate improved planning, budgeting, and execution.

A sustainable and economic network can only be established by a proactive approach. A proactive approach to asset management will be needed to handle the problems of ageing infrastructure. With this method, major structural damage can be prevented before it occurs and optimal utilisation of the asset can be achieved over its lifetime.

Include regulating and influencing road asset use by trucks in the usual toolkit of civil engineers. The projected growth in freight volumes means that there will be sustained increases in the tonne-kilometres of freight moved by heavy vehicles. This forecast, coupled with fiscal constraints that impact road asset maintenance and capital investment programmes, means alternative and innovative regulatory approaches need to be included to complement conventional options considered by policy makers and road asset managers. The 'do nothing' approach to regulation is not sustainable, as the result will be an ongoing increase in the volume heavy vehicle traffic, and the potential for increased wear of road infrastructure.

Integrating perspectives is a precondition for prolonging asset life. Planning, construction, maintenance and rehabilitation of infrastructure is a long-lasting process and future needs are difficult to perceive with increasing population and traffic loads and a changing climate. It is particularly challenging to adapt the maintenance and rehabilitation strategies of existing infrastructure built many years ago. Overcoming these issues requires improved interaction between experts (infrastructure, vehicle technology, regulations, traffic management, logistics), infrastructure owners and policy makers. Engage with demand side actors to optimise the management of road assets.

Figure 8.1: Demand-oriented policy categories considered in this report to extend road asset life



The report considered three policy categories (see Figure 8.1):

1. **Demand-responsive policies***:* Prolonging road asset life requires better alignment of infrastructure maintenance and management actions with current and future road freight transport demand. This means better utilizing financial, human, and technological resources to plan, design, inspect, and maintain road infrastructure and adopting more proactive and systematic approaches to asset management

   a. Introduce step-by-step plan for a proactive approach for the maintenance of road assets as it has become critical to ensure a robust network and efficient cost management vis-a-vis increased road use by trucks and climate change impacts.

   b. Build a proactive, data-driven approach to the maintenance of road assets which models development in demand and traffic and anticipates growing demands on the network. For trucks users this will translate into a higher service level (LOS), expressed in terms of traffic safety, road capacity, accessibility, user mobility and finally ride quality and comfort.

c. Strive for continuous professionalisation in asset management, building development plans and backing these up with sufficient resources for development. Establish the elements of a future-proof asset management system including: (1) planning approaches to respond to variations in user requirements, (2) explicit consideration of risk in asset management, (3) access to data from advanced ICT systems and (4) effective governance arrangements for cross-jurisdictional alignment.

d. Extend asset management across assets, towards cross-asset optimisation (CAO). For road organisations that have mastered asset management practices for individual assets (a road section or a bridge) or groups of assets (e.g. bridges, and roads), the next challenge is to apply and harmonise practices across all assets to support door-to-door trips.

2. **Policies that regulate demand**: Road infrastructure protection is a common objective of truck regulation and enforcement. However, the pursuit of regulatory compliance typically occurs outside the civil engineering domain and without a clear understanding of the complexities of asset management. The policies in this category aim to close this knowledge gap.

   a. Adopt regulatory frameworks that treat the use (and consumption) of road assets as an economic input, aiming to improve the productivity of road transport and the utility of road use.

   b. Implement infrastructure pricing and introduce market incentives to improve the recovery of costs and to encourage behavioural change in transport operators.

   c. Establish the reasons for non-compliance with regulations so that the right approach can be selected for an effective compliance framework.

   d. Move towards innovative approaches to regulatory design and compliance approaches, which include a combination of 'carrots' and 'sticks' with the emphasis on positive incentives.

3. **Policies that influence demand:** To our knowledge, the policies in this category have seldom been thoroughly considered as opportunities to extend the life of road assets. While fraught with complexity and uncertainty, these policies aim to purposefully influence real-time and longer-term road freight transport decisions and behaviours. Gradual and careful integration of these policies as asset management strategies diversifies the toolkit normally considered to extend the life of road assets.

   a. To cope with the uncertainties associated with the development of digital infrastructure for truck traffic management, develop use cases (the different ways of road utilisation by different groups of road users at specific locations, for example long distance road freight transport on motorways) and related business models. Within these use cases research can be done on what is required of digital infrastructure in order to achieve an effective implementation of truck traffic management.

   b. Create benefits for the logistics sector (fewer road works, wider access to areas or objects with limited access, less travel time and higher delivery time reliability) from implementing truck traffic management systems in order to increase the willingness to share in-vehicle and in-house company data. Making use of such data should reduce the costs of truck traffic management strategies.

c. An integrated approach to policy making is needed. Infrastructure should be considered as one of the foundations of a sustainable freight transport system, as it is a key enabler of environmentally and socially responsible freight activity. Measures designed to improve the environmental performance of road freight transport can often contribute to a longer life span of road assets. Where this is not the case, a multi-modal, cross-function and multi-stakeholder approach enables a reasoned social trade-off to be made.

d. The focus should be on creating a comprehensive regulatory environment, rather than on single measures. Policy aimed at extending the life of road assets is best supported by bundles of measures such as cross-modal infrastructure investments, performance-based standards, and infrastructure pricing that encourages shippers, forwarders and carriers to reduce the number of trucks and the number of kilometres driven by them to achieve the freight task.

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Policies to Extend the Life of Road Assets

This report presents policy options for extending the life of road assets by mitigating deterioration caused by trucks. Beyond traditional engineering responses, it considers the role of trucks in road asset deterioration from a broader, demand-oriented perspective.

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