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Applicability of ITS Solutions in The Field of Winter Maintenance in Estonia

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Abstract

The objective of this article is to identify and assess options for improving the effectiveness of winter road maintenance as well as road safety through the implementation of intelligent transport systems (ITS). The research focused on the situation in Estonia. A survey was conducted and results analysed to map the concerns and wishes of winter maintenance workers and assess the readiness of stakeholders to implement ITS solutions. The sample was compiled to include the entire country, i.e. the survey included both local and state roads. Local roads were selected on the basis of the population of said administrative unit and the amount of funds allocated to local roads from the state budget. The research examined which ITS solutions could Estonia transfer from other states and under which terms and conditions. It also identified the terms (economic efficiency, mandatory nature, improving road safety, sustainability of the environment) under which the authorities and companies engaging in winter road maintenance would consider implementing a new ITS solution, as well as the extent of such implementation.

Keywords: intelligent transport systems, winter road maintenance, government agencies, private companies, new technologies

1. Introduction

In the course of the project titled "The Estonian Road Cluster", financed by Enterprise Estonia with funds obtained from the European Regional Development Fund, the Estonian Asphalt Pavement Association carried out a survey "Applicability of ITS solutions in the field of winter maintenance". The authors of this article were among the respondents of said survey, and have used, with the approval of the Estonian Road Cluster, a part of it for writing the article. In the course of it the authors analysed similar researches [1],[2] where it was stated that although ITS technologies can be promising aids in the field of winter maintenance, extensive implementation of each technology is currently hindered. The obstructions are mostly, but not only, of technological nature. Thus, additional research and development are required in order to ensure further improvement of this field. We also analysed the situation in our neighbouring countries where several surveys on winter road maintenance have been carried out [3],[4],[5][6].

ITS brings together many different parties related to the transport sector. Development of ITS to ensure comprehensive development of the transport system that would consider all the above-mentioned parties, is impossible without efficient cooperation. In Finland, for example, a non-profit association ITS Finland [7] comprises over 60 agencies and companies. While the transport support

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system is mostly directed at the end-user of the transport system, i.e. the road user, the clients of ITS also include various non-road-users such as parties related to the planning and administration of the transport system, road maintenance companies, vehicle owners and possessors, and several others.

In Finland it is considered very important to provide road weather information for different customer groups, not only the professionals but also other users of information. Data collected and information are worth using effectively for various purposes. Administration grants the right of use the Road Weather Information System equally for road maintenance contractors and road management centres to ensure uniform quality of road maintenance all over the country. On the other hand Finnish Transport Agency's Traffic Management Centres use the same information for traffic management and information. For road users Finnish Transport Agency with ELY Centre for Southeast Finland provides traffic and road weather information in order to improve traffic safety, traffic fluency and comfort of travelling. In Finland administrations give public data to service providers of value-added services according to open data principles so that they can create new and innovative solutions to utilize the data for services for different devices. [8]

So far, the development of intelligent transport systems in Estonia has mostly been related to the needs of road administration. The development of ITS solutions based directly on the needs of road users has only started to increase recently. Knowing this, it becomes clear why the opportunities of the private sector in developing various public services have been rather limited and why the applications have mostly been developed by the public sector.

A survey was conducted to map the concerns and wishes of winter maintenance workers and assess the readiness of stakeholders for the implementation of ITS solutions.

To reduce expenditure on winter road maintenance and improve effectiveness and road safety through ITS solutions, we mapped the current situation in Estonia and analysed the results of the survey. Likewise, we provided an assessment on the applicability of ITS solutions in Estonia.

Andrey. I et al. (2001) [9], wrote that for motorists in transit the most useful information is real-time, site-specific information on visibility and road conditions. Intelligent transportation systems (ITS) offer the potential to deliver such information through variable roadside message signs, highway advisory radio and, in the future, message relays to in-vehicle navigation systems. Advances in weather prediction, remote sensing, computer, telecommunications, and engineering technologies since the mid-1980s have facilitated the development of new tools that provide the specified data. However, more emphasis should be placed on the quality/usability of information from the perspective of the road maintenance operator.

Pruunsild and Antov (2013) [10] wrote that the importance of weather forecast has become one of the most significant factors in cleaning the roads from ice. This is a field that can help to save immensely on materials, increase work efficiency and decrease damages to the environment. Therefore it is necessary to implement intelligent transport systems for supporting road maintenance. All the future perspectives for road maintenance should be tested and their cost-effectiveness should also be taken into account. All new requirements and technologies implemented for road maintenance must ensure that solutions are found for the problems and that the maintenance of Estonian roads shall provide a long and quality lifetime for roads.

The Norwegian Road Administration conducted a thorough research titled “SaltSmart” [11] to identify options for improving winter road maintenance. For example, the research indicated that proper winter maintenance alone (e.g. with the help of ITS solutions) does not guarantee better road safety. If the driving speed increases 5-10 km/h after road salting, the number of serious accidents will most likely increase too, cancelling the positive effect of the increase in friction. Increase in

friction should be accompanied by speed limits and compliance checks so as to prevent speeding. The Norwegian Road Administration also published a manual recently, with additional information on road maintenance [12], focusing first and foremost on the aspects of the environment.

Chapman et al. (2014) [13] wrote about the Internet of Things (IoT). The Internet of Things (IoT) quite literally means 'things' (e.g. sensors and other smart devices) which are connected to the Internet. Since 2008, the number of 'things' has outnumbered users online. The recent miniaturisation of technologies coupled with reducing costs of sensors of comparable accuracy to operational and scientific instrumentation has led to the growing potential of dense sensor networks, which becomes central to the smart cities agenda, and indeed the IoT. Winter maintenance is exceptionally well placed to take advantage of this rapidly changing technological landscape given the complexities of operations and the need for high resolution data that will ultimately drive decision making. Indeed, given the maturity of the science in the sector, it could well be used as an exemplar for other industries to follow. There are already many examples which are effectively following the IoT approach. There now exist fleets of Internet connected commercial and passenger vehicles with the potential to make the high resolution surface observations required by the winter road maintenance.The data from such mobile platforms could be hugely significant in improving and verifying road weather forecasts.

Technology is developing rapidly and we should take advantage of it as much as possible so as to make winter road maintenance more effective and improve road safety. These are the reasons for this research.

2. Methodology

In the course of the research, major road maintenance companies in Estonia as well as state and local government authorities responsible for commissioning road maintenance were asked to complete a survey. The survey had two main goals:

- To assess the readiness of stakeholders (providers of winter maintenance, authorities responsible for commissioning maintenance) to implement ITS solutions;
- To compile an extensive map of the concerns, expectations, wishes and recommendations of winter maintenance workers.

The questionnaire was sent to 33 institutions, 18 of whom were clients commissioning maintenance (5 of them being the Road Administration with its regional offices) and 15 providers of maintenance. There were 21 respondents, i.e. *ca* 64% of sent questionnaires was returned, 11 of whom were clients and 10 providers of maintenance. If we look at the questionnaires of providers of maintenance on the basis of the total length in kilometres of the roads maintained by the Road Administration, we will see that the proportion of responses was 93.7%, i.e. based on the division of maintenance work (Fig. 1) 15 areas out of 17 responded to the survey, which means that the responses covered at least 25,929 kilometres of the 27,653 maintained kilometres. This proportion may actually be bigger as 4 surveys were anonymous – for two of them it was only stated that the respondent was a client, for the other two, a maintenance provider. Such overview of responses on the basis of total kilometres is not available for local roads.

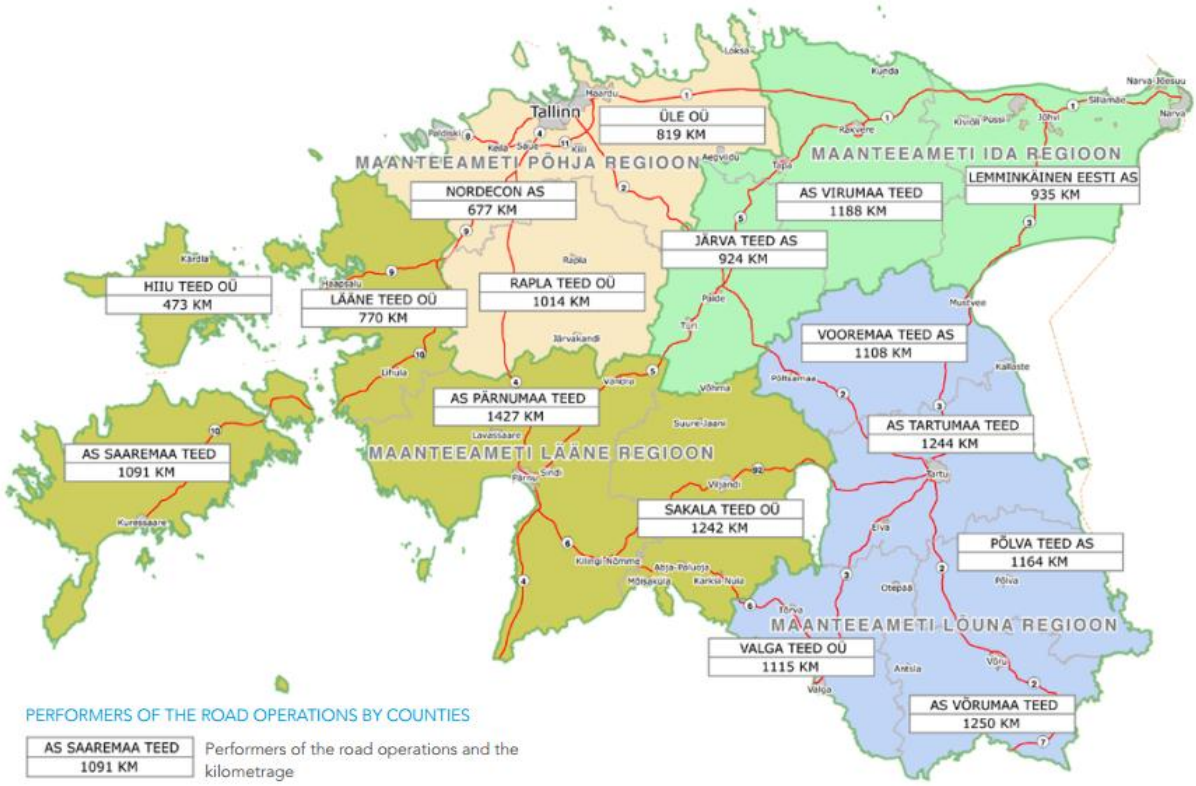

Fig. 1. Division of maintenance work in counties by maintenance provider [14]

The sample was compiled to include the entire country, i.e. the survey included both local and state roads. Local roads were selected on the basis of the population of said administrative unit (Statistics Estonia) and the amount of funds allocated to local roads from the state budget.

3. Results

The survey was conducted online. Below we will provide an overview of the results by questions, followed by respondents' comments, recommendations and observations on the subject. As already said, there were 21 respondents, i.e. the proportion of a respondent forms *ca* 4.76%. In the overview below we have rounded this figure up to 5%.

3.1. Question 1: List the solutions you use for winter road maintenance.

67% of respondents use data from road cameras frequently or very often; 5% use said data sometimes and 28% of respondents said they seldom or never use road cameras.

Weather services provided by the Estonian Weather Service (EWS) are used frequently or often by 76%, and sometimes or seldom by 24% of respondents. Just like with foreign websites, no one said they never use the EWS services.

The information system Teeilm (Road Weather) is used frequently or very often by 72% of respondents; sometimes or seldom by 14%, and never by 14% of respondents. This information system is frequently used by 90% of maintenance providers who responded to the survey.

Weather forecast websites of other countries are used frequently or very often by 80% of respondents; sometimes by 10%, and seldom by 10% of respondents. These weather forecast

websites are used by all respondents, though at different frequency – no one said they never use them.

The information system for measuring friction is a relatively new application, and this is evident from the responses. The system is used frequently or very often by 24% of respondents; sometimes by 14%, and seldom or never by 62% of respondents.

Also, 43% of respondents claimed to use the website tarktee.ee: 1/3 of respondents use it frequently, 1/3 often and 1/3 sometimes.

The respondents mentioned that in addition to location, the GPS equipment of road maintenance vehicles records speed, time and type of activity (ploughing, salting, etc).

Other used applications included ilm.ee, personal presence, regional surveillance, road information centre, surveillance log (http://hoole.mnt.ee) and satellite images of temperature and precipitation.

Respondents' comments:

The respondents' comments on the use of winter maintenance solutions included the following:

- If the required level is ensured, salting norms and ploughing methods should be of no concern.
- GPS solution must be adjusted to provide data on the type of activity and salting norms.
- There is no information system for measuring friction and the GPS shows only the location.
- I mostly follow information systems intended for specialists, which is why I seldom use the application Tark Tee (Smart Road) as its options are limited. Supervision (and maintenance) logs are in great need of updating.
- Operational and practical information provided by road-users on the state of roads is of great help as it is not possible to check every road and it might not be necessary anyway.
- The accuracy of Estonian weather forecast systems is limited to one country; foreign systems are rather more accurate and can forecast a change in 24 hours also on county level.

3.2. Question 2: On what terms would you consider implementing new ITS solutions?

If it were cost-effective within 5 years after implementation, 71% of respondents would (definitely or probably) implement a new solution, and 10% would maybe implement a new solution; if the solution were cost-effective within 5-10 years, the indicators would be 57% and 19% respectively.

If a new solution were mandatory, it would (definitely or probably) be implemented by 62% of respondents. 19% said they would consider implementing a new solution, and 19% were not sure, which was entirely understandable as no information was given to respondents on the nature of such solutions.

If new solutions were to improve road safety, they would (definitely or probably) be implemented by 86%, and maybe implemented by 14% of respondents.

If new solutions were to improve sustainability of the environment, they would (definitely or probably) be implemented by 67% of respondents; 28% said they would consider it and 5% would rather not do it.

If the effectiveness of an ITS solution (in the broadest terms: sustainability of the environment, improving road safety, etc. were also considered in addition to economic efficiency) were certain, it would (definitely or probably) be implemented by 85% of respondents; 10% said they would consider it and 5% would rather not do it.

Other reasons for implementing new ITS solutions included the following: desire to be innovative; only if such new service were to replace the current requirement to send data on road conditions to the Road Information Centre; improved effectiveness of work; operational implementation; user comfort.

Respondents' comments:

Comments in response to the question "On what terms would you consider implementing a new ITS solution?" were as follows:

- If the contract expires in less than five years – I do not know.
- The solution should be easy and comfortable to use on a smart device.
- It is difficult to assess the economic efficiency of better notification of drivers, enabled by many ITS solutions. The same applies to improving road safety. The requirements of the client, included in the contract, are to be complied with.
- ITS solution should be cost-effective within the duration of the maintenance contract. The solution should benefit both the client and the maintenance provider. It should improve maintenance quality. Its only purpose cannot be fining the maintenance provider. The best results are achieved through cooperation between the client and service provider. Pointless requirements should be avoided, such as sensors for ploughs and determining the amount of salt. Unfortunately the reliability of sensors has not been very good so far. I am certain that service providers encountered on roads are not there for their own pleasure but with the intention of working.
- ITS solutions must support applications developed to ensure user comfort, stability and operational implementation. ITS solutions seem to be preferred by software developers, not considering the needs of the end-user.

3.3.Question 3: What are the possible negative aspects of ITS solutions?

As possible negative aspects of ITS solutions, 62% of respondents stated that the software may fail (definitely or probably) while 38% said there can sometimes be problems with the software.

In terms of hardware failure, 52% of respondents stated that this was a problem (definitely or probably); 38% said there can sometimes be trouble with hardware; 15% said there are mostly no problems, and 5% did not know.

When asked whether there are too few ITS solutions and whether their standard is uneven, 43% of respondents said it was definitely or probably so; 47% said it was maybe so; 5% stated it was not the case, and 5% did not know.

When asked about modern solutions and options and whether these should be introduced more extensively, 47% of respondents stated it was definitely or probably so; 24% said it was maybe so; 24% stated it was not the case, and 5% did not know.

Other reasons listed included the following: road weather stations and cameras should be located more densely; communication problems; obtaining information from different systems takes up more time than driving to the site. More detailed descriptions are given in the section of the respondents' comments.

Respondents' comments:

The respondents' comments on the possible negative aspects of ITS solutions:

- There are currently no estimate values for road conditions and road temperature; more attention should be paid to the training of maintenance workers.
- Currently used older weather stations do not provide sufficient information.
- Seeing is believing. Once, the road camera showed an image of a snowy road while it was known not to be accurate. In the end it turned out to be a lighting error.
- Unfortunately, this questionnaire fails to specify what this "ITS" will enable to achieve in road maintenance sector.
- Friction measuring is ambiguous. Preventive salting based on forecasts is not profitable.
- Excessive reliance on ITS data.
- Weather station data are not always accurate. There should be more road cameras.
- The system needs further development to ensure reliability. After all, this work is carried out in an aggressive environment, with exposure to salt.
- Road weather station network is defective. Road cameras only benefit road users and do not provide assistance in making maintenance decisions. Accuracy of information can be identified only when accidents occur. There is no proper overview of the provision of maintenance with the help of ITS.
- Frequent glitches in both software and hardware.

3.4.Question 4: Which are the positive aspects of currently used solutions?

85% of respondents said that ITS solutions definitely or probably help save time; 10% were not certain, and 5% said that current solutions do not save time.

76% of respondents said that ITS solutions definitely or probably help save funds; 14% were not certain; and 10% said that current solutions do not help save money.

57% of respondents agreed that current ITS solutions definitely or probably have a positive effect on road safety; 38% were not certain; and 5% said it was not so.

52% of respondents agreed that current ITS solutions definitely or probably help ensure sustainable environment; 33% were not certain; and 15% said it was not so.

Other positive aspects included operational implementation and availability of data.

Respondents' comments:

- Good coverage by road weather stations. However, the number of stations should be even bigger.
- Facilitates maintenance activities, especially the analysis of completed work.
- Provides a general overview of road conditions that serve as a basis for drawing conclusions.
- Set of raw data that can be further processed; however, currently everyone must do it individually.

3.5.Question 5: List your concerns in relation to winter maintenance.

In response to the statement "Weather forecasts are inaccurate", 43% of respondents said it was definitely or probably so; 24% said it was maybe so; 28% of respondents said it was not so, and 5% did not know.

In response to the statement "There are no estimates of road temperature and road conditions", 52% of respondents said it was definitely or probably so; 14% said it was maybe so; 28% of respondents said it was not so, and 5% did not know.

Should the client's requirements be jointly reviewed by the client and the contractor? For example, our systems are too modern for the client's requirements; or vice versa, we have requirements as a client but the contractor is not capable of fulfilling them, etc. Regarding this statement, 57% of respondents said it was definitely or probably so; 23% said it was maybe so; 10% of respondents said it was not so, and 10% did not know. Separate analysis of the responses of clients and maintenance providers reveals that 45% of clients are of the opinion that the requirements should be reviewed (definitely or probably) while the respective indicator was 73% for maintenance providers. This indicates that both parties are somewhat dissatisfied with the client's requirements.

Is the information provided to road-users on road conditions insufficient? Here, 33% of respondents said it was so; 29% said it was maybe so; 33% or respondents said it was probably not so, and 45% did not know. It is evident from the responses that there is no consensus on this topic: responses were in the middle of the scale and the use of absolute values (definitely, definitely not) was less common.

In response to the statement "Acquisition of modern equipment and development of ITS systems is not cost-effective", no one said it was definitely so. Only 23% of respondents stated it was probably so; 10% said it is maybe so, and 57% of respondents disagreed with the statement (definitely not or probably not), meaning that they are of the opinion that the acquisition of modern equipment and development of ITS systems is cost-effective.

Other concerns related to winter maintenance included expenditure, speed cameras, identifying offenders, necessity of a PR campaign, and a notion road-users have to consider – road conditions are different in winter.

Respondents' comments:

- Compliance with service levels. Provision of current and accurate information to road-users. Different options for displaying the work of maintenance vehicles via (functioning) online application. Make maintenance data more available for people – if road-users have an overview of maintenance activities, the number of calls made on this subject will decrease and officials responsible for maintenance management can focus on proper work and quality.
- Winters are different; road-users do not seem to understand service requirements and service times. They wish for the maintenance vehicles to rush over to where they are. Hopefully, the situation will improve in the future.
- Delays in commencing work, lack of budget funds,
- High expectations of road-users.
- Insufficient preventive measures during changing weather conditions.
- Weather.
- Making road-users aware of the message \"ROADS CAN BE SLIPPERY IN WINTER \".
- Poor awareness of road-users of the requirements of service levels. Speed cameras on Tallinn-Tartu road are located at the edge of the road and hinder snow control operations. Insufficient funding of winter maintenance.
- Rapidly changing weather. Harassing attitudes of road-users towards maintenance providers.
- Decisions have to be made on the basis of unprocessed data. Instead of looking at a software-compiled analysis, the on-call worker must himself conduct a quick analysis and assessment. There are no statistical data necessary for later analysis.

- Different contracts and requirements concerning the provision of winter maintenance! Lack of supervision resources.

3.6. Question 6: List your expectations, wishes and recommendations in relation to ITS solutions.

Below is a list of the respondents' expectations, proposals and recommendations in relation to improving the effectiveness of winter maintenance:

- We need more road sensors to facilitate the work of road maintenance providers and make it more accurate; likewise, we need more information on different roads, and more weather stations should be located on secondary roads.
- Further development of applications related to friction measuring (real-time mapping of measuring results).
- There should be a road camera at the T-2 and T-89 intersection (in Saverna) or at the T-2 and T-62 intersection (in Erastvere).
- More software solutions for smart devices. Current applications are too slow and uncomfortable to use.
- More extensive implementation of friction measuring information system and operational publication of results in addition to road weather station data.
- ITS solutions must be user-friendly to function as aids in maintenance management and supervision. Constant development is preferred to complete solutions.
- There should be more road cameras and weather stations; all road weather stations should be equipped with automatic friction measuring devices.
- Further develop the system and avoid using excessive requirements that will not be implemented. Consider establishing region-based information centres to provide more specific and accurate information. These centres will monitor road conditions 24 hours a day and will forward obtained data to the maintenance provider (Finnish system).
- In a country as small as Estonia, ITS should help provide accurate estimates for winter maintenance. Unfortunately, this is not the case. Due to the influence of the Baltic Sea, the temperature may be +3°C on the islands and -34°C in Värska. Models compiled on the basis of satellite images should be linked to the network of road weather stations in order to obtain accurate information on the conditions prevalent at each station, and analyse data in retrospect to ensure better estimates in the future. Likelihood of errors due to human factor (on-call maintenance worker oversleeps, lack of experience, etc.) should be kept to a minimum. In the spring of this year, salting application rates of de-icing were inaccurate in several counties, which made the situation a lot worse. Advance salting may not be effective during snowstorms as the snow gets stuck on the road. Forecasts are of great importance.
- In addition to the GPS, sensors should be installed on the ploughs and salting equipment of maintenance vehicles. Likewise, more road cameras and road weather stations should be installed.

4. Conclusions

One of the objectives of the research was to identify which ITS solutions and on what conditions can be transferred to Estonia from another countries.

The conducted survey revealed that *ca* 71% of respondents would implement a new ITS solution if it were cost-effective within 5 years; if the solution were cost-effective within 5-10 years, the respective indicator would be *ca* 57%. This means that the proportion of expenditure and revenue

related to new solutions should be made very clear. If the effectiveness of the ITS solution were to be proved beforehand, *ca* 86% of respondents would implement it.

The results also indicate that if a new solution were to be mandatory, it would be implemented by *ca* 62% of all respondents; the respective indicator was 80% for contractors. This shows that initiative of clients is one of the relevant aspects upon implementing new solutions.

New solutions should definitely help improve road safety. If this were the case, the solution would be implemented by *ca* 86% of respondents. And if said solutions would help ensure sustainable environment, it would be implemented by *ca* 67% of respondents.

Complete solutions should be preferred when considering transferring systems from other countries, i.e. both hardware (sensors, etc.) and software (administration programs) should be transferred simultaneously. Right now this would either require replacing current software systems and sensors (weather stations) or implementation of parallel systems. Replacement of current systems should be justified. Results of the survey revealed that the road weather information system is frequently used by 72% of respondents who are of the opinion that there should be more stations. The respondents did not claim to be unsatisfied with the systems. However, they did mention that the use of systems should be easy and comprehensible. This will probably not be the case if several parallel systems were implemented.

The respondents also stated that there is need for a more extensive implementation of friction measuring information system, more operational publication of results in addition to road weather station data, and constant development of current systems. All this can be achieved using domestic expertise.

Therefore, considering the cost of systems used elsewhere in the world, and issues related to intellectual property rights (cost of licences and patents), potential risks accompanying the transfer (compatibility of new systems with current systems and sensors) as well as rapid growth of the IT sector (which constantly requires further development; however, this could be complicated – even impossible – for finished goods), it is probably reasonable to develop the applications (software) on site. When transferring complete solutions, the suitability of each product should be assessed separately (expenditure and revenue, compatibility, etc.).

Several respondents stated that managers have high expectations in terms of winter maintenance. Likewise, managers have insufficient knowledge of road condition requirements, and they tend to forget that conditions are different in winter. These observations are accurate but traffic management is more or less the same in summer and in winter – meaning that speed limits stay the same throughout the year while driving conditions change. We could pose a rhetorical question here - are we driving too slow in summer or too fast in winter? As such, the question is undoubtedly simplified, but it does indicate a certain contradiction. This topic should definitely be examined further.

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