

Prestudy

# Research and development in infrastructure maintenance

An investigation of needs for and orientation of  
R&D initiatives for a possible Mistra programme

November 2016

**Authors:**

**Johan Skarendahl, Eva Schelin and Olle Samuelson,  
IQ Samhällsbyggnad**

The authors are responsible for the content of this prestudy.

Prestudy

# Research and development in infrastructure maintenance

An investigation of needs for and orientation of  
R&D initiatives for a possible Mistra programme

November 2016

**Authors:**  
**Johan Skarendahl, Eva Schelin and Olle Samuelson,**  
**IQ Samhällsbyggnad**

The authors are responsible for the content of this prestudy.

# Contents

<b>1. Introduction and background</b>	<b>3</b>
<b>About Mistra</b>	<b>3</b>
<b>2. Purpose and parameters</b>	<b>4</b>
<b>Initial parameters</b>	<b>4</b>
<b>3. Method</b>	<b>5</b>
Initial data collection	5
Definition of issues and sources	5
Implementation of interviews, workshop and literature review	5
Analytical phase	5
<b>4. Analysis</b>	<b>6</b>
<b>Reasons for limitations</b>	<b>6</b>
<b>Ongoing initiatives</b>	<b>7</b>
InfraSweden2030	7
BVFF	7
BBT	8
The Transport Administration's nine R&I portfolios	8
Road2Science	8
Shift2Rail	9
Swedish Water Development	9
<b>Conclusion 1: Existing initiatives in the area are inadequate</b>	<b>10</b>
<b>State of knowledge</b>	<b>10</b>
State of knowledge in water and sewerage	10
State of knowledge in the rail sector	11
State of knowledge in the road sector	11
<b>Conclusion 2: Major new knowledge needs call for research initiatives</b>	<b>12</b>
<b>Priority areas</b>	<b>12</b>
Knowledge of the condition of infrastructure	12
Forecasting and decision support	13
Financial instruments, ownership and business models	13
Organisation and processes	14
Sustainability	14
Digitisation	15
<b>Conclusion 3: There are six key focus areas for an initiative</b>	<b>15</b>
<b>5. Conclusions and recommendations</b>	<b>16</b>
<b>6. Appendices</b>	<b>17</b>
<b>Matrix of interview respondents</b>	<b>17</b>
<b>Work meetings</b>	<b>18</b>
Business intelligence committee	18
Implementation committee	18
<b>7. References</b>	<b>19</b>

# 1. Introduction and background

The Swedish Foundation for Strategic Environmental Research (Mistra) has assigned the Swedish Centre for Innovation and Quality in the Built Environment (IQ Samhällsbyggnad) to carry out a prestudy to investigate needs for an environmentally strategic research and development (R&D) programme in the area of ‘infrastructure maintenance’. Infrastructure in Sweden is, in certain parts, severely neglected and the global challenges we face — climate change, urbanisation, housing provision, robust transport systems and demographic changes — are connected in clear ways with long-term functioning infrastructure systems. Existing infrastructure must be administered and maintained to optimise its service life, and new investments in infrastructure with distinct life-cycle perspectives and a focus on maintenance issues over long periods.

Accordingly, there may be good reasons to invest in long-term accumulation of knowledge through expanded, focused R&D initiatives. IQ Samhällsbyggnad’s assignment involves investigating whether such a need exists and, if so, what the main emphasis of the efforts should be. This report describes the results from the investigation.

The work was carried out by Johan Skarendahl, project manager, with Eva Schelin and Olle Samuelson. The steering group comprised these three members, all from IQ Samhällsbyggnad, and Thomas Nilsson of Mistra.

---

## About Mistra

The Swedish Foundation for Strategic Environmental Research (Mistra) supports research of strategic importance for a good living environment and sustainable development of society. The purpose of Mistra’s investments are:

- ▶ To create strong research environments of a high international class. For research to bring about benefits, its high quality is crucial.
- ▶ To solve key environmental problems. Many environmental challenges are complex and new solutions require research of strategic importance that combined a range of knowledge and approaches from a variety of areas.
- ▶ To boost Swedish competitiveness. Companies, public-sector stakeholders and other users must develop new products, services and working methods that contribute to employment. The initiatives must also result in Sweden being, in a broad sense, a good place to live in.
- ▶ To be valuable for users. The results must contribute to work for sustainable development. Users and other individuals with key roles in ensuring that the research is put to practical use will therefore participate in the research.

## 2. Purpose and parameters

The purpose of this report is to answer the following two questions:

### 1. Is an environmentally strategic research and development programme in the area of ‘infrastructure maintenance’ necessary?

This overarching question will be broken down into subsidiary ones, such as:

- ▶ *Is the area neglected? If so, why is this? What measures are needed? Are increased R&D initiatives the answer to what is required, or are other measures necessary?*

### 2. What are the main aspects a programme of this kind should focus on?

This overarching question will be broken down into subsidiary ones, such as:

- ▶ *What knowledge is lacking, and at what level? Which parts of the process are most central to focus on? Which are the most important stakeholders? In which areas is new knowledge needed — technology, processes and organisation, financing, planning or life-cycle perspectives, for example?*

---

### Initial parameters

The notion of ‘infrastructure’ is open to broad interpretation. An introductory definition is therefore provided in consultation with Mistra. Here, the term relates to physical technical systems for mobility and supply.

Thus, the concept does not refer to interpretations of infrastructure as institutions, customs or culture, which might be relevant in another context. With this definition, the term is then divided into two main parts:

#### 1. Transport infrastructure

This category includes roads, railways, ports, harbours and airports, with associated buildings and constructions, such as bridges, viaducts and tunnels.

#### 2. Supply infrastructure

This category relates to water and sewerage (WS) installations, electricity grids, district-heating networks, telecoms and data networks, and to some extent (where it takes place in fixed installations) waste disposal.

In consultation with Mistra, a hypothetical demarcation was then imposed: the sectors considered most important are roads and railways, with their associated structures and equipment, and installations associated with WS. Maintenance in the other sectors was assumed to work better, partly owing to clear financing solutions and business models. This assumption continued in the phase of data collection, to be confirmed or denied.

## 3. Method

The investigation was carried out in four stages, including analysis of data collected.

### **Initial data collection**

Initially, brief interviews were conducted with three key people selected to represent the relevant stakeholders in light of the purpose and parameters presented above. These people were chosen from IQ Samhällsbyggnad's network, focusing on their proficiency in the area, overall knowledge about R&D in the sector and specific knowledge of some portion of the area, and also with good networks of their own and knowledge of suitable people for in-depth interviews. In this phase, the question of our assumption regarding parameters was also raised.

### **Definition of issues and sources**

The steering group devised a semistructured form of interview with a number of initial main issues and various associated questions depending on the answers given. This semistructured form with a common framework, but a flexible capacity to record the respondents' replies in detail and follow them, was considered suitable for the purpose.

With the proposals based on the initial data collection and using IQ Samhällsbyggnad's broad network, a matrix was drawn up in which a range of experts from different stakeholders addressed the various categories of infrastructure, to obtain a comprehensive picture from the respondents. The matrix in section 6 includes all the respondents.

### **Implementation of interviews, workshop and literature review**

Data collection took place through 16 in-depth interviews, two working meetings with IQ Samhällsbyggnad's committees and information retrieval from the Internet and reports. The process of collecting data from the various sources took place in parallel and successively added to the overall picture emerging from the report.

The two working meetings were held with IQ Samhällsbyggnad's committees for 'Implementation' and 'Business intelligence', with 18 and 14 people respectively taking part. The groups were divided into small 'beehives' of three, who discussed issues for some 30 minutes including presentation of results. The results were documented and have been inserted in the complete analysis.

### **Analytical phase**

The analysis was carried out as follows. All the material was read and key terms and words were coded to find patterns in the material. Conclusions were then drawn on the needs perceived among the stakeholders. This approach is qualitative, which means that all the observations are assumed to represent existing perceptions in the sector. Similar observations from two or more respondents reinforce the patterns found and make it clear that they recur in several places, but cannot be used to make quantitative assessments and size comparisons.

## 4. Analysis

### Reasons for limitations

The preliminary assumption that the investigation should be confined to three categories of infrastructure — railways, roads and WS installations — was explored in the initial interviews and studies of the academic literature. The respondents largely confirmed this assumption, for two main reasons:

► **The areas identified are neglected and impose extra costs on society.**

In a 2014 study, KTH Railway Group estimates that the increasingly frequent unplanned disruptions in Swedish rail transport boost costs by 10% for transport operators and 18% for (industrial) purchasers of transport services, giving an overall boost of 28% to transport costs (Nelldal 2014).

Swedish Water's 2015 'Sustainability Index' showed that the status of installations 'is presumably the biggest challenge to water utility organisations' (Swedish Water 2015).

Road maintenance, in terms of the carrying capacity of roads, is a particular threat to the forest industry, which uses roads where traffic is relatively light, but also because of the massive rise in goods transport in and around urban areas. Economic development and the growing demands of international competition for rapid, cost-effective transport and road safety require better preventive maintenance (Confederation of Swedish Enterprise 2016).

► **Presumed causes are sluggish knowledge development and inferior workings of business logic in general.**

Other parts of Sweden's infrastructure are managed in a way that entails maintenance that is sustainable in the long term, with enough income from users to maintain installations. The Port of Gothenburg, through which a third of this country's foreign trade goes, states, for example, that the Gothenburg Port Authority

*'does not receive any financial support from the owner, the City of Gothenburg. Revenue derives from customers in the form of concession charges, port charges, freight charges and rents and leases'* (Port of Gothenburg 2016).

The state-owned airport operator Swedavia owns and operates 13 of Sweden's busiest airports. An in-house consultancy, Swedavia Konsult, develops and follows up maintenance plans for the company's own airports. Consultancy services are also sold to other airport owners. The company has a good financial position and stable credit ratings (Swedavia 2016).

According to the Energy Market Inspectorate, the distribution grid for district heating, which expanded by 30–40 % in terms of line length between 2009 and 2015, naturally boosted costs of planned maintenance. In terms of the number of 'unannounced disruptions', i.e. service breakdowns due to unforeseen defects, leaks etc., there was no rising trend during the same period (Energy Market Inspectorate 2016). The electricity grid companies, whose charges within a particular tariff range are inspected and regulated by the Energy Market Inspectorate, is responsible for maintaining the electricity grids. The

Inspectorate carries out regular studies of the status and resilience of the electricity grid in terms of supply reliability (or, otherwise expressed, the rate of unannounced disruptions). Major rises, especially in disruptions lasting more than 24 hours, especially for rural customers, took place in 2007, 2011 and 2013 and these are believed to have been caused by extreme weather conditions. Otherwise, the number of unannounced disruptions has been stable and, in some categories, declined slightly over time (Grahn & Wallnerström 2016:10–21).

Refuse collection is performed largely by means of vehicles, rather than fixed supply infrastructure. There are exceptions, such as Envac's vacuum waste suction system in Hammarby Sjöstad and Tekniska verken's underground culvert system for all kinds of supply infrastructure in Vallastaden, Linköping. However, these are new systems and on such a small scale that they cannot be said to be perceived as a substantial maintenance problem in need of research support.

This general picture of maintenance requirements means that they are most acute for WS, railways and roads, and that long-term sustainable models for maintenance financing and planning are lacking, as the interviews confirm. The decision to confine the investigation to these three sectors therefore applies to the investigation itself and to the meanings of the terms 'infrastructure' and 'installations' as referred to below in this report.

---

## Ongoing initiatives

There are a number of ongoing measures in the area of infrastructure, but their degree of focus on maintenance varies. A brief account of the initiatives identified is given below.

### **InfraSweden2030**

The programme focuses on transport infrastructure, and to judge from the 'lines of action' the programme includes and the projects started in October 2016, in practice this means land-based transport infrastructure. InfraSweden2030 is a Strategic Innovation Programme (SIP) funded by Vinnova (Sweden's Innovation Agency), with support guaranteed up to year-end 2018, but which is intended to continue for up to 12 years. The programme came into being in collaboration among civil engineering companies, academia, institutes and the Swedish Transport Administration. The funding for the programme in 2016–18 comprises SEK 60 million from Vinnova and the same in cofunding from the participating companies.

'Line of Action 5', regarding the next generation of licensing assessment and maintenance of transport infrastructure, is interesting in relation to the maintenance issue. The document describes a need for development both in computerised maintenance methods and in tools for licensing assessment of installations. These two themes are given high priority by respondents in this study as well.

### **BVFF**

BVFF (an acronym of *Bana väg för framtiden*, meaning 'Pave the way for the future') may be described as the Transport Administration's own programme of cooperation with the civil engineering sector, focusing on implementation of knowledge, methods, materials etc. in ongoing contract work on roads and railways. The partners included in the

programme, besides the Administration, are the Swedish National Road and Transport Research Institute (*Statens väg- och transportforskningsinstitut*, VTI), KTH Royal Institute of Technology (KTH), Luleå University of Technology (LTU) and Ramböll (an engineering, design and management consultancy). The strategic emphasis of the programme is the same as in the Transport Administration's 'Positioning document for R&I portfolios'. In 2016 the programme embarked on about 100 projects, divided among VTI, KTH and LTU, with the absolute majority allocated to VTI.

### **BBT**

This programme, *Byggnadsverk inom Transportsektorn* ('Construction in the Transport Sector'), which started in October 2013, was developed in close collaboration among the Transport Administration, Swedish Universities of the Built Environment (SBU) and SP Technical Research Institute of Sweden (SP). Its principal aim is to reduce society's relative costs of construction in infrastructure through efficient, sustainable building. This is to include maintenance and administration as well. By November 2016, 19 projects — excluding those that may have come into being in a funding call that closed in September 2016 — had begun. Most of them relate to bridge mechanics and properties of building materials (concrete), and a few handle process issues and environmental impact. The programme may be expected to contribute to skills provision in materials technology for bridge maintenance, in particular (Swedish Transport Administration 2016).

### **The Transport Administration's nine R&I portfolios**

The Transport Administration organises its internal R&I activities in nine 'portfolios' with different emphases. For maintenance of roads and railways, the following three are considered relevant:

- ▶ 'An Energy-Efficient Transport System' mentions the need to include maintenance measures in life-cycle analyses of installations. The budget for 2016–18 is SEK 54 million (Swedish Transport Administration 2016:9).
- ▶ 'Robust and Reliable Infrastructure' describes a need for development: for example, a better understanding of how choices of technical solutions and systems can reduce disruptions and life-cycle costs for an installation, and increased knowledge of ageing and disintegration of installation components. The budget for 2016–18 is SEK 183 million (Swedish Transport Administration 2016:24).
- ▶ 'More Benefit for the Money' deals with how the Transport Administration organises its operations, runs its procurements and works jointly with the suppliers for greater efficiency (through BVFF, for example). Indirectly, this affects maintenance issues. The budget for 2016–18 is SEK 300 million (Swedish Transport Administration 2016:40).

It is important in this context to point out that the portfolios contain numerous issues and priorities in addition to maintenance. Within the framework of this survey, it has not been possible to carry out an assessment of how large a share of the whole picture composed of research and innovation with relevance to maintenance.

### **Road2Science**

Road2Science (R2S) is a Centre of Competence at KTH Royal Institute of Technology in Stockholm that, jointly with its industrial partners, strives to bridge the gap between academia and industry within the area of transport infrastructure. The Centre arranges

numerous cooperative activities to induce industry and academia to work better together and to ensure dissemination of research results. The emphasis of research in the network is on materials technology for road application, but also on issues relating to the transport system's design and sustainability (such as life-cycle analyses, LCAs). The Centre's activities are distinctly relevant to development of maintenance, although their focus is generally to get industry to adopt new technology and methods. The Centre is one of the initiators of InfraSweden2030.

### **Shift2Rail**

Shift2Rail is a public-private partnership (PPP) financed within the framework of Horizon 2020, the EU's Framework Programme for Research and Innovation. The project will focus on research, innovation and market-driven solutions in the rail sector, and speed up the introduction of new, advanced technical solutions, products and services.

The project is intended both to help realise the EU's ambitions on shifting traffic from road to rail and to support the competitiveness of the European rail industry and the realisation of a joint European railway system. Specific benefits anticipated from the project are a 50% reduction in life-cycle costs of rail transport, doubled capacity and a 50% improvement in reliability and punctuality. The programme covers railway development in a broad sense, but some of its components focus on maintenance issues, such as preventive maintenance of bridges and tracks, and better knowledge of the condition of installations (Shift2Rail 2016).

### **Swedish Water Development**

Swedish Water Development (*Svenskt Vatten Utveckling*, SVU) is the municipalities' own research and development programme for municipal WS technology. It focuses most on applied R&D, which is of interest to Swedish Water's members.

SVU's funding for R&D are intended to be distributed as follows:

- ▶ programme initiatives at higher education institutions (HEIs) and centres of competence: 30–50% of the total
- ▶ high-priority R&D areas: 30–50% of the total
- ▶ non-earmarked funding for unforeseen needs and genuinely interesting project proposals: 20–30% of the total.

The annual R&D charge for 2016 is SEK 1.92 per municipal resident. This represents a modest turnover of less than SEK 20 million a year (based on the simple fact that Sweden's population is slightly below 10 million). This is modest compared, in particular, with the investments in transport infrastructure described above. In this context, it should be pointed out that the replacement cost of Sweden's aggregate WS network is estimated at SEK 500 billion a year (Swedish Water 2016).

The initiatives mentioned at centres of competence are located at KTH, LTU, Chalmers University of Technology and the Faculty of Engineering at Lund University (Lunds Tekniska Högskola, LTH). Of these, only Chalmers is deemed to be connected with maintenance, since the DRICKS centre focuses on drinking water, and maintenance is

touched upon not least through projects that investigate technical risks in the mains (Chalmers 2016).

From a search in SVU's project database covering the past few years, the picture emerges that issues relating to microbiology, drug contamination and recovery of energy and resources from flowing water, for example, have been given considerably higher priority than research on maintenance of infrastructure contained in the WS system (SVU 2016).

## **CONCLUSION 1**

### **Existing initiatives in the area are inadequate**

Sweden has a network of roads exceeding 216,400 km in length, a rail network of 16,500 km and WS mains of which the replacement cost is estimated at SEK 500 billion (Swedish Transport Administration and Swedish Water 2016). Given these substantial assets and the considerable environmental impact they represent, the economic and environmental benefits of investments in R&D on the maintenance side are large. The initiatives described above do not have maintenance as their main focus, although it is included in some of them and several respondents have pointed to a fragmented and rapidly ageing research community with weak or non-existent regeneration. There have been some improvements thanks to long-term initiatives like InfraSweden2030 but in WS, in particular, financing remains inadequate.

---

## State of knowledge

The 18 in-depth interviews conducted within the project convey a distinctly negative picture of knowledge provision at vocational, graduate and postgraduate levels alike.

### **State of knowledge in water and sewerage**

In the WS sector, engineering courses' difficulty in recruiting students with an interest in maintenance is mentioned, but so is the fact that those attending these courses often lack the required basic knowledge. Greater freedom of choice among courses has meant that new graduate engineers often have a longer starting phase in employment before they can engage in operational work on maintenance issues. Overall, the WS sector finds it difficult to compete with, for example, IT or, for that matter, other courses relevant to community planning. Moreover, maintenance has lower status than developing and working on investments in new technology. The whole trend has gone so far that, today, Sweden entirely lacks training in maintenance of WS installations. The sector seeks a dialogue with HEIs to enable them to train engineers with more relevant skills and qualifications.

Operations technicians and pipe fitters are also in short supply. As on the engineering side, the low visibility and unpopularity of the sector are cited as causes. At postgraduate level, strong research environments with a comprehensive approach to maintenance of WS installations are lacking. That academic conferences are not held in this subject area in Sweden is symptomatic of its low status. Although to some extent the research that takes place in other countries may be beneficial, locally based research proficiency with respect to the natural and technological conditions applying here is needed. For society to have its

own knowledge production in such an essential area as its water supply and management may also be described as a matter of civil protection and emergency preparedness.

At all levels, impending high retirement rates are expected to make the problem considerably worse.

### **State of knowledge in the rail sector**

In the rail sector, too, all the respondents think knowledge provision works poorly. KTH is the only HEI that arranges courses in this sector at undergraduate level. Among technologists, interest in these courses is weak. As pointed out above, students' interest in maintenance issues is generally weak, and this applies to rail too.

Above all, what is deemed to be lacking is the comprehensive view: a strategic understanding of how design, investment and maintenance requirements are economically connected during a life cycle. Several respondents also emphasise the inadequacy of technical proficiency and the failure of the Transport Administration and, by the same token, contractors as well to prioritise forward-looking maintenance.

Technical consultants are considered to have greater skills than other operators in the sector. But they too cite young people's lack of interest in entering the maintenance field; the customers' short-term view of maintenance; and the low status of the sector.

### **State of knowledge in the road sector**

In road transport, several respondents regard that the supply of new engineers as adequate. However, as in other sectors, this applies mainly on the investment side; few wish to work in maintenance. The prevailing boom in community planning attracts people from installations to housing construction, where market conditions are relatively more favourable.

Today, a coherent research environment in road maintenance has been lacking since KTH's Centre for Operation and Maintenance of Infrastructure (CDU) closed. In both road and rail, one problem is believed to be the HEIs' insufficient interdisciplinary collaboration, which would be a precondition for working on usable life-cycle analyses.

One feature that WS, railways and roads have in common is that, at present, much maintenance is perceived as being of an 'ad hoc' nature. More long-term maintenance planning and understanding of the connection between design, investment and maintenance is deemed capable of raising the status of the area, allowing better maintenance planning and thus also making the area more attractive to future workers. Given these three sectors' economic significance, their poor supply of skills and low regeneration pose clear risks to society.

In summary, all the respondents and participants in the working meetings are also found, without exception, to have answered 'yes' to the question of whether a programme of strategic environmental research is needed in this area.

## **CONCLUSION 2**

### **Major new knowledge needs call for research initiatives**

The state of knowledge in the maintenance area is inadequate in all three sectors, but strongest in rail and WS. This applies to all levels, from training of skilled workers, including technicians and engineers, to postgraduate and senior research work. The dialogue between educators and those in need is inadequate in all three sectors and needs strengthening. By definition, research involves developing new knowledge, and investments in R&D environments are required to establish training courses, enhance these sectors' status and give them space in public debate.

---

## **Priority areas**

Interviews and working meetings have yielded numerous proposals and recommendations in areas where new knowledge and development inputs, and thus data on needs for an environmentally strategic research programme, are currently needed. These proposals have been categorised and collected under the following six headings, the order of which should not be seen as indicating relative priority.

The first four headings may be regarded from a chronological process perspective based on knowledge of the condition of the various infrastructure installations. This knowledge then allows needs and remedies to be forecast and adopted. Implementation of these measures requires long-term funding and incentives connected with ownership of the installations. This implementation needs organising and describing in terms of processes for the right measure to be taken at the right time; for the right stakeholder to be responsible for it; and for there to be a clear connection between early investment and long-term maintenance.

The subjects addressed under the fifth and sixth headings are horizontal and run through the entire process. Here, all actions need to be based on a sustainability perspective and digitisation is included as a means of making new ways of working possible.

### **Knowledge of the condition of infrastructure**

In the prestudy, the most commonly sought-after area of knowledge was improved know-how and management (retrieval, structuring, analysis and decision tools) of data on the actual condition of installations. This issue is perceived as fundamental and needs to be resolved. Several reasons are given for this.

Substantial sums of money are invested in roads, railways, WS systems and associated buildings and installations. Being able to take informed decisions about where, in these systems, maintenance should be prioritised has immense implications for the economy, and investing in R&D to improve performance in this matter is likely to be highly profitable, in both corporate and macroeconomic terms.

Many people emphasise the fact that maintenance in road and rail transport and WS can learn from how maintenance is organised in process industry, which is based to a larger extent on long-term planning and preventive measures. This is contrasted to community

planning, in which shortcomings are perceived in the connection between investments and long-term maintenance planning: forecasts of maintenance needs during the life cycle of installations are not sufficiently considered during the operational phase. Several respondents seek to explain the problem with reference to organisational factors — that business logic for long-term effective maintenance is lacking. On the WS side, many customer organisations are seen as lacking the critical mass required for planning and purchasing of long-term maintenance. If maintenance of roads, railways and WS installations is done only in emergencies — when critical situations arise — costs are high and it is difficult to bring about the productivity rises that take place in more long-term, predictable relationships between purchasers and those who perform the work.

### **Forecasting and decision support**

To be able to take good decisions on long-term maintenance, we need to understand the connection between measures and effects — whether, for example, it is more efficient to carry out maintenance operations on a bridge at a particular time of year than at another. Making detailed comparisons of this kind calls for knowledge of the condition and characteristics of installations, in the form of data flows over time that are continuously followed up. Statistical methods and models then need developing, to convert data at various levels of detail and quality into documentation for better-functioning preventive maintenance.

One precondition for better decisions is further development of life-cycle analyses (LCAs). Knowledge of the life-cycle environmental impact of materials, their sustainability and their service life under various conditions is urgently needed. Knowledge of the likely maintenance needs of components and entire installations, and of the intervals at which these needs arise, needs to be included in decision data at an early stage. For the calculations of benefit to society that are used, too, updating is necessary. One common view is that these calculations underestimate the losses to society resulting from unforeseen disruptions in operations, especially for goods transport.

### **Financial instruments, ownership and business models**

To create incentives for a sound maintenance situation, many people demand knowledge of how business logic for maintenance can be based more on free competition and diversity. In Sweden today, roads, railways and WS are central and local government monopolies. Should it be possible for them to be owned and run by private companies, as they are at least partially in other countries, and what would this mean for their long-term maintenance? Can forms of business enterprise, tax rules and financial instruments be devised to provide incentives for private stakeholders to engage in long-term operation and maintenance in these three sectors, and arouse their interest in doing so? Many people consider it imperative to attract private capital — both to boost the proportion of capital available for investments and to sell off installations so that they can then reinvest this public capital in new installations. Can pension assets be invested in assets of this type, as an alternative to government bonds with low interest rates? And if so, which regulations would create the right incentives for a business model that is sustainable in the long term?

‘Green Bonds’ are one form of financing that has expanded greatly in recent years. Its purpose is for tax-free savings in bonds to be used to fund development and refurbishment of properties in need of environmental remediation. Could this be used to finance investments in and maintenance of infrastructure as well? A greater diversity of

stakeholders and forms of financing would, many people think, entail faster learning through workable benchmarking.

### **Organisation and processes**

Several respondents describe the most severe shortcomings as linked more to organisation, processes and stakeholder coordination than to purely technical factors. Here, the overarching problems associated with the structures of the sector act as inhibiting factors. They include fragmentation of the sector, with many stakeholders operating at a suboptimal, low level; low proficiency among purchasers, who at present order maintenance for specific parts of an installation rather than in line with quality defined as a long-term objective; and splitting of responsibility among various parties with perceived needs, which does not incentivise long-term development.

The solutions called for, in which new knowledge is needed, are a matter of enhancing purchasers' expertise to take long-term maintenance into account from an early investment stage. They also involve creating incentives for individual stakeholders to contribute to long-term benefits rather than to their individual assignments. For new solutions to be found, the stakeholders' roles, incentives, business models and overarching processes need to be studied. An understanding of which incentive structures and organisational forms make actions economically rational at all levels — in terms of the whole economy, administration of businesses and organisations, and individuals' finances — is important for bringing about maintenance work that is sustainable in the long term.

### **Sustainability**

Sustainability is a central purpose for the respondents, and recurs frequently in the data. The overarching purpose of 'better infrastructure maintenance' is sustainability, from several points of view — both economic and ecological sustainability. Social sustainability is not mentioned but there may be connections with this aspect too.

Climate change is mentioned by many as the biggest challenge. It includes the fact that increased amounts of rainfall will impose new requirements for both planning and maintenance. For WS installations, this is crucial and has helped to bring about greater investments in R&D in the area. For roads and railways, too, heavier rainfall will have consequences that must be tackled to prevent risks of social disruption. However, it is not only climate change that call for investments; so, too, do requirements of clearer control of service life, robustness and resource management. Here, further development of life-cycle costs (LCCs) and LCAs, as decision tools and to optimise material and resource needs over the life cycle, is needed.

Economic sustainability is a matter of the great benefits to society that infrastructure affords and of assuming responsibility for the investments made. It is about, first, good management of investments by making use of the resources to which we have laid claim and, second, avoiding the heavy costs to society of unplanned disruptions and downtime in installations that inadequate maintenance may cause.

Here, new knowledge is needed both about impact analyses, at national level, of insufficient maintenance and about which measures need to be adopted to avoid this impact occurring.

## **Digitisation**

Digitisation is mentioned by many people as a highly interesting area to explore and develop in order to come up with solutions. Today, there is already abundant technology that can be put to considerably more use, and technological development is proceeding very rapidly. Applications in the 'Internet of Things' are now available in which sensors can be used, for preventive purposes, to collect data for condition assessments of bridges, tunnels, roads, WS mains etc. Sensors can serve to measure humidity levels, temperatures, loads, corrosion and movements, to mention but a few examples. Another way of collecting data on the condition of installations is, for example, through apps and online questionnaire surveys in which users can directly report defects in the installations.

New technology can also be used to analyse the 'big data' collected. Data are collected in models where estimates and optimisation can be performed simultaneously from many different perspectives. The analyses, in turn, can be used to generate forecasts and good decision data. A research programme in infrastructure maintenance should therefore contain parts that create new knowledge of how applications in new technology can, with the driving power of digitisation, be implemented in existing work procedures and how these applications can also drive new ways of working and processes.

### **CONCLUSION 3**

#### **There are six key focus areas for an initiative**

The needs that have emerged in the investigation of what a research programme should contain may be summarised in six areas:

1. Condition of infrastructure
2. Forecasting and decision support
3. Financial instruments, ownership and business models
4. Processes and organisation
5. Sustainability — the overarching purpose
6. Digitisation — the enabling factor

## 5. Conclusions and recommendations

The need to establish stable, secure and long-term provision of knowledge and skills for maintenance of infrastructure that is critical to society — such as roads, railways and WS systems — is great. In existing initiatives to form research centres and start research programmes, maintenance is at best an aspect that is included but subordinated. In the long run, this shortcoming is a threat to society since infrastructure in poor condition has considerable negative repercussions on the economy and the environment.

A research environment dedicated to maintenance of roads, railways and WS systems needs to be set up. It needs to be of a sufficient critical mass and have adequate long-term funding to enable the initiative, in earnest, to yield a long-term increase in the provision of skills in the maintenance area.

### **Our recommendations to Mistra:**

1. Set up, using a suitable form of call for funding applications, a strategic programme of environmental research for maintenance of infrastructure critical to society, focusing on rail, road and WS installations and associated buildings and structures. This recommendation is made in the light of Conclusions 1 and 2.
2. Give the programme an overarching purpose to support ecological and economic sustainability for long-term benefits to society in the area. This recommendation is made in the light of Conclusion 3.
3. Make the programme focus on licensing assessments, forecasting and decision support, financial instruments, ownership and business models, processes and organisation, and ensure that it makes use of the scope of digitisation. This recommendation is made in the light of Conclusion 3.

## 6. Appendices

### Matrix of interview respondents

Respondents were selected to cover, first, all three categories of infrastructure and, second, various points in the chain from research to order and delivery. The three key figures referred to in the account of the initial interviews were Daniel Hellström of Swedish Water (*Svenskt Vatten*), Lars Redtzer of the Swedish Construction Federation (*Sveriges Byggindustrier*, BI) and Stefan Jonsson of the Maintenance Department at the Swedish Transport Administration (*Trafikverket Underhåll*).

One detail to note with respect to the matrix below is that, for many respondents, the dividing line between roads and railways is not particularly clear. People often work on, for example, bridges, tunnels and materials for both modes of transport and the division into transport modes may therefore be somewhat arbitrary. Issues relating to materials, such as concrete, are also overarching for all three categories of infrastructure. Some people possess understanding of and experience from more than one section of the chain, and are therefore included in several boxes.

	<b>Roads</b>	<b>Railways</b>	<b>Water &amp; sewerage</b>
<b>Research</b>	<i>Mårten Lindström</i> , More10 AB; <i>Staffan Hintze</i> , NCC; <i>Lars Redtzer</i> , Swedish Construction Federation; <i>Bror Sederholm</i> , Swerea KIMAB	<i>Mårten Lindström</i> , More10 AB; <i>Staffan Hintze</i> , NCC; <i>Lars Redtzer</i> , Swedish Construction Federation; <i>Bror Sederholm</i> , Swerea KIMAB; <i>Sebastian Stichel</i> , KTH Railway Group	<i>Daniel Hellström</i> , <i>Ann Adrup</i> and <i>Hans Bäckman</i> , Swedish Water; <i>Birgitta Olofsson</i> , Tyréns
<b>Purchasing</b>	<i>Ted Ell</i> , City of Stockholm Transport Department; <i>Lahja Rydberg-Forsbeck</i> and <i>Rickard Rosenlund</i> , Swedish Transport Administration Investment; <i>Stefan Jonsson</i> , Swedish Transport Administration Maintenance	<i>Lahja Rydberg-Forsbeck</i> and <i>Rickard Rosenlund</i> , Swedish Transport Administration Investment; <i>Stefan Jonsson</i> , Swedish Transport Administration Maintenance	<i>Daniel Hellström</i> , <i>Ann Adrup</i> and <i>Hans Bäckman</i> , Swedish Water
<b>Consultancy</b>	<i>Ann-Catrin Malmberg</i> , WSP Infrastructure	<i>Ann-Catrin Malmberg</i> , WSP Infrastructure; <i>Björn Svanberg</i> , Sweco Infrastructure	<i>Birgitta Olofsson</i> , Tyréns
<b>Contracting</b>	<i>Staffan Hintze</i> , NCC; <i>Lars Redtzer</i> , BI	<i>Staffan Hintze</i> , NCC; <i>Lars Redtzer</i> , BI	<i>Stefan Indahl</i> , Aarsleff
<b>Supply</b>	<i>Malin Löfsjögård</i> , Svensk Betong ('Swedish Concrete')	<i>Malin Löfsjögård</i> , Svensk Betong	<i>Malin Löfsjögård</i> , Svensk Betong

---

## Work meetings

### **Business Intelligence Committee**

The Committee's meeting was held on 14 September, with some 35 minutes being devoted to group discussions for the investigation. The following 14 people attended:

- ▶ *Anders Persson*, Swedish Federation of Consulting Engineers and Architects (*Svenska Teknik&Designföretagen*, STD)
- ▶ *Eva Schelin*, IQ Samhällsbyggnad (the Swedish Centre for Innovation and Quality in the Built Environment)
- ▶ *Therese Pehrson*, Swedish Association of Local Authorities and Regions, Skåne Region
- ▶ *Ulrika Stenkula*, White Arkitekter
- ▶ *Erik Westin*, Akademiska Hus (one of Sweden's largest property companies)
- ▶ *Lotta Werner Flyborg*, NCC Group
- ▶ *Anna Jarnehammar*, IVL Swedish Environmental Research Institute
- ▶ *Per Åhman*, BI
- ▶ *Ann-Sofie Eriksson*, Swedish Association of Local Authorities and Regions (SKL)
- ▶ *Caroline Dahl*, Swedish University of Agricultural Sciences
- ▶ *Magnus Brink*, IQ Samhällsbyggnad
- ▶ *Katarina O'Cofoigh*, Architects Sweden (*Sveriges Arkitekter*)
- ▶ *Johan Skarendahl*, IQ Samhällsbyggnad (process manager)
- ▶ *Thomas Nilsson*, Mistra

### **Implementation Committee**

This Committee's meeting was held on 26 September, with some 35 minutes being devoted to group discussions for the investigation. The following 18 people attended:

- ▶ *Ronny Andersson*, Cementa
- ▶ *Anna Land*, IQ Samhällsbyggnad
- ▶ *Daniel Hellström*, Swedish Water
- ▶ *Maria Brogren*, BI
- ▶ *Anita Ihs*, VTI
- ▶ *Mårten Lindström*, More10 AB
- ▶ *Ruben Aronsson*, Development Fund of the Swedish Construction Industry (*Svenska Byggbranschens Utvecklingsfond*, SBUF)
- ▶ *Agneta Persson*, WSP Group
- ▶ *Hans Söderström*, Installatörerna (association of WS installation companies)
- ▶ *Amy Rader Olsson*, IQ Samhällsbyggnad
- ▶ *Jenny Gode*, IVL
- ▶ *Kristina Mjörnell*, SP Technical Research Institute of Sweden (SP)
- ▶ *Johan Skarendahl*, IQ Samhällsbyggnad (process manager)
- ▶ *Lisa Daram*, Arkus (an independent Swedish forum for R&D in architecture and community planning)
- ▶ *Staffan Hintze*, NCC
- ▶ *Olle Samuelson*, IQ Samhällsbyggnad
- ▶ *Lahja Rydberg Forssbeck*, Swedish Transport Administration, Investment
- ▶ *Thomas Nilsson*, Mistra

## 7. References

- Bergman, M., & Hallberg, A. (2016). *Svenskt Näringslivs inspel till regeringens infrastrukturproposition* ('The Confederation of Swedish Enterprise's commentary on the Government's Infrastructure Bill'). Stockholm: Confederation of Swedish Enterprise.
- Chalmers University of Technology (27 October 2016). The DRICKS Framework programme for drinking water research at Chalmers. Retrieved from Chalmers University of Technology: <http://www.chalmers.se/en/departments/cee/centres/Pages/DRICKS.aspx>.
- Energy Market Inspectorate (27 October 2016). *Energimarknadsinspektionens Statistik* ('Statistics from the Swedish Energy Market Inspectorate'). Retrieved from the Energy Market Inspectorate: [http://www.ei.se/Documents/Publikationer/arsrapporter/fjarrvarme/rapporter\\_om\\_drift\\_och\\_affarsforhallanden/Distribution\\_per\\_prisomrade.xlsx](http://www.ei.se/Documents/Publikationer/arsrapporter/fjarrvarme/rapporter_om_drift_och_affarsforhallanden/Distribution_per_prisomrade.xlsx).
- Grahn, E. & Wallnerström, C.-J. (2016). *Leveranssäkerhet i Sveriges elnät 2014* ('Supply Reliability in Sweden's Electricity Network'). Eskilstuna: Energy Market Inspectorate.
- Nelldal, B. L. (2014). *Storre trafikavbrott vid Sveriges järnvägar 2000–2013 och dess effekter på transportkunderna* ('Major transport disruptions on Sweden's railways in 2000–2013 and their effects on transport customers'). Stockholm: KTH Royal Institute of Technology.
- Port of Gothenburg (24 October 2016). The Port of Gothenburg. Retrieved from: <https://www.portofgothenburg.com/about-the-port/the-port-of-gothenburg/>.
- Shift2Rail (3 November 2016). *Infrastructure – Innovation Programme 3: Cost-Efficient and Reliable High-Capacity Infrastructure*. Retrieved from Shift2Rail: <http://shift2rail.org/research-development/ip3/>.
- Swedavia (24 October 2016). Financial information. Retrieved from Swedavia: [https://www.swedavia.com/about-swedavia/financial-communication/?\\_ga=1.10025085.933039036.1482835963](https://www.swedavia.com/about-swedavia/financial-communication/?_ga=1.10025085.933039036.1482835963).
- Swedish Water (2 November 2016). *Rörmät & Klimat* ('Mains and Climate'). Retrieved from Swedish Water: <http://www.svensktvatten.se/vattentjanster/rornat-och-klimat/>.
- Swedish Water (2015). *Svenskt Vattens Hållbarhetsindex* ('Swedish Water's Sustainability Index'). Stockholm: Swedish Water.
- Swedish Water Development (27 October 2016). *Svenskt Vatten Utveckling Filarkiv* ('Swedish Water Development File Archive'). Retrieved from Swedish Water: <http://vav.griffel.net/vav.htm>.
- Swedish Transport Administration (27 October 2016). *Trafikverkets inriktning för forskning och innovation 2016–2018* ('The Swedish Transport Administration's focus for research and innovation, 2016–2018'). Retrieved from the Transport Administration: [http://www.trafikverket.se/contentassets/869f2edcbb3c40a795aa59c2f0a0feef/inriktningsdokumnet\\_foi\\_portfoljer\\_2016\\_2018\\_ver\\_1\\_0.pdf](http://www.trafikverket.se/contentassets/869f2edcbb3c40a795aa59c2f0a0feef/inriktningsdokumnet_foi_portfoljer_2016_2018_ver_1_0.pdf).
- Swedish Transport Administration (2 November 2016). *Sveriges järnvägsnät* ('Sweden's railway network'). Retrieved from the Transport Administration: <http://www.trafikverket.se/resa-och-trafik/jarnvag/Sveriges-jarnvagsnat/>.
- Swedish Transport Administration (2 November 2016). *Sveriges vägnät* ('Sweden's road network'). Retrieved from the Transport Administration: <http://www.trafikverket.se/resa-och-trafik/vag/Sveriges-vagnat/>.
- Swedish Transport Administration (3 November 2016). *Byggnadsverk inom Transportsektorn* ('Building structures in the transport structure'). Retrieved from the Transport Administration: <http://www.foi-bbt.se/web/page.aspx?refid=22>.