REAL-TIME MAINTENANCE MONITORING SYSTEM

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ABSTRACT

The Finnish public road network (78,000 km) is divided into 81 maintenance contract districts. Each district has a supervisor, who may be responsible for a large area. Traditionally, supervisors have spent many hours on the road. A more efficient way for monitoring contracts is needed.

In 2009, it was decided that a new method for monitoring maintenance contracts should be explored. A requirement to use a real-time maintenance monitoring system during a contract was included in requests for maintenance contract tenders. These systems gave new tools to supervisors.

The systems are the contractors' own systems or supplied by service providers. All data is stored in a database and can be viewed via the Internet on a map. Supervisors have also limited access to the information. These systems have opened new interesting ways to use data in mobile devices and social media.

Real-time maintenance monitoring systems have many positive effects at every user level. While some negative aspects exist, generally the positive effects outnumber the negative. These systems have also affected the contractors' ways of work and management. In the future this kind of information can also be used for the management of customer satisfaction.

1. INTRODUCTION

Finland has a public road network of approximately 78,000 kilometres. The national road network is divided into 81 maintenance contract districts. A contract district can cover 500 to 2,300 kilometres of road. The amount and difficulty of maintenance work depend on the total length of roads in the district, the maintenance categories, the type of environment (urban vs. rural area) and local characteristics. Each district has a supervisor (road inspector). A road inspector may be the supervisor for as many as three regional contracts. Traditional supervision methods involve spending many hours on the road. The supervisor is responsible for checking whether the contractor has started the work and how the work is progressing. The number of road inspectors has decreased, while the amount of work has not changed. Therefore, the efficiency of supervision needs improvement. New systems, more efficient use of current systems and new operating methods could be the keys to improved efficiency.

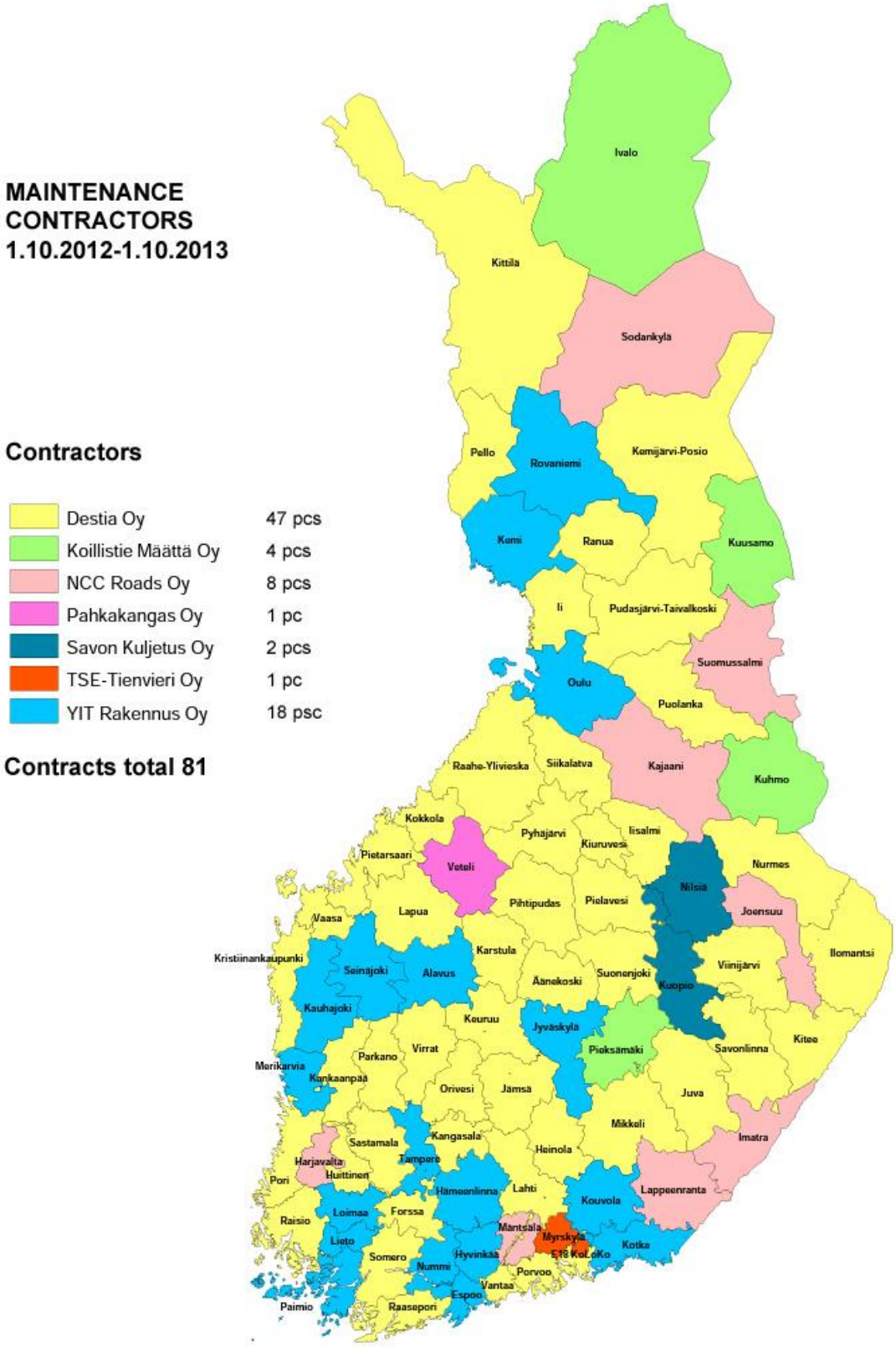

Figure 1. A map of regional maintenance contracts [1]

In addition to improving the actual supervision work, the flow of information also needs to be enhanced. Today, information is mainly exchanged by phone or email. Therefore, making phone calls and reading and responding to email messages takes up a considerable amount of supervisors' time. In Finland, road users give feedback on urgent issues through road users' telephone service to the Finnish Transport Agency. The feedback is forwarded to supervisors and contractors.

2. IMPLEMENTATION OF THE REAL-TIME SYSTEM

In 2009, a decision was made to look for new ways to monitor regional maintenance contracts. Clients and, in particular, supervisors of contracts needed to know/see where maintenance work was ongoing. Many felt that it would be a good idea if clients had a system where the parties involved could monitor and document maintenance work.

The Finnish Transport Agency (in 2009, the Finnish Road Administration) is using the AURA system for the monitoring of basic contract information, the number of maintenance activities and the actual work undertaken. The system can produce reports for road maintenance planning and follow-up reports [2]. Location data is sometimes available, but data stored in the system cannot be directly viewed on a map.

In 2009, it was concluded that the Finnish Road Administration has neither the time nor the resources to develop the AURA system or any new system into a monitoring system for clients. At that time, there were two companies in the market that offered coordinate-based work monitoring systems for contractors. An idea came up that real-time monitoring of work could possibly be purchased as part of the contract, so that information requested by the client could be obtained from the contractor's system. In addition, some contractors were known to use a somewhat similar system for their own purposes, but clients and supervisors did not have access to these systems. Clients have built open interfaces into their systems, through which contractors can deliver the required information from their systems to clients.

Furthermore, in 2009 a requirement to use a real-time maintenance monitoring system in contracts was included in requests for regional maintenance contract tenders in Northern Finland. It was also required that the client or a representative assigned by the client (such as a supervision consultant) must have access to the information. It was not necessary to make all data in the system available to clients; a description was drafted of the required information. Requests for tenders included a list of the jobs that must be monitored in the contract, as well as requirements for the characteristics of the system.

Table 1. Information to be included in the real-time system [3]

Winter maintenance	**Summer maintenance**
Ploughing or slush removal	Sweeping
Salting	Mechanical mowing
Spot sanding	Mechanical brush clearing
Line sanding	Grading of gravel roads
Smoothing of the road surface	Dust binding on gravel roads
Cleaning of traffic signs	Reshaping of gravel roads
Lowering of snow banks	Patching of paving
Prevention of damage caused by thaw water	Sealing with bitumen
	Cleaning of bridges

The request for tender [3] stated that the system must be in use on trunk roads and main roads from the beginning of the contract. From the second year on, the system must be in use on all roads. Minor work and work performed by individual subcontractors need not be entered into the system. In addition to maintenance work information, the system shows the contractor's road network inspections. Failure of the real-time system to operate was sanctioned.

Table 2. Requirements for the real-time system [3].

Technical representation	The latest completed maintenance activity should be clearly displayed on an interactive, zoomable map.
	Maintenance activities should be indicated in different colours.
	A list of the start and completion times and locations of activities should be provided.
	It should be possible to specify limits for the list and map on the basis of road addresses, date, time and activity.
Time-related requirements	The information must be available for viewing by the client within two hours of the start of the work.
	If telecommunications are not reasonably available within two hours, the information must be available in the monitoring system within six hours.
	In summer maintenance, reporting is not required until the following week day.
	The work information must be kept available for viewing for at least 12 months after the completion of the work.
	The information must be available in the archive database for the entire duration of the contract and for three years after the completion of the contract.

3. DIFFERENT SYSTEMS

Requests for tenders for regional maintenance contracts included a requirement for the contractor to use a real-time monitoring system. These systems are the contractors' own systems or supplied by service providers.

At first, contractors were using three different systems. One of them was the contractor's own, partially integrated system, and two were partially tailored systems supplied by service providers.

In these systems, raw data (coordinate-bound information) is sent from maintenance vehicles. All data is stored in a database where it can be viewed using a web browser. Place-bound data is processed for use and made available for viewing on a map. Contract supervisors have limited access to all data in the information system. These real-time systems are also used for the contractor's own purposes, such as financial management, project management and subcontractor management. Information requested by the client now usually constitutes a minor part of all the data in the system.

The contractor that used its own system already had the system in place. This system supported the required features to some extent, but some characteristics were added in order to comply with the requirements included in the request for tender. The benefits of this system included the monitoring of contractors' own maintenance vehicles. The system sent information about work performed by the vehicles to servers. A terminal device was not always needed for entering the data; information was also received directly from the vehicle's control equipment. The price of the monitoring equipment and installation was high. Subcontractors' maintenance vehicles were to be included in the system as well. However, it was not cost-efficient to integrate the system into these vehicles. The software was also rather old and its scalability did not meet today's standards. It was difficult to find

programmers for that software at a reasonable cost. Later the contractor who used this system switched to a commercially available system and customised it according to need.

Figure 2. The inside of a truck with an installed control device [4].

Two Finnish software houses also offered real-time monitoring systems. They both involve a terminal device installed in the maintenance vehicles or other vehicles, with data being sent from the terminal to servers. On the servers, the data is processed and information for different purposes is available through the Internet. The software house offers a full service package, so the contractor does not have to provide the IT environment. Mobile phones are usually used as the terminal device. Other devices, such as laptops and separate keyboards, have also been used. GPS is used for location determination. A location determination service is often already integrated into various devices, such as modern mobile phones. Relatively low-priced and easy-to-install terminal devices facilitate the implementation of the system.

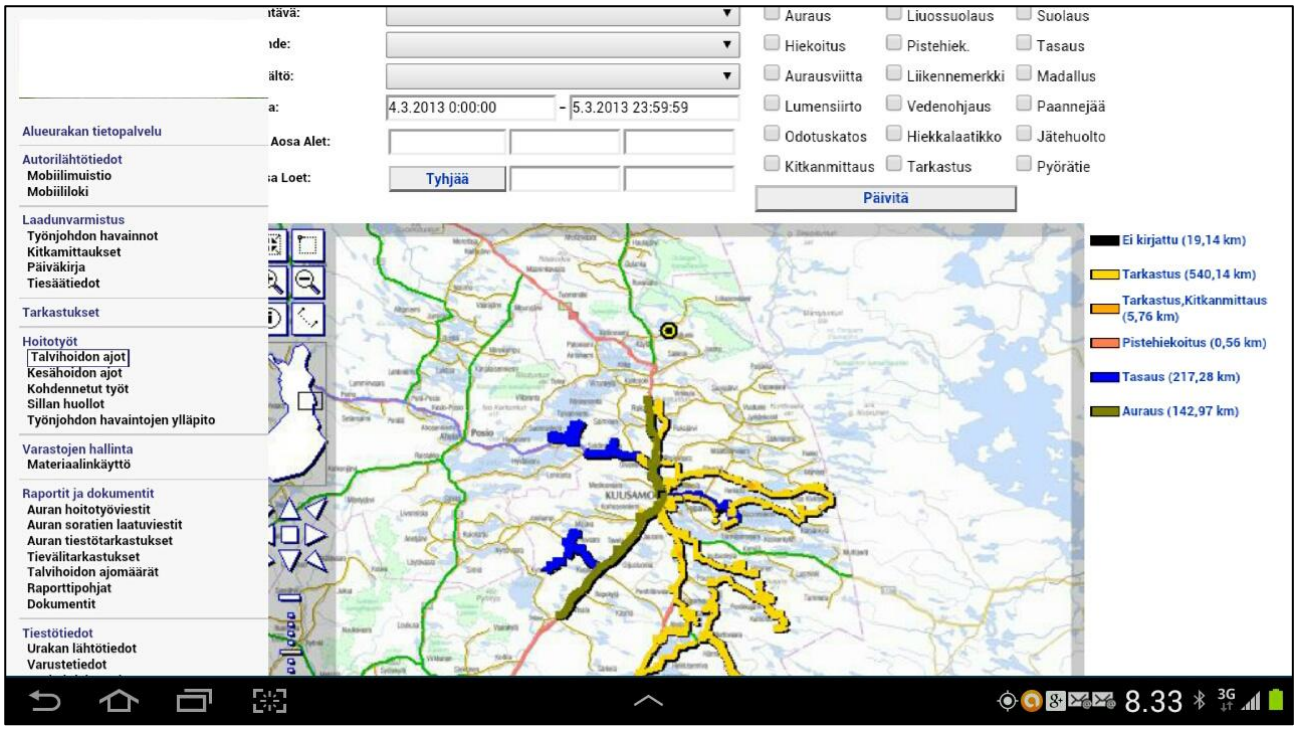

Figure 3. A screen included in a commercially available real-time system.

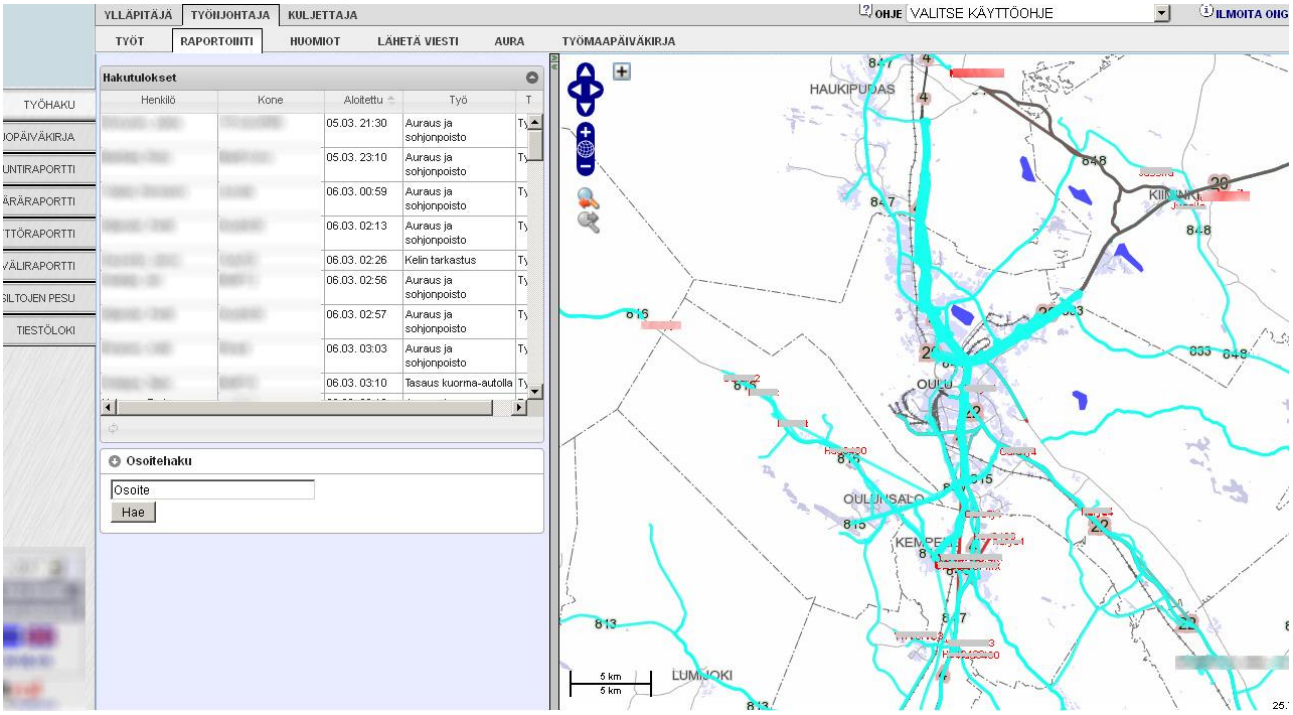

Figure 4. A screen in another commercially available real-time system.

Systems are commercially available, but contractors want to tailor them according to their own needs. In addition to map interfaces, contractors may have other screens in their systems for the viewing of quality measurements, reports, material management information, etc. Many of these modifications do not directly concern the client, but they help the contractor in contract management. Contractors have also proposed improvements to these systems in order to facilitate intercommunications.

4. EXPERIENCES, BENEFITS AND DISADVANTAGES

Before the implementation of real-time systems, there was much debate between clients and contractors with regard to their cost-effectiveness. Opinions varied greatly. Some thought that the systems were expensive and required too much work with no benefits gained. Others found the systems to be useful but did not provide enough benefits for those involved. Finally, some believed that the systems could improve productivity for clients and contractors. In addition, some contractors suspected that the systems treat contractors unequally. Personal interviews, discussions and questionnaires were used to collect opinions from those involved.

4.1 Benefits

Many different opinions were expressed in the interviews, discussions and questionnaires on the benefits of real-time systems. The systems were seen to provide benefits for many different users. Benefits could be general or associated with a small detail. Below are listed some benefits mentioned in the interviews.

General benefits:

- real-time systems have a number of positive effects at every user level (client – consultant – contractor – subcontractor – road user)
- quality management at every level,
- increased transparency between parties involved,
- management of the whole instead of management of subareas
- management of undesirable quality fluctuations (cost savings),
- processing of damages (obtaining evidence for claims handling during and after the contract),
- improved accuracy and efficiency of operations,
- less customer feedback,
- no need for separate printed reports and report summaries,
- information is obtained directly from the site.

Benefits that make contractors' work easier:

- a supervisory tool for contractors (management of subcontractors' work, invoicing, monitoring, a clear picture of the situation),
- handling of customer feedback becomes easier,
- automatic data transfer -> less manual work,
- reports delivered directly into clients' systems,
- road register address-based observations with images -> easier work management,
- monitoring of the amount of work/materials
- particularly in winter, real-time monitoring and history data help to manage the situation and control vehicles in action,
- you see the movements of vehicles and can then plan work supervisors' road inspection routes,
- you can find information with regard to completed work later,
- location determination is simple on the basis of the road register address,
- you can perform various inventories and
- sending messages is simple.

Benefits for clients:

- inspections can be scheduled more efficiently and feedback on quality can be provided to contractors before the occurrence of sanctionable failures (relating to deadlines, etc.)
- progress reports can be run on the computer,
- an overall picture can be obtained more easily and more quickly than before,
- fewer site visits (potential inspection sites can be assessed),
- handling of customer feedback becomes easier,
- intercommunication with supervision consultants becomes easier,
- can be used for demonstrating sanctionable action (shows the situation at the time in question),
- clients can see the routes of supervision consultants, and clients' supervisors can use this information for their own supervision rounds.

4.2 Disadvantages

As with benefits, a number of different views were expressed in the interviews, discussions and questionnaires regarding the disadvantages of real-time systems. Generally, the costs of the implementation and use of these systems can be seen as a disadvantage. The cost effects should be allocated to the regional contract in question. Cost effects largely depend on the acquisition method of the system. The costs of the system can include fixed costs and costs with a unit price. In large companies, the large volume alone causes costs, but costs also result from the co-ordination with current systems and any system integration. Smaller companies may implement these systems more easily if they do not have other systems to consider. Below are some disadvantages (other than system cost-related) mentioned in the interviews.

General disadvantages:

- some feel that even the two-hour delay is too much for a real-time system,
- temporary disturbances occur in systems and telecommunication.

Disadvantages that complicate contractors' work:

- inaccuracy and slowness of gps in obtaining the correct road register address,
- training of new users can be hard even though the software is simple to use (installation of software, personal user instruction),
- applications delivered by service providers cannot be kept up to date with the rapid technical development of phones (only specific models can be used),
- service providers are sometimes slow in developing software to match the needs of the field.

Disadvantages experienced by clients:

- inaccuracy and insufficiency of data (contractors do not always pay attention to what data they send),
- the system does not always provide information on the actual quality of work (such as the quality of mowing).

4.3 Experiences

In general, the positive effects of the real-time system outnumber the negative ones. The systems have had a positive effect on contractors' operating methods and management methods. As always, it takes some time to adapt to a new operating model and become familiar with it. After a while, people will not even remember that they had to learn to use a new system. In general, it is interesting to note that before the implementation of the systems the disadvantages were expected to be much more numerous than has been indicated in the interviews conducted this year.

According to contractors, the system makes the management of equipment and subcontractors easier for work supervisors. Other characteristics have been linked to these systems which make daily work easier, such as management of payments. Many said that the system reduces paperwork in the office and simplifies the work process. Contractors' employees do not find the systems difficult to use, once they have been trained in the use of the equipment. For some people the implementation of the system has been easier than for others. For many employees, the system has become part of their basic routine at work and now they cannot actually think of working without it.

Supervisors find that the system provides new opportunities for the supervision of contracts. Supervision rounds can be more accurately focused to work sites in the contract district, and it is easier to give feedback on the results of completed work before work has been performed throughout the district. Early feedback on the quality of work has generally improved the final result. At the same time, the contractor has benefited from avoiding sanctions, as the quality of work has been adjusted to comply with the agreement before the completion of the particular work phase. Supervisors have also found the monitoring system useful in the execution, routing and scheduling of work.

Supervision consultants have benefited from real-time systems by using the information for their own supervision rounds and analyses. Consultants who use real-time systems can achieve better results and incur savings for the client by driving fewer kilometres.

Since 2011, the requirement for contractors to use a real-time monitoring system has been included in all requests for regional maintenance contract tenders. Now it seems that real-time systems continue to be part of regional maintenance contracts.

5. OPPORTUNITIES

Even though real-time systems provide supervisors with the opportunity to improve their efficiency, a real-time system is still a system among a number of other systems. In order to further improve efficiency, other systems should utilise the real-time system. Data should be processed further so that supervisors can easily and quickly access the information they need. In addition, the same information could be made available to others, such as the management, in a summary form.

Currently, real-time systems are located in contractors' systems and clients have access to them. However, clients have felt that they should have the information also in their own systems. The basic information could still be kept in the contractor's system, because these systems also support other operational activities. The requested information could be automatically transferred through the agreed software interface into the client's system. The client's system would enable further processing of data for different purposes. Currently, such systems are not in use in Finland. However, the Finnish Transport Agency has systems into which data could theoretically be delivered, but this would require a

rather extensive data management project. Information obtained from consistent real-time data could also benefit road traffic management centres, as these centres could use the information for customer services to provided information about road maintenance work. For instance, a road user may be concerned about snow ploughing, while the plough truck might be on its way just a few kilometres away.

These systems open up interesting prospects with regard to supervision. Smart phones and tablets are technically advanced today. They have enough power and sufficiently large displays for these purposes, and they can be controlled using a touch keyboard. With modern 3G devices, you can access systems while you are mobile in the field. In the field, supervisors can change their inspection routes if they notice something out of the ordinary. This is particularly useful in rapidly changing winter conditions when operational activities are conducted in accordance with the conditions. Mobile devices can send modified reports directly from the field.

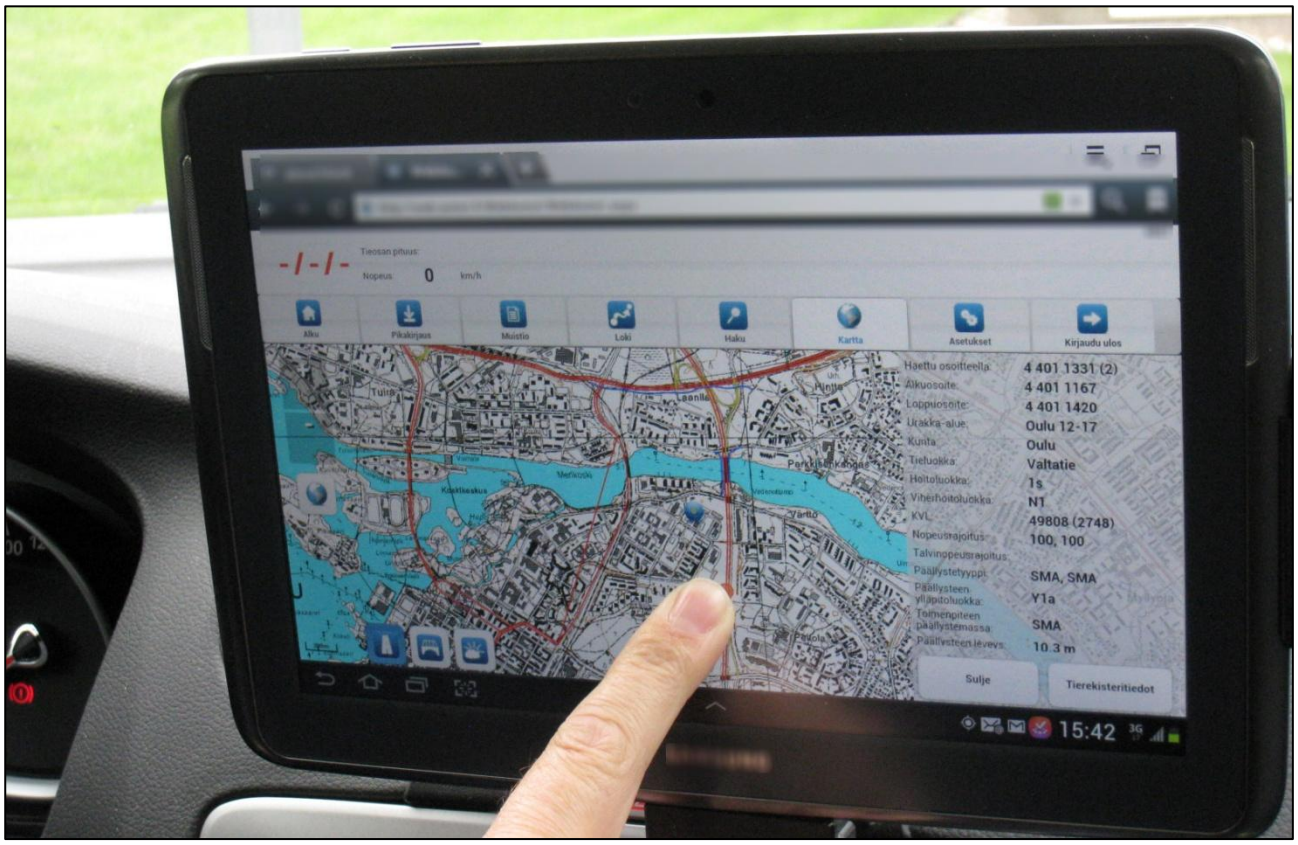

Figure 5. A tablet in a road inspector’s car.

Information obtained from the systems can also be used in social media, such as Google+ and Facebook. Social media can be used for internal or public communications related to the contract. Social media makes distribution of information easier, because the information reaches many recipients at the same time. In traditional communications, information is sent individually to each recipient. In public use, social media can be used for customer satisfaction management. However, in order to achieve the desired positive effects, public use of social media requires expertise in communication. A minor failure in communication can sometimes lead to a major negative response.

Internal use of social media during contracts can simplify the distribution of information and decrease the use of other information channels, such as email and phone calls. The Centre for Economic Development, Transport and the Environment in Northern

Ostrobothnia has used Google+ and Facebook in various contracts with Markku Tervo as the co-ordinator. Social media has been experimented with in different kinds of contracts, such as bridge, investment, paving and maintenance contracts.

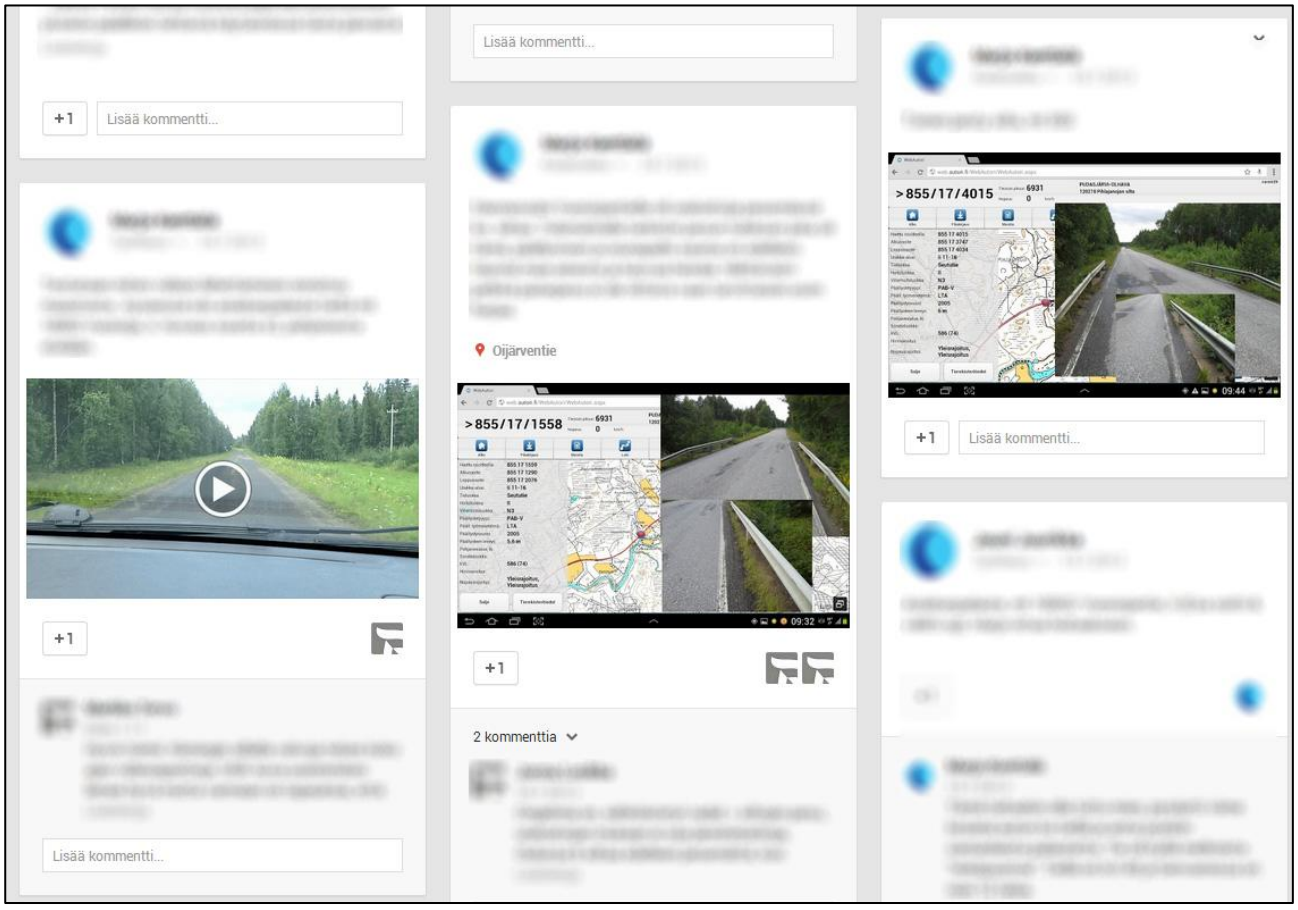

Figure 6. Google+ communities screen.

Social media is particularly convenient for reporting. Explanations, comments and, in particular, images can easily be shared with all the relevant parties. There will be no gaps in communication chains, which can easily happen with email. Thus, everyone involved (supervisors, their substitutes, foremen and all the other relevant parties) will be kept informed. In addition, social media can replace some of the traditional weekly and monthly reporting, because reports are published in social media in real time.

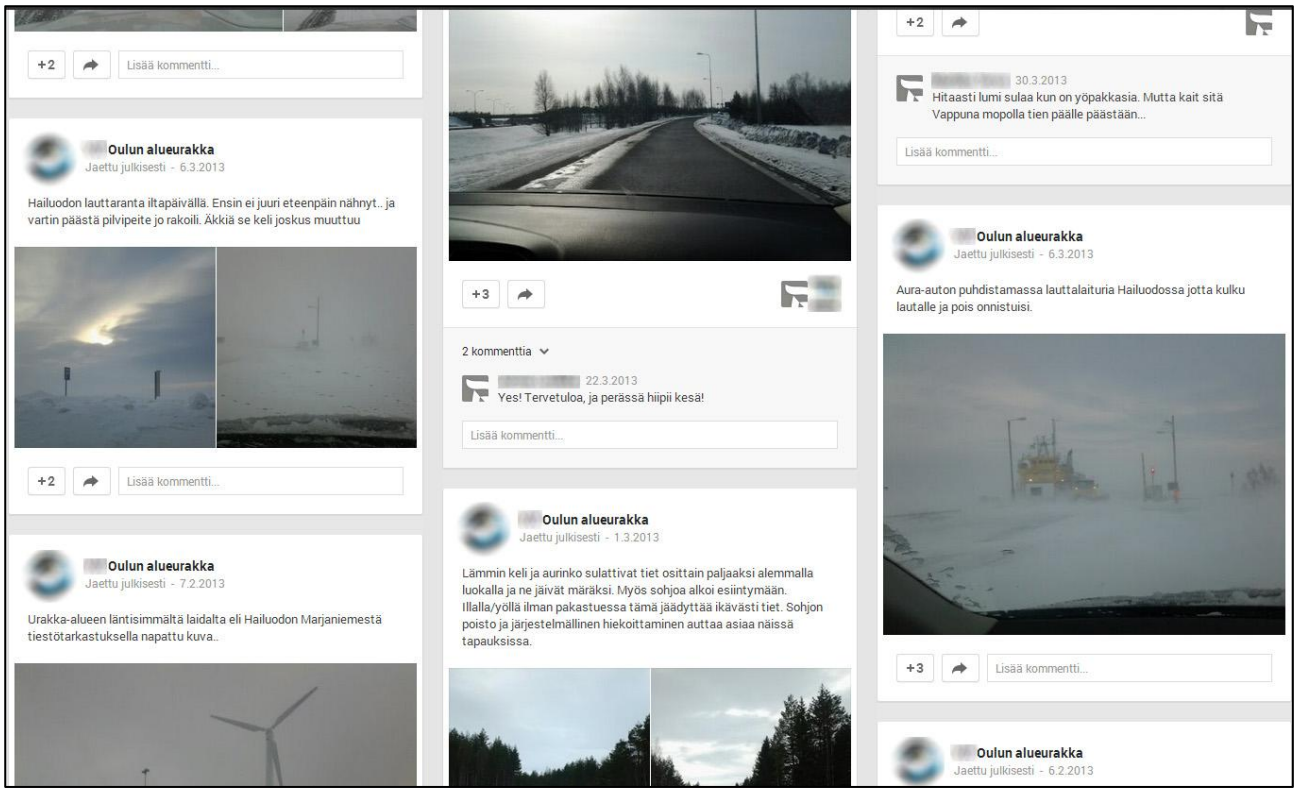

Figure 7. Google+ discussion window.

6. CONCLUSIONS

In conclusion, it can be said that real-time systems are a good accessory for maintenance contracts. They involve benefits and disadvantages, but virtually everyone has a positive impression of their use – the benefits are greater than the disadvantages.

While experiences of real-time systems are positive, many find that we have not seen the final system yet. The use of the systems has triggered ideas for further development concerning the systems themselves and their expansion. The systems have generated new operating models for work and management.

The use of real-time systems has also triggered needs to develop other operations along with the developent of technical equipment and software. Social media is an interesting direction into which the use could be expanded. In addition, new devices, such as smart phones, tablets and mobile broadband, provide new opportunities for use in mobile road maintenance work.

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