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Better winter road weather information saves money, time, lives and environment

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ABSTRACT

Weather service systems that collect, refine and distribute information to road users as well as network and maintenance operators can generate significant benefits to the stakeholders and the society. For maintenance operators improved efficiency through timely reactions, smaller amounts of de-icing materials and better personnel utilization offer clear potential for reduced costs. In the future, better weather models will result in more accurate longer-term forecasts thus increasing the potential for benefits. New technology enables new kinds of services (e.g. decision support systems). This paper provides a structured view of the benefits of weather information services to different stakeholders. A framework on the impacts of weather information on winter road management will be presented.

Keywords: road weather, services, RWIS, DSS, benefits

1 INTRODUCTION

Adverse weather conditions in the wintertime result in significant losses both in life and well-being as well as in material due to increased accidents. This paper will present a review of researched ex ante and ex post impacts of weather services specifically for winter road maintenance. The emphasis is on weather information services impacts.

Weather forecast services are based on collecting weather-related information, refining it using forecast models and then distributing the information to road users and maintenance operators. The information can be offered as free, publicly available forecasts and warnings, or it can be packaged as a premium service specifically tailored for the needs of each client.

In Finland, specialised road weather centres offer round-the-clock monitoring of weather and road weather conditions to road maintenance operators so they can get alerts as soon as conditions seem to require maintenance operations. A new addition to the weather domain are decision support systems (DSS) that provide assistance to a variety of actors from policy and decision makers to maintenance operator staff. DSSs can suggest the best course of action in a given situation and demonstrate the potential impacts of the actions to be taken. DSS takes a step forward in the utilisation of weather information by introducing decision making rules which in the past were only in the heads of maintenance operators.

Weather services obviously provide significant cost reduction potential for the maintenance operators by improving efficiency through timely and well-targeted reactions. They help in optimising the ordering, storing and using of salt, sand and other materials needed in road maintenance. Savings in the amount of salt used on public roads alone in Finland have been estimated to reach 400000 euros annually. Weather information also provides similar benefits by making the utilisation of personnel more efficient and enabling timely responses to changing conditions. Up to 2.2 million euros could be saved each year in Finland in personnel costs and avoided fines due to delayed maintenance operations. On top of this come the environmental externalities and other user benefits.

2 MAIN BODY

2.1 Approach

This paper examines the benefits of winter road weather information in the domain of road transport. The positive impacts of weather information are segmented by user groups (e.g. road users, fleet managers, infrastructure owners, and maintenance operators) and types of benefits (e.g. societal benefits, helping a specific function).

The goal of this paper is to identify what kinds of benefits have been studied the most and where research on the subject might be lacking. Another goal is to pinpoint the aspects and user groups where the biggest benefits from winter road weather information are found. Potential new areas of research on the subject are a significant outcome of the paper.

To achieve this, a literature review collating existing research results on the benefits of road weather information is done with a specific focus on winter conditions. Only results published in 2000 or later are considered. As an output of this process, a summary framework of the identified positive impacts is presented.

2.2 Winter road weather information

The changing climate and increasing number of severe weather phenomena is posing serious challenges to both the transport infrastructure and the people using and maintaining it. The EC-funded EWENT project has done a detailed examination of the potential impacts of extreme weather [1].

In terms of winter road transport, the most significant extreme weather phenomena are snowfall, low temperatures and blizzards [1]. Snowfall often causes significant delays in travel times and increases the likelihood of accidents. This is due to slippery road conditions, the presence of excess snow on the road surface and limited visibility. Low temperatures result in reduced accessibility and quality of the transport network. Roads become more slippery, especially in temperatures just below freezing, and flooding can be observed. As in the case of snowfall, the main impacts are increase in the number of accidents and longer travel times due to lower speeds. The impacts of blizzards are similar to those of snowfall and low temperatures.

Road weather information can help to better respond to these kinds of severe winter weather conditions and mitigate their impacts. The role of winter road weather information is pronounced especially in battling against limited visibility and increased slipperiness as conveying information about these conditions to road users and maintenance operators increases awareness and helps to prevent and mitigate accidents and to improve preventive maintenance operations.

Organisations that are responsible for operating and maintaining the transport network can use surveillance, monitoring and prediction technologies to help them mitigate the impacts of adverse weather [8]. Road weather information systems (RWIS) utilising roadside sensor stations provide observed and forecast weather and road weather condition information to transport network managers and maintenance operators to aid in deciding on the best control and road treatment strategies for any given situation.

Information on the current and predicted conditions can be provided to road users and fleet operators by using variable message signs (VMS), web sites and services that display information to the driver during the trip (using either a mobile phone or an in-vehicle system). On the traffic control measures front, speed limits can be varied and traffic signal timing modified based on the prevailing conditions. Location-based fleet management systems combined with mobile or on-board sensors can help to optimise sanding and de-icing operations. In problematic locations fixed de-icing systems that are automatically controlled and activated by road weather information can be installed.

Road maintenance operators can get road weather information from specialised road weather centres that offer round-the-clock monitoring of weather and road weather conditions. The road weather centres can provide alerts to maintenance operators as soon as conditions seem to require maintenance operations. A relatively new tool for maintenance operators are maintenance decision support systems (MDSS). They integrate weather and road weather observations and forecasts, maintenance rules of practice, and maintenance resource data to help winter maintenance managers choose the optimal road treatment strategies for different situations. U.S. Department of Transportation's MDSS project is one example of such a system [4].

2.3 Benefits of winter road weather information

The benefits of road weather information have been studied by different authors and organisations from many different perspectives. A good summary of existing research is presented e.g. in [7]. We limit our examination to studies published in the year 2000 or later.

A U.S. study on the benefits and costs of road weather information systems and anti-icing technologies found RWIS to be a key enabler of anti-icing capabilities. The study estimated the potential benefit-cost ratio of road weather information system (RWIS) and de-icing technologies in the US to be in the range of five [2]. However, a case-related example calculation of a benefit-cost ratio in the same study gives a B/C ratio of only 1.1. Cost savings reported in the study came from reduced need for equipment and staff, reduced use of salt and reduced need for patrolling. Other identified benefits included improved driver information, increased maintenance efficiency (scheduling and asset management), reduction of environmental impacts and improved safety. Only qualitative benefits were listed.

The benefits of RWIS on rural roads were studied on U.S. 395 highway in Spokane [9]. RWIS was studied as an integrated concept combined with enhanced traffic management centre (TMC) services. A survey among road users and employees of Washington State Department of Transportation was done to find out the impacts. The results showed several positive impacts including improvements in winter road maintenance efficiency due to increased availability of relevant RWIS data and other information. This enabled more efficient allocation of resources and personnel and making proactive treatment decisions. RWIS also made travellers more prepared and better enabled to make travel decisions resulting in more driving satisfaction and safer driving.

The use of variable message signs for providing weather information or adapting speed limits to prevailing conditions has been examined in several studies. In alerting drivers about slippery road conditions using VMS in Finland, the average speeds were found to drop 1.2 km/h [10]. During the night the reductions in average speeds were more significant. Another study analysed the wide-scale use of variable message signs at the Finnish national network level [11]. After the weather-controlled VMSs were installed on a wider scale, reducing the relative fixed cost of investments, the system was found to be profitable with benefit-cost ratios ranging from 1.1 to 1.9.

The impacts of variable message signs on driver behaviour were also studied in Idaho, U.S. [6] In the study, the drivers were informed about changing weather conditions (high winds and other extreme weather conditions) using VMS. The use of VMS had an impact on the driver behaviour so that in poor weather conditions speeds were reduced more than without using VMS.

The U.S. Department of Transportation has examined the risks related to extreme weather conditions on U.S. roads [8]. Limited visibility or slipperiness caused by fog, snow or ice accounts for more than 500 million hours of delay annually. Every year approximately 7400 people are killed and more than 670000 injured in weather-related accidents (based on statistics acquired in 1995–2005). Estimated annual losses of these weather-related accidents vary between $22 billion and $51 billion.

The DoT summary [8] points out that 80–94 per cent of motorists accessing on-line traveller information find that road weather information increases their safety and ability to prepare for adverse weather conditions. On short sections of road that are vulnerable to limited visibility or strong winds, warning systems using variable message signs or other signalling devices have been found to gain the attention of drivers and affect their driving behaviour in a way that reduces crash risk.

Up-to-date road weather information can help maintenance operators react proactively to changing weather conditions [8]. Effective anti-icing and pre-wetting strategies have been reported to reduce sanding and chemical applications by 10 to 30 per cent. They can also have environmental benefits by reducing chloride and sediment runoff in local waterways. Anti-icing programs have been shown to lower snow and ice control costs by 10–50 per cent and reduce crash rates by 7–83 per cent.

Many benefit-cost studies of different road weather information technologies have been done [8]. The provision of detailed weather forecast information to winter maintenance personnel in Salt Lake City, Utah reduced labour and materials costs for winter maintenance activities and yielded a benefit-cost ratio of 10. In another context, more efficient application of anti-icing materials reduced maintenance costs and delays while increasing safety. The benefit-cost ratios for the combination of RWIS and anti-icing strategies range from 2 to 5.

The British Department for Transport (DfT) has also examined the impact of weather-related transport disruptions on both welfare and the GDP [3]. The estimated average daily cost of transport disruption due to severe weather conditions is £280 million in England. This includes costs resulting in loss of welfare that do not factor in when calculating the GDP.

There is significant uncertainty involved in estimating the impact of severe weather. This is why the DfT's weather-related cost estimate can range from £100 million to £520 million [3]. The single figure estimate is put at £280 million. The costs on a normal day due to congestion are approximately £60 million. The estimate is based on the assumption that ten per cent of each day's work is lost due to workers' lost time. It is also assumed that half of this lost time is eventually made up.

The investment assessment by DfT [3] does not provide a detailed analysis of road weather information benefits. However, it presents a number of improvements that the Highways Agency (HA, responsible for operating, maintaining and improving the strategic road network in England) has identified as ones that could be delivered at a reasonable cost and within defined budgets. These improvements include:

- developing a process for warning heavy goods vehicle operators of severe weather conditions;
- developing the use of VMS to improve information to road users ahead of and during severe weather incidents;
- improving communications with road users so that they can plan journeys and adapt their driving behaviour during severe weather; and
- developing improved guidance for the treatment of roads at extremely low temperatures.

The European QUANTIS project looked at how the quality of road weather information services affects the benefits gained from them [12]. In the project service quality was examined as the error probability of the service providing information outside of predefined quality boundaries.

The service quality (i.e. error probability) of the Finnish road weather information system was examined at two points in time: in 1998 and in 2003 after improvements in the road weather infrastructure. In 1998 the error probability was estimated to be 14%. In 2003, after updates to the road weather stations, sensors and analysis software, the error probability was estimated at 11% accounting for a reduction of 3 percentage points.

The benefits of improved service quality were examined from a socio-economic point-of-view. A majority of the benefits was found to come from improved road user safety. The estimated decrease of 3 percentage points in error probability in 2003 translated into an annual reduction of four more injury accidents and 0.5 more fatal accidents compared with the situation in 1998. The savings in annual accident costs were therefore 5.1 M€ greater in 2003 than in 1998. However, it could not be shown that the increase in benefits was solely due to the decreased error probability.

An analysis of the effectiveness of meteorological services in Finland examined the benefits of weather information and warning services for road transport on public roads in Finland [5]. The safety benefits of providing weather and road weather information to road users were estimated to be from €16 million to €32 million. The potential additional benefits resulting from more advanced weather information and warning systems were assessed to equal the current benefits (i.e. €16–€32 million). The clear majority of these benefits result from the reduced number and severity of personal injury accidents. Benefits related to winter road maintenance came primarily from three sources: reduction of unnecessary and belated operations and needed materials (sand, de-icing substances). These totalled €2.7 million in cost savings consisting of savings of €400 000 in reduced need for materials, €450 000 in less unnecessary operations and €1.8 million in fewer belated operations.

The same study also identified pedestrians and bicyclists as a potential target group for weather and road weather information and services that could yield significant safety benefits. In this user group, the benefits come from preventing slipping accidents. It was estimated that current weather and road weather services targeting end-users reduce slipping accidents requiring medical attention annually by 1 000–1 500. This reduction would bring in cost savings of €49–€73 million every year, as the average cost of such a slipping accident was estimated to be approximately €50 000. In addition, weather and road weather services provided to road maintenance operators were estimated to prevent about 2500 slipping accidents requiring medical attention resulting in annual savings of €120 million. Based on the study, the total benefits of current weather and road weather services for pedestrians and bicyclists thus range from €170 million to €190 million.

Table 1 presents a summary of the examined research results classified based on one hand the user group and on the other hand the function or aspect that the benefits are focused on.

		Function				Societal benefits		
User groups		Road use	Road maint.	Traffic mgmt.	Asset mgmt.	Safety	Environment	Economy (saved time)
Road users	Private drivers & travellers	[8][3][9] [10][6]				[12][2] [10][11] [5]	[8][2]	[8][3][11]
	Pedestrians & bicyclists	[5]						
	Professional drivers; passenger, freight	[8][3]						
Fleet managers	Passenger							
	Freight							
	Maintenance				[8]			
	Emergency services	[2]						
Infrastructure service providers	Maintenance contractors		[8][3][2] [9][5]					
Authorities	Road authority							

Table 1. Summary of research results on the benefits of winter road weather information to different user groups.

3 DISCUSSION AND CONCLUSIONS

The role of extreme weather phenomena is widely expected to become increasingly important as the global climate is undergoing slow but demonstrable changes. For areas experiencing typical winter conditions this can mean more snowfall, lower temperatures and increased potential for blizzards. The effects of snow and low temperatures can also be experienced in areas that have typically had relatively mild and snow-free winters.

The impacts of snowfall, lower temperatures and blizzards are mainly longer travel times and increased number of accidents. This results in more lost lives, more personal injury accidents and loss of time both for businesses and individuals. The prevalence of winter conditions calls for more winter maintenance operations, which in turn translate into a bigger burden on the environment through the increased use of anti-icing and de-icing materials.

The literature review clearly showed that weather and road weather information can significantly help to combat against and to mitigate the impacts of winter conditions. The use of weather information in variable message signs has clearly been shown to have an impact on driving behaviour in suboptimal conditions by reducing speeds. Lower speeds reduce the severity of accidents and improve safety. On a larger scale as well, weather and road weather information services have been found to provide significant benefits to road users through the reduction of fatal accidents and the mitigation of personal injury accidents. However, the identified benefits are largely qualitative in nature – studies outlining clear quantitative benefits are still few and far between.

The reduction of slipping accidents by pedestrians and bicyclists is also a very noteworthy impact of weather and road weather information. In Finland, hundreds of slipping accidents requiring medical attention are avoided due to weather services and hundreds more could be prevented by developing and adopting additional services. The impacts of road weather information on this user group are something that definitely calls for more detailed studies both at the European and the global level.

In maintenance operations, road weather information can help maintenance operators to better predict and prepare for sudden changes in weather. This is realised in more optimised use of personnel, fleet and preventive materials resulting in significant financial savings in personnel, equipment and material costs as well as a reduced environmental footprint.

The compiled summary framework on the research of impacts of road weather information shows that safety impacts have been studied and identified most frequently when looking at the societal side of things. In addition, road use by private drivers and maintenance operations by contractors have been found to provide positive impacts in several studies. Evident gaps are found in examining the benefits to fleet management both in

passenger and freight transportation as well as to pedestrians and bicyclists. Benefits to authorities come mainly from the societal impacts, but the potential impact of road weather information to traffic management is something that definitely calls for more detailed examination. Across the board, qualitative studies outnumber quantitative studies by a mile exposing an issue that should be addressed.

On the technology front, decision support systems providing assistance to maintenance managers and operators are starting to become available and could offer major benefits in planning and executing maintenance operations. Very little research into the impact of DSSs is available as they have not been used for long, and this is a topic that should be addressed more in the future. Another key trend is the explosive increase in the number of smartphones. People are getting accustomed to having Internet and related services along wherever they are: at home, in the office, driving or taking a walk. This provides new opportunities for exposing people to more up-to-date road weather information in a context where it would be most useful.

Going forward, the development of weather and road weather models will provide significant improvements in the accuracy of especially longer-term forecasts. New technology (e.g. sensors in vehicles) is making more information available enabling the creation of new services (e.g. mobile friction measurements). The gradual automation of automotive transportation is also a development that will significantly increase the importance of having accurate and up-to-date information on the weather and road weather conditions as well as services and applications that can take advantage of this information to provide for safer and more efficient travel on the road.

5 REFERENCES

[1] Bläsche J, Kreuz M, Mühlhausen T, Schweighofer J, Leviäkangas P, Molarius R, Nokkala M, Athanasatos S, Michaelides S, Papadakis M, Ludvigsen J. 2011. *Consequences of extreme weather.* EWENT deliverable 3.4. Available at http://ewent.vtt.fi/Deliverables/D3/EWENT_D34_v1_0_20111201.pdf.

[2] Boselly E. 2001. *Benefit/Cost Study of RWIS and Anti-Icing Technologies.* Final report. Washington: Transportation Research Board, National Research Council.

[3] Department for Transport. 2011. *Winter Resilience in Transport: an assessment of the case for additional investment*. December 2011. London: Department for Transport. Available at http://assets.dft.gov.uk/publications/winter-resilience-in-transport/an-assessment-of-the-case-for-additional-investment.pdf.

[4] Department of Transportation web site. 2011. *Projects and programs: FHWA Road Weather Management Program Projects and Activities.* Available at http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#p3. [Accessed: March 6, 2012].

[5] Hautala R, Leviäkangas P. 2007. *Ilmatieteen laitoksen palveluiden vaikuttavuus: hyötyjen arviointi ja arvottaminen eri hyödyntäjätoimialoilla.* VTT Publications 665. Espoo: VTT. Available at http://www.vtt.fi/inf/pdf/publications/2007/P665.pdf.

[6] Kyte M, Shannon P, Kitchener F. 2000. *Idaho Storm Warning System Operational Test - Final Report*. Prepared by the University of Idaho for the Idaho Transportation Department. Available at http://ntl.bts.gov/lib/11000/11100/11191/cc01.pdf.

[7] Leviäkangas P, Hietajärvi A. 2010. Weather Information for Transport – The Value Shift. *Value World.* Vol. 33, no. 2, pp. 4-13. SAVE International. Available at http://www.value-eng.org/valueworld/Value_World_Summer_2010.pdf.

[8] Maccubbin R, Staples B, Kabir F, Lowrance C, Mercer M, Philips B, Gordon S. 2008. *Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned: 2008 Update.* U.S. Department of Transportation. Available at http://www.itslessons.its.dot.gov/its/benecost.nsf/images/Reports/$File/BCDLL-14412_full.pdf.

[9] Meyer Mohaddes Associates Inc. 2004. *Evaluation of Rural ITS Information Systems along US 395, Spokane, Washington.* Report prepared for the U.S. Department of Transportation ITS Joint Program Office. Available at http://ntl.bts.gov/lib/jpodocs/repts_te/13955/13955.pdf.

[10] Rämä P. 2001. *Effects of weather-controlled message signing on driver behaviour.* VTT Publications 447. Espoo: VTT. PhD thesis.

[11] Schirokoff A, Rämä P, Tuomainen A. 2005. Vaihtuvien nopeusrajoitusten laajamittainen käyttö Suomessa [Large-scale use of variable message signs in Finland]. *Publications of the Finnish Ministry of Transport and Communications*, 89/2005.

[12] Öörni R, Innamaa S, Kulmala R. 2010. Road weather information service in Finland: the impact of error probability on service benefits. In: Düh J. 2010. *Data and Mobility: Transforming Information into Intelligent Traffic and Transportation Services: Proceedings of the Lakeside Conference 2010.* Berlin: Springer Verlag.