TRUCKS MATTER! PROACTIVE MAINTENANCE AND ASSET MANAGEMENT TO EXTEND THE LIFE OF ROAD ASSETS





A. ZOFKA
Full Professor at Road and Bridge Research Institute (IBDiM), Poland. Obtained his PhD from the University of Minnesota, USA

L. TAVASSZY
Full Professor in Freight and Logistics at Delft University of Technology, Netherlands.

A. ŽNIDARIČ
Researcher and current director of Slovenian Nat. Building and Civil Eng. Institute (ZAG). Obtained his PhD from the University of Ljubljana, Slovenia

T. MOSER
Asset Manager at ASFINAG (Operator of the Austrian motor-ways and express-ways). Obtained his PhD from the University of Natural Resources and Life Sciences Vienna.

P. PAFFEN
Teamleader, Division for large projects/ maintenance, Rijkswaterstaat, Ministry for Water State and Infrastructure, the Netherlands. Drs./M.Sc. Univ. of Amsterdam.

Abstract
Transport agencies in both developed and developing economies face problems with ageing infrastructure, 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 urgent. In this context, digitalisation offers new opportunities.

The OECD-ITF working group *Policies to Extend the Life of Road Assets* (2017-2018) brought together policy options for extending the life of road assets by mitigating deterioration caused by trucks. Beyond traditional engineering responses, they considered the role of trucks in road asset deterioration from a broader, demand-oriented perspective. This resulted in 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. The new policy framework contains three groups of policy measures: demand-responsive policies; policies that regulate demand; and policies that influence demand.

The OECD-ITF working 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. For the HVTT16, under the name *Trucks matter!* the working group *Policies to Extend the Life of Road Assets* has elaborated the new demand-oriented policy framework in four papers, illustrated with current best practices and experiences.

Keywords: Heavy Vehicles, Asset Management, Proactive Maintenance, Digitalization, Enforcement, Regulatory Framework, Traffic Management, Logistics Management

1. Introduction

Transport agencies in both developed and developing economies face problems with ageing infrastructure, yet 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 urgent. In this context, the proliferation of unconventional data sources and digitalisation offer new opportunities to manage assets in response to road freight transport demand and to regulate and even influence this demand.

In 2017-2018, the OECD-ITF convened a working group to develop new policy options for extending the life of road assets by mitigating deterioration caused by trucks. The working 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. Beyond traditional engineering responses, the group considered the role of trucks in road asset deterioration from a broader, demand-oriented perspective. This resulted in 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. The new policy framework contains three groups of policy measures: demand-responsive policies; policies that regulate demand; and policies that influence demand (ITF, 2018).

As a special contribution to the HVTT16, under the theme 'trucks matter!', members of the working group have elaborated the new demand-oriented policy framework through four papers. The four papers will examine: (1) the need for the new policy framework (this paper), (2) proactive maintenance and asset management, (3) supportive regulatory and compliance frameworks, and (4) traffic and logistics management. Each paper will illustrate policies using best practices and experiences from around the world.

This paper deals with proactive maintenance and asset management. Such a strategy relies primarily on the prevention of damage by forecasting performance and by rational risk management. The effects of a proactive strategy are coordinated activities that in an informed and controlled manner allow road managers to provide the appropriate level of services, prepare infrastructure for future challenges and meet the strategic goals of an organisation. A proactive strategy is an alternative to the traditional reactive strategy, where corrective actions are taken only after a failure occurs. Therefore the reactive strategy in road asset management has led in many developed countries to the current infrastructure crisis and huge overdue costs required to restore the road infrastructure into a satisfactory condition. Nowadays, there is a shift towards a proactive strategy in these developed countries. Although its introduction is most effective when the infrastructure is relatively new, as it is the case of Poland, at least at the national and voivodeship level. In a broader context, a proactive strategy should be introduced and continued at all stages of the asset lifecycle, starting from the concept phase and investment planning through recycling and disposal.

2. A demand-oriented policy framework to extend the life of road assets

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.
- *Policies that regulate demand*: The pursuit of regulatory compliance typically occurs outside the civil engineering domain and without a clear understanding of asset management complexities. 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.

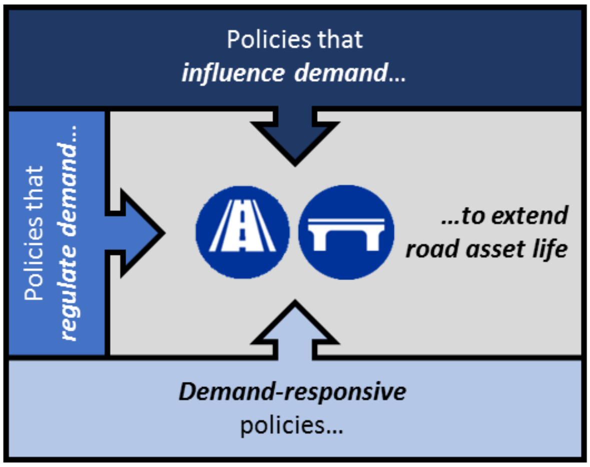

Figure 1. Polices to extend the life of road assets (OECD, 2018).

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.

Road authorities and policymakers face complex choices throughout the lifecycle of road infrastructures. Planning, design, construction, operation, maintenance, rehabilitation and more and more expansion of infrastructure are long-lasting processes affected by increasing population and traffic loads and changing climate. Under such circumstances, future needs are difficult to perceive. A significant increase in road freight movements is expected in the next decades. This translates into a growth in truck traffic that consequently contributes to the 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., and may exceed 30% of the total volume of truck traffic. While it is challenging to determine the exact consequences of overloading, some research studies suggest that 20% of vehicles overloaded may reduce the pavement service life 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 the 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, which can have significant unfavourable consequences for the owner, users and environment. Particularly the old, heavily loaded and already damaged road networks often face resource bottlenecks, which affect maintenance and influence traffic safety and mobility. Such an approach is not sustainable and should be avoided by network administrators to mitigate financial and environmental burdens for future users and generations. Thus there is an urgent need to replace a traditional reactive approach with a proactive approach to maintenance.

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 & Benbow, 2016; PIARC, 2016) provide state-of-the-art reviews of pavement condition assessment techniques.

From the survey data, parameters of physical pavement condition are calculated. 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 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. Specifically, in the context of increasing truck traffic, such reactive approaches 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 top-layer pavement condition are 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, technology developments have allowed a collection of information on bearing capacity on a more regular basis and with non-destructive-techniques at 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 countries (i.e. Poland, Germany, UK, Australia, Italy, China, USA).

Bridge maintenance

Bridges are designed for 75 to 100 or even 120 years, compared 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 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 that stage, the most beneficial monitoring techniques are measurements of actual traffic loading and structural behaviour under traffic loading, to measure reserves that otherwise could not have been considered in the analysis. Various tests to assess steel and concrete characteristics and degradation processes 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. It should include an 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, particularly traffic, and the structure's behaviour under the moving vehicles. Unfortunately, today's practice with respect to bridge management and maintenance policies is often based on current condition (deterioration) only, resulting in demand-driven, not proactive maintenance. This can lead to excessive spending on strengthening and replacing bridges. Instead, infrastructure owners should benefit from collecting structural and traffic information. Associating monitoring data with advanced assessment techniques and appropriate modelling and economic analyses can prevent many bridges from the most severe rehabilitation measures and load restrictions. Today, the important bridges with high traffic volumes are often already monitored and proactively maintained to avoid significant damage. Unfortunately, this is seldom the case for smaller bridges, which can cause similar traffic jams due to repairs or replacement. Lack of proactive maintenance can ultimately result in the most rigorous measure, bridge replacement.

3. Results – best practices

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 a proactive maintenance strategy, damage growth is anticipated and often predicted, so appropriate actions are taken ahead of time (Figure 2), even before any signs of damage are detectable (Zofka 2018). This is especially needed now because of the expected increase of road freight and consequently 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 experiences. A need exists for the advanced algorithms for stochastic forecasting of wear and capacity evolutions, and for relevant supporting information. This information goes beyond the existing databases, containing data on traffic volumes and climate or damage inventories, used today as key inputs for decision making. In this context, digitalisation of the transport infrastructure sector, including machine learning, neural networks or artificial intelligence, will play a key role.

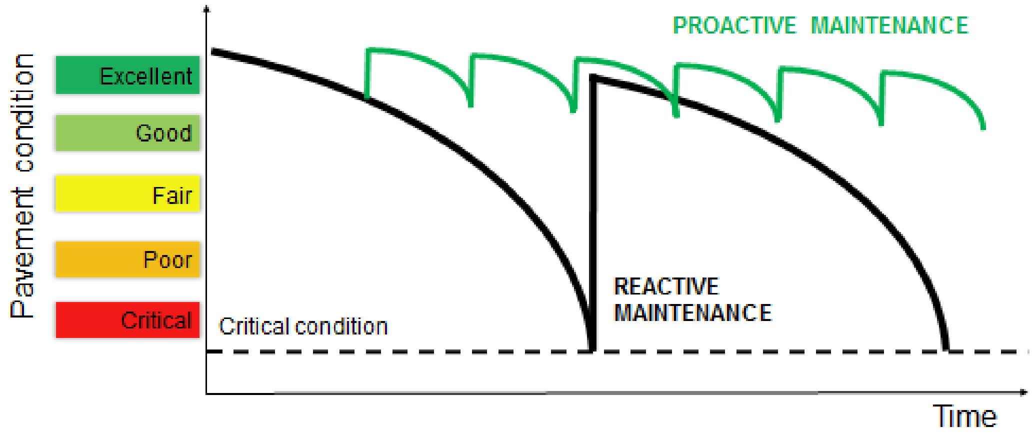

Figure 2. Comparison of proactive vs reactive maintenance (Zofka, 2018).

A proactive maintenance strategy is the ultimate goal, but realistic transition scenarios consider the 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 standard practice since it supports effective network management, with the lowest agency and social costs as well as the smallest environmental footprint.

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.

Components of risk analysis are the risk identification and the risk assessment both for individual structures as well as for the interdependencies in the road network. Risk-based CBA should account for not only direct agency costs but must also include various social and environmental aspects. Reliability analysis and stochastic elements allow 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 the 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 right procedures now with a self-assessment feedback loop based upon correct KPIs (Key Performance Indicators), 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.

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. This 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 the 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, the influence of measurable deterioration processes on the 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 the 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, which load effects (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 the bridges.

4. Conclusions

Based on the work of this OECD group, the following policy options have been recommended:

1. Gradually implement elements of a proactive approach to the maintenance of road assets, as it has become critical to provide a robust network and effectively manage maintenance costs, due to the growing and changing use of road assets by trucks and developments like climate change. Accordingly, it is recommended to:

   a. Introduce and maintain the culture of 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 innovative solutions in the future.

b. Introduce educational initiatives that focus on comprehensive reliability-centred maintenance (RCM).

c. Include various risk-based elements into CBA, such as technical, social and environmental aspects.

2. Build a proactive and data-driven approach to the maintenance of road assets which, in the case of trucks, 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. 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 a proper framework to enforce reliable quality assurance of processed data. Promote linkage between various data sources, such as construction, climate, weather and traffic data necessary for proactive maintenance. Follow developments in digital technology and support new concepts such as big data, smart data, and artificial intelligence that will take a greater role in the decision support for maintenance planning in the near future.

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