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Exploring information needed in maintenance backlog-related decision-making in the Finnish road network

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Received 9 July 2024
Revised 4 November 2024
21 December 2024
Accepted 30 December 2024

Abstract

Purpose – Road maintenance backlog (MB) is increasing rapidly in many countries, partly as a result of the changing climate conditions, increasing traffic volumes and insufficient funding for maintenance. This study aims to identify the type of information used and needed when making decisions concerning the MB of the road network.

Design/methodology/approach – This qualitative study involved 21 semi-structured interviews with experts in Finland, including road authorities (7), politicians (3), maintenance specialists (4) and business representatives (7). Participants were selected using purposive sampling based on criteria such as professional designation, knowledge and experience in the field. The data were analyzed using content analysis.

Findings – At the operational level, most information pertains to the technical condition of the road network. At higher decision-making levels, MB is used more as a monetary value and a basis for budgeting. More information is required on the impact of changes in road conditions in terms of safety, the social economy, companies' operational capabilities, logistics and CO2 emissions. These impacts need to be quantified in monetary terms for society as a whole.

Research limitations/implications – This research covers the years 2018–2022. Although Finland served as the target country for this study, we believe that the results, presented at the political decision-making level, can be adopted and modified for countries with similar governmental decision principles and where further justifications for funding decisions are required. Additionally, insights from the asset owner perspective can assist road authorities in developed countries, while operational-level findings can be applied to other developed countries with similar geographical characteristics. The results of this study were collected from an industrialized country for the years 2018–2022. Consequently, the applicability of these findings to different time periods and countries may be limited.

Practical implications – With the help of these findings, road authorities will be able to make decisions in a more data-driven way, which has long-term economic implications.

Originality/value – The results of this study will provide information that can be utilized by decision-makers at various levels. The research has scientific value, and in addition, the results presented in the study can lead to changes in practical applications in the field, which in turn have societal and economic impact.

Keywords Maintenance backlog, Decision-making, Road network, Maintenance, Condition monitoring, Maintenance management

Paper type Research paper

The authors would like to thank The Finnish Transport Infrastructure Agency for the financial support and co-operation.

Built Environment Project and Asset Management
Vol. 15 No. 2, 2025
pp. 271-287
Emerald Publishing Limited
e-ISSN: 2044-1258
p-ISSN: 2044-124X
DOI 10.1108/BEPAM-05-2024-0131

1. Introduction

Roads are a vital component of infrastructure. Developing countries are currently in the phase of constructing functional infrastructure, whereas the existing road networks in developed countries predominantly date back to the 1960s and 1970s. The quality of existing transportation infrastructure is considered a critical foundation for the economy. Transport infrastructure can depreciate if not properly maintained, leading to an increase in the maintenance backlog (MB). For instance, the road MB in South Africa for provincial and municipal roads was estimated to be six to eight times higher than the amount spent on road maintenance by provinces and municipalities in 2017/2018 (Ross and Townshend, 2019). Similarly, in the United States, the MB for existing roads was estimated at $435 billion (ASCE, 2021). In contrast, Denmark can maintain a safe and high-standard road network without any backlog by ensuring maintenance funding through data-driven asset management and by optimizing infrastructure investments (Ebbesen, 2021). The aim is to minimize the total life cycle cost of the road network while maintaining the agreed service level (Ebbesen, 2021).

To minimize and control MB, it is essential to know what data or information is required for decision-making at various levels from operational to political. Good decisions are effective only when they are based on accurate, relevant, and up-to-date information (Laihonen *et al.*, 2013). The requirement for this information may be different on each occasion – for some decisions, superficial knowledge is sufficient, some require only investigation or evidence-based results, some use tacit expertise, and others require creative insight, intuition, and judgment (Bennet and Bennet, 2008; Snowden and Boone, 2007). A company's potential to effectively use the information gathered during day-to-day activities is called business intelligence (Shollo and Kautz, 2010). Although a piece of information is not automatically valuable, collecting unnecessary information can impair business decisions. Valuable information needs to be both relevant and available to the user at the right time and in the right format. To affect decision-making situations positively, information needs to be further construed (Laihonen *et al.*, 2013).

Previous literature contains information that can be used at the operational level. Example Vitalis and Ephather (2022) conducted tests with falling weight deflectometers (FWD) in Tasmania to estimate the remaining life of flexible pavement, and Pantuso *et al.* (2019) examined what kind of information is effective at network level pavement management in Kazakhstan. However, the findings do not clarify what information is needed or missing, and especially what information is used at different decision-making levels. This paper aims to address the gap that currently exists and point out information used, needed, and missing when making decisions concerning MB. The main research question in this study is:

(1) What data and information are required to make decisions concerning the management of MB?

To unravel the answer to the main question, three sub-questions were defined:

(1) What decisions are made regarding the road maintenance backlog at various levels of decision-making?

(2) What information is available in decision-making situations?

(3) What information is missing or insufficient?

The structure of this article is as follows: Section two presents the basics of road MB in Finland, along with relevant studies from the literature that relate to MB of road network and condition monitoring. Next, section three discusses the chosen research methodology. Section four examines the results obtained in the study, with a summary of the findings presented in section 4.5. This is followed by a discussion in section five and a conclusion in section six.

2. Literature review

2.1 Maintenance backlog

The maintenance backlog (MB) of roads in Finland has been systematically calculated since 2009, following the principles and stages outlined in the backlog study of the ERANET ROAD research program (Aijo and Virtala, 2011). In both the aforementioned research program and this paper, maintenance backlog is defined as follows: *"The maintenance backlog of road infrastructure represents the amount of unfulfilled demands at a specific point in time, explicitly referencing predefined standards to be achieved. Maintenance backlog can be expressed in either functional (non-monetary) or monetary terms and pertains to individual components, sub-assets, or the entire road infrastructure asset"* (Weninger-Vycudil *et al.*, 2009). Over the years, calculation methods have evolved, and today, the calculation and utilization of this information is a standard annual procedure in Finland (Mannisto, 2023). Typically, MB is expressed in monetary terms, whereas road condition is described using technical parameters. It is important to note that alternative definitions for MB exist, particularly across different disciplines. In contrast, Affan (2022) questions why there is such a thing as MB. He is justifying his opinion with the lack of consistent definitions for "maintenance" and "MB", but most of all with the need to shift the focus from MB to asset management.

In Finnish MB calculations, assets are categorized based on their type and maintenance category (FTIA, 2021). For instance, paved roads (assets) are managed under three different maintenance categories, each with five condition levels: very good, good, acceptable, poor, and very poor. Bridges are another example of assets. The assessment of each category is conducted through measurements, expert inspections, visual inspections, or estimations based on the asset's age and usage (Aijo and Virtala, 2011). The primary functional condition properties evaluated for paved roads include rutting, roughness, and surface defects such as incorrect lateral inclination and cracks (FTIA, 2021). If an asset's condition is classified as poor or very poor, it meets the criteria for unfulfilled demands and, consequently, the criteria for MB (FTIA, 2021).

Each country defines its own condition criteria and threshold values to be used. Consequently, a given measured roughness value may meet the criteria for good condition in one country but can be classified as poor in another. The latest maintenance backlog (MB) calculation for public roads in Finland was conducted in 2023, with the estimated MB value being approximately €2,550 million (Traficom, 2023). Over the past decade, the total length of paved roads in poor condition in Finland has doubled, now reaching 8,800 km (17%) (Traficom, 2023). The strategy of the Finnish Transport Infrastructure Agency (FTIA) aims to prioritize the maintenance of main roads. In practice, the length of main roads in poor condition has consistently ranged between 1,000 and 1,300 km over the past decade (Traficom, 2023). Concurrently, the length of other roads in poor condition has shown an upward trend (Traficom, 2023).

Consequently, decision-makers must consider both the physical state of the road infrastructure, and the monetary value associated with the MB. According to the literature, the underlying reasons for the MB of roads are presented in Table 1.

It is noteworthy that opinions diverge regarding maintenance measures other than paving. For instance, the impact of drainage efficiency on road deterioration has been studied by numerous researchers, e.g. by Austroads (2024) and Hatmoko *et al.* (2019), and the significance of effective drainage in slowing down road deterioration is indisputable. Additionally, winter road maintenance, particularly the use of salt on thin pavements (Saarenketo *et al*., 2022; Wang *et al.*, 2021), as well as delayed snow clearance from the road shoulders, has been proven to be associated with pavement deterioration (Saarenketo *et al*., 2022).

A key principle of road maintenance is that today's investments can result in significant future savings, not only in maintenance expenses but also in broader societal costs. World Road Association (2014) has presented these as "*factors which drive the importance on road*

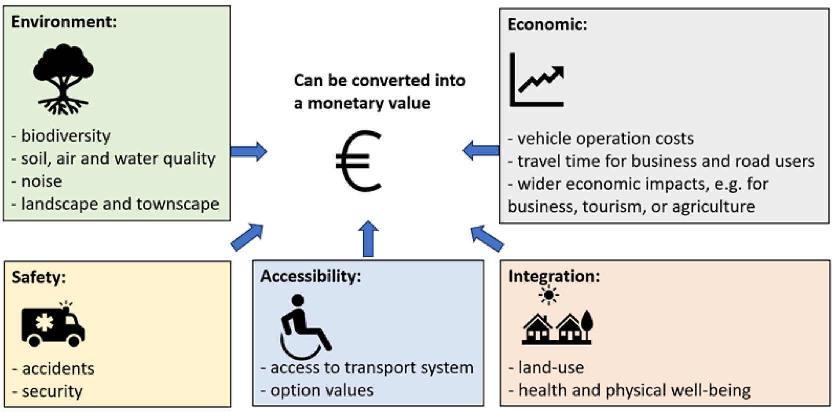
Table 1. Underlying reasons for the MB of roads according to literature

Underlying reason authors	Schliesser and Bull (1993)	Gahm (2008)	Giglio *et al.* (2018)	Chen (2023)
Absence of a system ensuring adequate financing	x			
Competition of the budget with other allocations by treasure				x
Agencies' lack of accountability/Ineffectiveness and inefficiency	x		x	
Relative unattractiveness of road maintenance to politicians			x	
Highly prioritized new road investments compared to road maintenance		x	x	
Highly prioritized winter maintenance, cleaning, and grass mowing measures compared to other maintenance measures such as road paving		x		
Poor communication between road authorities and politicians		x		
Complicated decision-making bases		x		
Invisibility of road structure deficiencies to road users		x	x	

maintenance" (Figure 1). Whereas Salem *et al.* (2013) has called these "*user costs*", in rehabilitation alternative evaluation study. In any case, neglecting maintenance impacts the condition of roads, which in turn has consequences for safety, the environment, the economy, the integration, and the accessibility.

Studies on the relationship between road condition and safety have been conducted by, among others Cafiso *et al.* (2021), and Mkwata and Chong (2022). Whereas Khan *et al.* (2023) and Setyawan *et al.* (2015) studied the effect of pavement conditions on vehicle speeds (travel time - > economic impacts) and motor vehicle emissions (air quality → environmental impact).

Johnston *et al.* (2018) created two budget scenarios for road maintenance over a 20-year timeline in Scotland and calculated the overall impact on society (including the drivers presented in Figure 1). Similar research made by Thiessen *et al.* (2017) presented a scenario of a temporarily increased budget in England can provide a benefit in terms of reduced user cost



Source(s): Developed from World Road Association (2014); Parkman *et al.* (2012)

Figure 1. Drivers of the road maintenance

of £2.70 (discounted) for each extra £ 1 spent on direct work cost. Correspondingly, reducing the budget for 5 years resulted in a reduction in benefits of £2,90 for every £1 saved in direct costs.

The previous research elucidates the potential consequences that can arise from inadequate maintenance. It is noteworthy, that the precise numerical values presented in these studies, cannot be directly transferred from one country to another. To achieve accurately representative values, calculations must be adjusted to align with the specific context of the destination country. In Finland, corresponding studies on the effect of road conditions on fuel consumption have been conducted by FTIA (2019), Mantynen *et al.* (2022), and Virtala (2010). Conversely, Ristikartano *et al.* (2015) examined the impact on vehicle speeds and accidents, while Holm and Tyynila (2022) estimated that the length of truck transportation time would increase by 10% due to more advanced road deterioration. However, no research has been found that evaluates the consequences for society as a whole or converting these effects into monetary values specific to Finland.

2.2 Information concerning road condition

Literature review results agree on the importance of maintenance of roads (e.g. Burningham and Stankevich, 2005; Wall, 2021; World Road Association, 2014). When monitoring the condition of roads, the most important measurable attributes are (Harvey, 2012):

(1) "Roughness, measured in meters per kilometer (International Roughness Index, IRI);

(2) Rutting, measured by rut depth;

(3) Cracking, measured by the percentage of area cracked;

(4) Pavement strength, measured by modified structural number."

The first three attributes as stated by Harvey are still the most frequently used in the USA (Marcelino *et al.*, 2019). Peraka and Biligiri (2020) have separated the road condition information into structural and functional condition information. Example France uses a combination of the surface (functional) and structural indices. The surface indicator depends on skid resistance, transverse evenness, and texture. The structure indicator depends on cracking rate and deformations (Marcelino *et al.*, 2019). As Saarenketo *et al.* (2022) stated, the dysfunctionality of the drainage system increases deterioration in Finland, and therefore the monitoring of the condition of drainage structures cannot be overlooked.

Current literature presents a wider selection of indicators, as well as the latest assessment methods at hand. Peraka and Biligiri (2020) categorized information collection methods into manual, semi-automated, automated, and cost-effective methods. Findings suggest that the unique nature of each national road administration results in the definition of road network requirement at a national or local level, based on specific experiences, expectations, resource availability, and the knowledge of local needs.

In addition, when observing the condition of a road, it is necessary to employ pavement inventory data, design information, maintenance history, and auxiliary information (Peraka and Biligiri, 2020). Chong *et al.* (2019) collected, listed, and categorized factors on maintenance prioritization from publications 1990–2016. The factors were labeled as technical, financial, social, and political. The ten most used factors in descending order in Chong *et al.* research (2019) were: condition, maintenance cost, occurrence, severity, importance of usage, safety, time, resource, nature of asset, and risk. The findings presented can be used when making decisions concerning maintenance of roads.

2.3 Organization of road maintenance in Finland

In Finland, the Finnish Transport Infrastructure Agency (FTIA) is a public agency responsible for asset management of public roads, railways, and waterways (FTIA, 2024b). Based on public funding (Parliament of Finland: politicians), the operation of FTIA is controlled by the Ministry of Transport and Communication. The Centers for Economic Development, Transport, and the Environment (ELY Centers) are responsible for the regional implementation, and development tasks of the central government. ELY Centers are responsible for maintaining a total of 78 00 km of public roads, including adjoining structures (Traficom, 2023). Road maintenance and paving work have been outsourced to companies competing and operating in the open market (FTIA, 2024b). This means that maintenance backlog decisions are made at various organizational levels. Nordic climate, studded tires and heavy vehicle loading (maximum truck weight limit of 76t) are the main reasons for pavement deterioration and maintenance needs (Belt *et al.*, 2000; Finlex, 2020; FTIA, 2024a).

3. Research methodology

Qualitative research was selected as the research method due to its effectiveness in addressing the research questions. This method allows for an exploration of the quality and meanings of phenomena, aiming to uncover the "what," "why," "when," "where," "who," and "how," rather than merely quantifying events (Lim, 2023; Islam and Aldaihani, 2022). Interviews were employed as the data collection method, as they yield insights into experts' perspectives, experiences, and ideas. Furthermore, interviews facilitate a deeper understanding of causal relationships (Islam and Aldaihani, 2022; Qu and Dumay, 2011).

The interviews were conducted as semi-structured interviews, as this format allows for a more flexible dialog between the interviewer and the interviewee compared to structured interviews. Both parties have the freedom to deviate from the initial questions within the thematic framework, enabling the collection of more nuanced information regarding the research topic. Semi-structured interviews facilitate two-way communication, allowing the researcher to guide the discussion while also following the interviewee's insights, thereby permitting more detailed inquiries related to various research themes (Evans and Lewis, 2018; Saunders *et al.*, 2018). This study, covering the years 2018–2022, aimed to gather information about the current situation and extend the results across two different government terms.

A total of 21 semi-structured interviews were conducted for this study. This number provided a diverse perspective on the research topic. Additionally, the chosen number fit within the available resources and timeline. The primary focus in identifying interviewees was their professional role. Therefore, relevant organizations for the study were first identified, followed by individuals within those organizations who had influence and knowledge related to the research questions. Potential interviewees were approached via email. Only one candidate could not be reached; the others were willing to participate in the study. Therefore, key experts from various decision-making levels, each possessing a minimum of 15 years of experience in the field, were selected for interviews. Within the Finnish road authorities, seven individuals from the Finnish Transport Infrastructure Agency (FTIA), ELY Centers, the Ministry of Transport and Communications, and the Ministry of Finance were interviewed, all of whom play crucial roles in road maintenance decision-making. Additionally, three politicians were interviewed, as they have the capacity to influence budgetary decisions. Furthermore, four specialists in maintenance and seven experts in business and social economy were also included in the interviews. The selection criteria for maintenance experts focused on their experience in data collection, road condition assessments, and maintenance backlog (MB) analysis, while the business experts represented the Finnish national economy, business sector, and industry. The profiles of the interviewees are presented in Table 2.

Qualitative content analysis was employed as the method for data analysis, enabling the examination of meanings, consequences, and relationships among phenomena. This approach relies on the classification of textual data, involving the systematic examination and quantification of the meanings of words or concepts to enhance understanding of the topic (Calefato *et al.*, 2016). The coding process follows a structured progression, beginning with open coding and culminating in the integration of codes into coherent code families (Strauss

Table 2. Profiles of the interviewees

Interviewee	Position	Category		Degree of education	Experience in the field
1	Director	Road Authority	Public sector	MSc (Eng) and MBA	~30 years
2	Senior Adviser	Road Authority		MA	~35 years
3	Executive Manager	Road Authority		MSc (Eng)	~25 years
4	Executive Manager	Road Authority		BSc (Eng)	~25 years
5	Executive Manager	Road Authority		BSc (Eng)	~30 years
6	Senior Specialist	Road Authority		MSc (Eng)	~20 years
7	Budget Councellor	Road Authority		MSc (Econ)	~20 years
8	Policy Adviser of Minister	Politician		BSc (Eng)	>15 years
9	Member of the Parliament	Politician		MHCM	>15 years
10	Member of the Parliament	Politician		MSc (Ed)	>15 years
11	Specialist	Maintenance Specialist	Private sector	MSc (Eng)	>15 years
12	Specialist	Maintenance Specialist		MSc (Eng)	>30 years
13	Specialist	Maintenance Specialist		MSc (Eng)	>40 years
14	Specialist	Maintenance Specialist		DSc (Tech)	>40 years
15	Director	Business Representative		MSc (Eng)	~25 years
16	Senior Adviser	Business Representative		DSc (Tech)	~30 years
17	Director	Business Representative		MSc (Eng)	>30 years
18	Senior Adviser	Business Representative		MSc (Eng)	>20 years
19	Director	Business Representative		MSc (Eng)	>30 years
20	Director	Business Representative		DSc (Tech)	~30 years
21	Director	Business Representative		Incomplete undergraduate studies	~25 years

and Corbin, 1990). This study identified five code families: decisions, existing information about MB, missing information regarding MB, other information available for MB decision-making, and additional findings. These code families were subsequently cross validated across different decision-making levels. During the analysis, which was conducted after the interviews, it was observed that theoretical saturation was achieved with the results: the presented findings consistently represent the general responses of each group.

4. Results

4.1 General overview

Based on the interviews, maintenance backlog (MB) plays a significant role in communication and is utilized across various stakeholder groups. Consequently, the importance of MB should not be underestimated. Making data-driven decisions necessitates a comprehensive understanding of MB and the condition of road infrastructure. In the Finnish Parliament, Ministries, and FTIA, MB is primarily regarded as a monetary value. In contrast, ELY Centers perceive MB more as a requirement for maintenance operations and as an indicator of the kilometers of roads in poor condition. Business representatives focus mainly on the drivers of MB.

The results of decision-making situations, available, missing, and insufficient information on MB is presented in the following sections. First the political level is presented in section 4.2, second the asset owner level in section 4.3, and third the operational level in section 4.4. Section 4.5 illustrates the summary of the results. The most important results have been added to these sections; however, in section 4.5, all the results are summarized. The section 4.5 presents Figure 2 with all the necessary information on MB-related decision-making. The Figure 2 details the information that is already available, as well as the information that is missing but needed.

4.2 Political decision-making level: more information on the impacts

At every level of decision-making, the primary considerations are legislation and long-term plan. Additionally, political decisions are influenced by the societal climate. When politicians campaign for parliamentary seats, they make various promises both as individuals and as party representatives. These promises often include specific investment projects related to the road network. The most critical decision concerning the road network's maintenance backlog (MB) pertains to the road maintenance budget, which was a prominent topic during interviews with politicians. Although budgeting is not the only factor in determining the monetary value of MB in the future, the influence of the budget, however, is significant.

> Undoubtedly, the most influential factor is the prevailing societal atmosphere and the approach towards the business sector, including the development of our industry and logistics chain. It also encompasses how we perceive the enhancement and strengthening of Finland's vitality in the coming years and decades. (I9)

> MB is included in the budget process. During springtime we determine the financial frame where Finland's budget is forecasted for the years ahead and MB plays an important role in these conversations. In autumn we look at next year's budget. (I10)

In defining the road maintenance budget, the goals outlined in the government program, previous promises, actions, and agreements are reviewed. Politicians also receive information on the condition of the road network and the impacts of the MB from lobbying groups, local businesses, and residents. Therefore, politicians were aware not only of the monetary value of the MB but also of the total length of the deteriorated road network and the annual need for road resurfacing in Finland to prevent the backlog from increasing.

> Primarily, we perceive MB as a monetary value, measured in euros, and its monetary value is substantial. Additionally, we are aware of the extent of roads in poor condition. I believe we should be paving approximately 4,000 kilometers each year to reduce the MB. (I10)

Politicians have emphasized that there is insufficient information regarding the impact of the maintenance budget on the actual condition of the road network and, particularly, on the societal impacts of changes in condition. This was highlighted by each interviewee, not just politicians. Societal impacts should encompass environmental, economic, safety, accessibility, and integration aspects. Furthermore, information should be presented as visually and concretely as possible, with a sufficiently long timeline to clearly illustrate the direction of change. Although the interviewees had some basic understanding of the societal impacts of road conditions, the concrete figures and the overall situation were unclear. It is also important to specify changes in standards and legislation that affect the monetary value of the MB.

> What are the costs when roads are allowed to deteriorate, affecting the business sector and road users? What are the expenses incurred when longer distances must be traveled, and vehicles suffer damage? (I15)

> Perhaps it has simply been observed that the increase in costs has led to fewer paving kilometers. We have not been presented a timeline of MB that would indicate a catastrophe. (I7)

The quotations above represent only a portion of the related comments. However, all interviewees, regardless of their decision-making level, expressed similar views on the issue. According to interviews, politicians are striving to determine the most beneficial solution for society as a whole. Therefore, the information on societal impacts is essential in decision-making.

4.3 Infrastructure owner level: more information on life cycle costs

According to the interviews with road authorities, MB is included in the strategy of FTIA, and therefore needed in situations when strategies are being defined. MB is used as initial information, and as justification when FTIA is making annual and four-year programs, preliminary programs, and when planning and proposing budget. FTIA also evaluates how the programs and budgets will affect MB. Moreover, FTIA defines goals and budgets for ELY Centers. In addition, FTIA has defined key data figures in which MB is included directly or indirectly: (1) MB as a monetary value, (2) the highest recommended traffic volume in parts of the roads (by category) that are in poor or very poor condition, (3) how many kilometers of paved roads are allowed to be in poor or very poor condition, and (4) the satisfaction levels of different road user groups. The results are followed up annually.

In decision-making situations, the budget frameworks and goals presented by the Ministries are considered first. Additionally, information on traffic volumes, condition criteria, and condition measurements is required to determine the condition of road network. Furthermore, FTIA meets yearly with the forty largest Finnish companies to discuss their transport and logistics needs. Alongside these companies, as well as reports on the satisfaction of road users,

The inclusion of other groups of clients was found to be an especially important source of information.

> We have a very good and systematic customer service model, for example, where we meet about 40 of Finland’s largest companies every year or several times a year and talk about their needs related to transport and logistics and coordinate them with what we do. This is a good channel for us to acquire that information. We also meet organizations representing citizens, such as the Bicycle Federation or various organizations representing e.g. disabled people. (I1)

The infrastructure owner has the primary responsibility for overseeing road infrastructure management. The timely implementation of appropriate operations is a critical factor from a cost-effective lifecycle perspective. However, there is currently a lack of information for this purpose, as stated by the infrastructure owner and the representatives of operational level. The criteria for operation needs should align with cost-effective timing in all aspects.

> In my opinion, we lack an automated system that would allow us to precisely determine the cost effects of repairing a specific asset this year versus waiting three years. While we may be able to provide such information through individual examples, we struggle to do it from a holistic asset management perspective. (I1)

Similar statements to the one above were also highlighted in the interviews at the operational level. All emphasized the importance of selecting the appropriate actions and the timing of these actions in relation to cost-effectiveness and lifecycle.

According to the interviews, the quality of information on road condition is not sufficient with certain sub-assets. This is presented in section 4.4. In addition, there is no defined method for adjusting unit prices used in MB calculations in relation to economic cycles.

4.4 Operational level: more information on structural condition of roads

MB is directly or indirectly linked to most tasks executed in ELY Centers and is utilized in strategic and operational planning. When planning current operations, road authorities calculate how MB changes due to these activities. Additionally, MB is incorporated directly or indirectly into goal setting (by asset owner, FTIA).

> MB is connected to everything. If you start to dismantle this process, you start with results and financial management at the top. Then there is the strategic planning, then operational planning, and then programming. (I3)

When planning programs such as paving, structural repairs, drainage maintenance, and pothole filling, ELY Centers compare measured condition data with established condition criteria. At this point, other information required includes traffic modes and volumes, location of road, maintenance history, and environmental data. Consequently, in ELY Centers' documents, MB is primarily presented as the quantity of poor or very poor assets and their trends. Beyond this, ELY Centers conduct physical inspections to assess condition of road network, comparing visual observations with measured data.

The operational level has indicated that technical information on the structural condition of roads is lacking due to the discontinuation of systematic bearing capacity measurements. Specialists have confirmed that this lack of structural condition information has led to overly optimistic assessments. In the absence of structural condition data, monitoring focuses solely on functional condition.

> Structural condition is one thing which is missing. And perhaps it is the most important. There is also a lack of information related to drainage. Of course, it has been tested, but there is no systematic approach to that. And no national guidance. But it would probably be worth investing more because there are some knowledge gaps. (I4)

> However, there is one issue that I have criticized in the MB formula. Overwhelming emphasis has been placed in functional-related repairs. Meanwhile, structural issues are overlooked. (I14)

> I would consider the risk for contractor as a major issue, because the chosen operations are far too optimistic for the situation. (I17)

The above statements originate from the operational level, specialists, and business representatives. Therefore, it is evident that the knowledge gap is acknowledged by various groups, although their viewpoints on the issue differ.

The information on functional condition was found to be quite reliable because ELY Centers receive feedback from road users, contractors, and local authorities in addition to the measured data. However, road authorities have highlighted that while some information on road conditions is very precise, the quality of information for certain sub-assets is not homogeneous. Example of sub-asset which condition is based on specialist evaluation includes drainage (culverts).

4.5 Summary of results

The results of this study are summarized in Figure 2. The required information concerning maintenance backlog (MB) consists of available and missing or inaccurate information at different decision-making levels.

At all levels of decision-making, MB is essential when preparing budgets. Furthermore, road authorities require information on MB when developing strategies and programs.

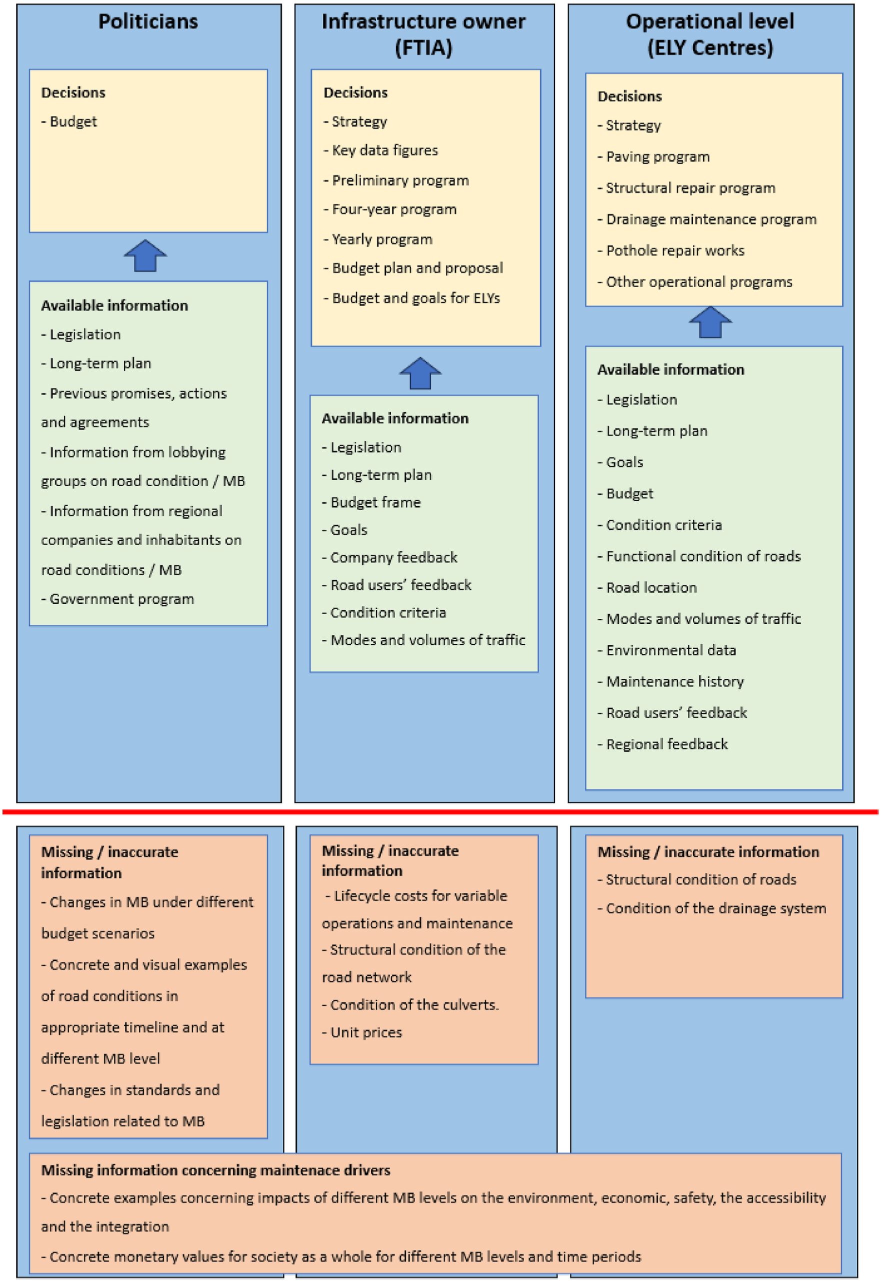


Figure 2. Required information concerning MB at decision-making levels

At every decision-making level, the primary considerations are legislation and long-term plan. Additionally, both politicians and road authorities receive valuable information from companies and road users. Based on the interviews, all decision-making levels expressed a desire for a clearer overall picture of the condition of the road network in relation to society.

Consequently, more information is needed on the impacts of various levels of road network condition and MB on industry, environment, the economy, safety, and accessibility. Moreover, politicians expressed a need for concrete and visual examples of road conditions under different budget scenarios and MB levels.

Road authorities underlined that information on the structural condition of the road network and the condition of the drainage system is not systematically monitored. In contrast, information based on the functional condition of the road network was found to be reliable. Additionally, the asset owner requested more information about the timing of various operations in relation to lifecycle costs and defined method for adjusting unit prices used in MB calculations.

5. Discussion

Based on the study, the concept of maintenance backlog (MB) is used at various decision-making levels, particularly in budgeting, but also in the formulation of strategies and programs among road authorities.

At the political decision-making level, legislation, long-term planning, and societal climate are primary considerations. The interviews revealed that politicians are aware of both the monetary value of MB and the extent of deteriorated roads, emphasizing the need for substantial annual road resurfacing to prevent the backlog from increasing.

Key data figures defined by the asset owner (FTIA) are essential for monitoring and decision-making. These metrics are followed up annually, ensuring a systematic approach to managing the road network. FTIA's engagement with the top 40 Finnish companies and other client groups highlights the importance of incorporating diverse stakeholder needs into decision-making. This systematic customer service model ensures that the transport and logistics needs of businesses and the satisfaction of road users are considered. In addition, politicians and operational-level personnel also receive feedback from road users and local businesses.

However, a significant gap identified is the insufficient information regarding the impact of the maintenance budget on the actual condition of the road network and its societal impacts. This gap is not only recognized by politicians but also by other groups interviewed. The societal impacts should encompass environmental, economic, safety, accessibility, and integration aspects, presented in a visual and concrete manner with a long-term perspective to illustrate the direction of change clearly. Therefore, this issue needs further research, following studies completed, e.g. in England and Scotland (Thiessen *et al.*, 2017; Johnston *et al.*, 2018). The implications of these results extend to the entire society. The same practice can be adopted in other countries with similar information gaps, where further justification for budgeting in decision-making is required.

Other missing information highlighted by the politicians (changes in standards and legislation, the impact of the budget on the amount of MB, and changes in road conditions over time) exists but has not been fully internalized. These issues likely stem from communication gaps. Although the problem may be complex and multifaceted, the politicians expressed clear desires: concrete examples, a sufficient timeline, and more visualization. This result is important for road authorities and lobbying companies and can be adopted in other countries, where more clarity in messaging is needed.

The infrastructure owner has the primary responsibility for overseeing road infrastructure management. The timely implementation of appropriate operations is critical from a cost-effective lifecycle perspective. However, there is currently a lack of information for this purpose, as stated by the infrastructure owner and operational level representatives. The criteria for operation needs should align with cost-effective timing in all aspects. The absence of an automated system to determine the cost effects of different operations timings further complicates holistic asset management. Addressing this issue necessitates country-specific data and further research. A statistical approach could be employed, integrating existing condition registry data with various operations and their associated costs.

As described in section 2.2, road condition monitoring information can be divided into functional and structural. In the present study, the functional information was found to be sufficient, whereas the structural condition information was missing, which was highlighted by operational level and specialists. Structural condition can be monitored using tools such as the falling weight deflectometer or the traffic speed deflectometer (e.g. Katicha *et al.*, 2022; Vitalis and Ephather, 2022). In the analysis of the results, one can either utilize directly calculated values from measurements (such as the surface curvature index) or develop an indicator specifically for assessing structural conditions. This indicator can be derived solely from deflection measurements or by combining the results with other information, such as pavement thickness. Leveraging this information, network level condition management can be improved and employed in planning interventions. The consequences of poor structural condition can be very expensive and long-lasting, especially in Nordic countries, where the combination of frost and heavy vehicles accelerates structural deterioration. Therefore, there is a call for future research on finding a feasible procedure for structural condition evaluation. With the help of these findings, road authorities will be able to make decisions in a more data-driven way, which has long-term economic implications.

Another critical factor for operational level to review is drainage management. Although information related to drainage has been collected, there is no national level systematic guidance for its processing and subsequent action. Monitoring and managing these aspects are crucial because ineffective drainage is directly linked to accelerated road rutting and, consequently, to increased life cycle costs (Saarenketo *et al.*, 2022).

6. Conclusions

The main research question of this study was: What data and information are required to make decisions concerning the management of maintenance backlog (MB)? Politicians, road authorities, specialists, and business representatives were interviewed, and reports were studied to thoroughly describe the concept of MB and its application.

The study underscores the critical role of MB in the decision-making processes of various stakeholders involved in road infrastructure management. The varying perceptions of MB among different groups highlight the need for a comprehensive and unified approach to understanding and addressing MB. The political decision-making process is significantly influenced by societal factors and long-term planning, as well as information from lobbying companies, regional companies, and inhabitants when deciding on road maintenance budget. The monetary value of MB and the condition of road network are highly influenced by the budget.

The findings indicate a pressing need for more detailed and concrete information on the societal impacts of road conditions and the maintenance budget. Addressing this information gap is essential for informed decision-making and holistic management of the road network. Future research should focus on developing methods to present this information in a clear and impactful manner, ensuring that all stakeholders have a comprehensive understanding of the implications of MB on road infrastructure and society.

Additionally, the engagement of FTIA with major companies and other client groups is crucial for aligning transport and logistics needs with infrastructure planning. The development of automated systems to evaluate the cost effects of different operations timings could significantly enhance the efficiency of asset management. Addressing this issue necessitates country-specific data and further research. Furthermore, there is a call for future research on finding a feasible procedure for structural condition evaluation and national guidance on evaluating the condition of drainage. These are necessary to ensure a comprehensive understanding of the road network's overall condition.

The objectives of the study were achieved, and the contribution of the study is summarized in Figure 2. In the target country, Finland, the functionality of the road network is crucial for the nation's logistical attractiveness. This importance is attributed to factors such as the extensive length of the road network, low population density, climate conditions, and the allowance of heavy axle loads. Consequently, monitoring MB and forecasting changes in road conditions are of paramount importance. However, these factors do not limit the generalizability of the results, as each country has its own specific reasons for the significant importance of road network maintenance. Although, Finland served as the target country for this study, we believe that the results, which were presented at the political decision-making level, can be adopted, and modified for countries with similar governmental decision principles, and where further justifications for funding decisions are required. Additionally, insights from the asset owner perspective can assist road authorities in industrialized countries, while operational level findings can be applied to countries with similar geographical characteristics. The results of this study were collected from an industrialized country for the years 2018–2022. Consequently, the applicability of these findings to different time periods and countries may be limited.

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