

Value of weather information for road management

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ABSTRACT

Weather information is valuable to road management value chain starting from the planning, construction and operating of roads, and yielding to value-added services to road users. Prior studies in the field show multiple use cases for weather information and tangible value in many respects. The technological changes and trends of new public management will however change the valuation logic. In the future, recognition of the business value will become more relevant. Many applications, such as variable message signs will be replaced by in-vehicle applications. Also the unbundling of the public sector functions will change the way that different actors look at weather information. Some systems, formerly regarded as public, will probably change into business tools of private/commercial operators.

1. INTRODUCTION

Weather information has value. We know that for sure, but we may not know exactly just how much it is worth in different situations and contexts. Without us getting too deeply involved in semantics of what is information and what is value, we can safely and without any loss of the contents state that information becomes valuable when it has an impact. The impact may be hitting the decisions or decision making processes or it might hit right the operations carried out in the field. Also in the latter case, however, some decisions must be made. In more general terms, information has value when it affects behaviour.

Information value studies have usually fallen under the science of information economics, where good references are to be found, such as Williamson (1982) and Lawrence (1999). On weather information, there are also a number of studies. Leviäkangas (2009) studied how to value meteorological information in general, and in particular from the service provision viewpoint. Leviäkangas and Hautala (2009) studied how useful were the services provided by Finnish Meteorological Institute (FMI). They found that the annual budget of FMI was used to provide a service repertoire that generated benefits to the society that annually exceeded the budget at least five times over. Some other benefit analysing studies on meteorological information and services are provided by e.g. Anaman *et al.* (1997) and Freebairn and Zillman (2002).

Value of information is not a one-lump concept. In fact, value can be decomposed into value attributes such as accessibility, accuracy and effectiveness. Herrala *et al* (2009) list those attributes quite extensively, using traffic information as an example and combining several prior research sources. There are also multiple methods and techniques how to value information, the most thorough presentation being in Leviäkangas (2009).

Hence also when considering the value of weather information for road management one should be aware that the valuation problem in itself requires different methods and techniques, depending on the nature and context of the valuation situation.

2. SCOPE, DATA AND METHODS

This paper reviews a number of different studies and makes a synthesis on the value of weather information. It focuses on road management use case and much of the emphasis is on winter road management in particular, but other transport modes are considered briefly too. We shall utilise as a main source the results of the FMI case study, carried out as a part of the EVASERVE project (www.evaserve.fi), where a wide-covering literature review was performed. We shall introduce the main results of prior studies on the subject and attempt to make a synthesis on those. This way, we hope to bring to use a condensed body of knowledge what weather information can do for road management in the light of reported research results and help the winter road community, meteorologists, road weather experts and road managers in general to justify the development of even more efficient forms of weather information utilisation in road management and transport infrastructure management in general.

Our empirical material is the published literature and this makes our paper a review. Our theoretical foundation comes from value engineering, information economics and transport engineering, being thus very much leaning towards applied sciences of engineering and economics.

We shall go through the empirical material, i.e. the different studies with tangible results on the benefits and value of weather information for road management, by introducing shortly some relevant studies. However, the list will be far from exhaustive, including those only accepted as material for the EVASERVE project. Then, we will take a brief look at studies covering other transport modes (also included in EVASERVE material).

Finally, we are synthesising the studies, grouping their results and making conclusions on how valuable weather information seems to be in the light of current knowledge. We shall distinguish between winter road management and other road management, as the former is on the focus of SIRWEC 2010. However, sometimes this distinction is not evident and there are overlaps - the reader should exercise care when making conclusions of one's own.

3. WEATHER INFORMATION AND TRANSPORT – REVIEWING SOME OF THE STUDIES

3.1 Winter road management

Boselly (2001) describes the use of road weather information system (RWIS) and de-icing technologies in the US. The study does not describe very well the empirical material, i.e. where and how the information is gathered, but it claims that the potential cost-benefit ratio of extensive use of RWIS may be as high as 5, but the case example calculation shows a B/C-ratio of 1.1. The cost components consist of RWIS equipment, weather service, winter road maintenance, labour and material costs. The benefits accrue from improved service level, cost savings (not identified in detail), reduction of environmental impacts and better safety.

Wass (1990) and Thornes (1990) estimated the costs savings in using de-icing substances in the UK due to improved weather service. During 1983-1988 the use of de-icing substances reduced by 15% and the total costs of winter maintenance due to this between 5%-30%.

Rural roads ITS (intelligent transport systems) information systems were studied on US 395 in Spokane by Meyer, Mohaddes Associates Inc. (2004). ITS was studied as an integrated concept using multiple applications, including RWIS and enhanced traffic management centre (TMC) services. The impacts were mapped through a survey among road users and employees of Washington State Department of Transportation. The survey showed that there was a strong belief that ITS would in general had beneficial impacts, such as reduced use of de-icing materials, better decisions to route and time journeys, and improved road safety.

Kempe (1990) estimated similar benefits as the above studies regarding the use of salt for de-icing. His conclusions was about 50% reduction material use reduction per winter. The study was carried out in Sweden.

Lähesmaa (1997) studied the benefits of weather-controlled winter road maintenance, looking the benefit-cost calculus from the socio-economic perspective, including the externalities. He found that pure maintenance cost savings did not mount to significant sums. Accident cost savings were substantial, but they were eaten up by increased time costs so that he ended up in a cost-benefit ratio of 0.5. The socio-economic profitability would change very quickly if a) the investment cost to related IT could be brought down; b) there is a substantial traffic volume (threshold value of 20 000 vehicles per day in the case example).

Pilli-Sihvola *et al.* (1993) investigated the impacts of road weather service on driving costs, including the external costs of accidents. The article did not mention details on how the study was devised and what was the data behind it. However, there were significant costs savings, the lion share of which was coming from accident savings. The conclusion was that road weather service would pay itself back with a benefit to cost ratio of 5 to 1.

Rämä (2001) had a decrease of vehicle speeds by 1.2 km/h on average, when alerting the drivers via variable message signs (VMS) to slippery road on one test site in Finland. Night time, the decreases of speeds were more significant. A very careful research set up included 139 situations which were analysed in detail.

Schirokoff *et al.* (2005) did an analysis on the wide-scale use of variable message signs, utilised especially in winter conditions in Finland, on a national network level. Once the weather-controlled

VMSs would be installed on a wider-scale, hence reducing the relative fixed cost of investments, the system became profitable with a benefit-cost ratio of 1.4.

3.2 Weather information and other road management aspects

Cooper and Sawyer (1993) studied the impacts of a fog warning system where dynamic message signs (DMS; essentially the same as VMS) were used to inform road users on the fog ahead. The speeds were lowered on average by 3 km/h, when the signs were activated. Hence, it was concluded that the fog warning system would improve safety. The study was commissioned during 1990-1992 in London and included 4.8 million observations on vehicle speeds.

Kyte *et al.* (2001) study the impacts of advanced weather information system on driver behaviour in Idaho, US. There was a field operational test in two stages between 1993-2000. The drivers were informed via variable message signs (VMS) on the changed weather conditions. VMSs did enhance the driver behaviour impact so that in poor weather conditions the lowering of speeds was more significant than without VMSs.

Skarpness *et al.* (2003) described FORETELL system in the US, the main idea of which was to gather real-time weather information in one place, or rather to be utilised via one single portal through the internet and dedicated website. The investigation was carried out during three winters during 2000-2002, but the actual investigation was for 1998-2002 including the design and reporting phases. The idea was to test the usefulness of such information that would be easily available and accessible. Interviews were the method of measuring usefulness. Most of the respondents (number varied along the study) were happy with the information and found it useful and understandable, but only 20% would have been willing to pay for it.

3.3 Other modes of transport and general aspects of weather information value

We found actually no studies that would explicitly look into how weather information could improve the performance of railway transport and railway operations. Only two studies emerged, by Thornes and Davies (2002) and Smith (1990) that presented what impacts weather has on railways in the UK. Impacts such as measurable reduction in the reliability of timetables, increased maintenance costs and interruptions in traffic were among the typical ones.

Motte *et al.* (1994) looked into how weather information affected the routing of sea vessels. The study was carried out using short-term (<72 h), medium-term (72 h < x > 240 h) and long-term (>240 h) forecast information. The study was commissioned in 1993 and surprisingly it concluded that the probability of errors in routing increase the shorter is the forecast horizon. In other words, routing “more in real time” did not improve performance!

Sonninen (2007) did an extensive analysis on weather information benefits to waterborne transport in Finland. She found that extensive benefits already with existing level of weather information service improves safety in boating, helps proactive measures in oil combating and results in operational savings to shipping lines, especially when thinking of routing of the vessels. As a method, Sonninen combined statistical data, interviews and prior studies (see e.g. Craft 1998) in the field. Empirical material as such was not really available.

In aviation, the use of weather information is self-evident and in fact there are few studies that directly address the question. Latorella and Chamberlain (2002) investigated the usefulness of graphical weather information to US airline pilots. Not surprising, of the 12 pilots that were testing graphical information found it very useful and some even insisted to have similar in the future.

Treinish and Praino (2004) studied new fog forecasting system designed for airports. The idea was improve forecasting of fog, that resulted in 2002 about 4.2 bill. USD losses for airlines. Of these costs about 1.3 bill. USD were estimated to be preventable with better forecasting tools.

Allan *et al.* (2001) estimated the potential reduction of airline delays when utilising Terminal Weather Information System in New York airports.

We should not forget the most relevant transport mode of all: light traffic. Hautala (2007) gathered information from several studies and concluded that the potential savings in reduced accidents and more effective winter maintenance resulted in 2006 already more than 100 mill. EUR accident cost savings in Finland. The potential for more savings was considerable. Those interested in Hautala's references, see e.g. Björnstig *et al.* (1997) and Vuoriainen *et al.* (2000). It is a pity that this mode of transport has

received so little attention, but perhaps our understanding of its significance is about to increase due to climate change and better awareness of the multiple benefits of the most natural mode of transport.

A number studies have been conducted on generic value of weather information, e.g. Thornes and Stephenson (2001), Murphy (1994), Adams *et al* (1995) on long-range information, Beysson (1997), Gunasekara (2004), Rollins and Shaykewich (2003). Most of them conclude, using various methods and valuation techniques, that weather information is most beneficial.

Table 1. Summary of reviewed research – how useful/valuable/beneficial is weather information?

Theme / aspect	References	Results / identified impacts	Notes
Winter road management, maintenance and operations	Boselly (2001)	Road weather information systems are profitable investments (B/C = 5)	Safety and service level impacts probably dominate the benefits
	Wass (1990), Thornes (1989)	Improved weather information will reduce winter maintenance cost for 5%-30%	Note that external environmental costs (reduced pollution of ground waters due to less salting) are not included
	Kempe (1990)	50% less salt for de-icing with more advanced road weather information systems	Pilot project in Sweden
	Lähesmaa (1997)	Investments in weather-controlled winter road management systems not easily profitable (B/C = 0.5)	Time costs due to reduced speeds eat up accident savings; operational savings in maintenance not significant
	Pilli-Sihvola (1993)	Road weather service is beneficial (B/C = 5)	A system level assessment based on mainly expertise and inside observation on pilot projects in Finland
Other road management, maintenance and other operations	Skarpness <i>et al.</i> (2003)	Weather information portal found very useful by road management personnel and road users. However, low willingness-to-pay.	USA
Safety effects in winter conditions	Rämä (2001)	VMSs reduce speeds (1.2 km/h on average) and result in accident savings	Increased time not taken into account and no benefit-cost analysis performed
	Schirokoff <i>et al.</i> (2005)	A wide-scale adoption of VMSs would enhance safety impacts and aggregate system would have a B/C=1.4	Finnish main road network
Safety effects in general	Cooper and Sawyer (1993)	Fog warnings by VMSs reduce speeds and improve safety	4.8 million observations on vehicle speeds in London for 1990-1992
	Kyte <i>et al.</i> (2001)	VMSs warning drivers on poor road weather conditions had an additional marginal impact on driver behaviour reducing speeds	Sweden
Other transport modes	Thornes and Davies (2002; Smith (1990)	Weather impacts significant on rail operations (schedule, safety, reliability), but not quantified	UK
	Motte <i>et al.</i> (1994)	Weather information used for waterborne vessel routing did not improve significantly performance	USA
	Sonninen (2007)	When efficiently utilising weather information, significant impacts on boating safety, vessel operations and oil combating efficiency	Sonninen's analysis utilised extensively other prior studies and statistics
	Hautala (2007)	More efficient utilisation has great potential in improving pedestrian and light traffic safety especially in winter conditions	Hautala's study synthesised extensively different prior research results and statistics

4. SUMMARY OF REVIEWED RESEARCH

If we summarise the reviewed research the pattern is clear, but perhaps not as clear as we might wish it to be. Table 1 shows the summary in one glance.

The aviation studies are not included in the summary table, but on the other hand, aviation case is that much evident that further repetition on the need of weather information in aviation operations is really meaningless.

What does the prior research then tell us? What is obvious is that the use of variable message signs did have a real impact on driver behaviour in poor road weather conditions, whether that be slippery surface or reduced visibility. Reduced speeds mean improved safety and less severe accidents if such occur. This road side technology did gain a lot of attention but is already pretty much outdated as the technological applications with similar functionalities have taken their place inside the vehicles. However, we do not yet know whether in-vehicle applications are as efficient in the long run as were the VMSs. Or they might be much more efficient. But nonetheless the road managers' role must obviously change from active information disseminator to something other, where this technological change is taken into account. Besides, reduced speeds mean also time losses, which tend to eat up safety benefits in socio-economic cost-benefit analysis. Hence, the controversy of this fact does not need to bother road managers too much, if the applications will be introduced by automotive industry as in-vehicle systems.

As to maintenance operations, the pattern is definitely clear: less salt, less environmental burden on e.g. ground waters, more efficient and better targeted de-icing operations. Here the potential of better road weather information systems is still intact. The only thing that really is changing and must be considered is the fact that unbundling of road administrations will shift the responsibility of winter maintenance operations from formerly integrated road managers to various maintenance service providers. Road weather information systems become actually more and more business tools of the service providers rather than tools for road managers, if we understand that term 'road management' refers mainly to the authority role of road infrastructure management. And when RWIS becomes a business tool, one starts to increasingly measure its impact in cash flow terms.

Considering other modes of transport, the business and safety impacts of weather information for aviation are and have always been considerable. Functional airports and open runways have direct impacts on airlines' and airport operators' profitability. Also here, one could easily be inclined to emphasise the business impacts, which by the way, is not at all detached from the questions of safety – quite reverse.

Waterborne transport can be easily put to the same category as aviation. Shipping lines and operators utilise weather information directly to reduce their costs. But Sonninen's (2007) analysis clearly pointed out the great potential for private boating, which has launched tailored services for boaters – in Finland, e.g. Finnish Meteorological Institute and the private met-service provider Foreca Ltd. both offer web-based and mobile weather services for boaters.

One of the great possibilities is light traffic, as shown by Hautala and Leviäkangas (2008). This could be a high-growth place for new met-information services and with very important socio-economic aspect.

5. WHERE DO WE GO FROM HERE?

The discussion concluded in the previous section that evidently we are on a shift from public road weather information systems and services towards private or semi-private systems. This occurs because of at least two reasons: first, there has been a considerable change in vehicle technology so that vehicles are in fact now monitoring the environment perhaps more efficiently and certainly more locally than any other monitoring system relevant for the driver; secondly, the unbundling (i.e. privatisation, commercialisation and restructuring) of former road authority functions have shifted the responsibility to private and/or commercial maintenance operators and service providers.

These changes are illustrated in Figure 1, which attempts to capture the shifts in the light of three simplified example systems:

- 1) RWIS, which is defined here as a system that comprises weather stations, the communication links and back-office systems which enable to monitor and forecast what the existing road conditions are now and in the near future.

- 2) Variable message signs, which in the authors' opinion represent already somewhat outdated technology and human-technology interface. Much of the same information will be in the near or medium-term future available through in-vehicle applications, either stand-alone or co-operative ones.
- 3) Weather-info services directly to end-users, by which we mean met-info services delivered mainly via wireless networks directly to personal devices; these systems may supplement or in some cases even replace in-vehicle applications.

What makes the situation interesting is that the logic to evaluate the benefit generating capability of the systems will also change as the system evolution proceeds. Variable message signs have been replaced by more promising and efficient technical means. Hence they are becoming automotive makers' value added systems for consumers and their justification of existence will change from "safety devices" to "accessories" to a certain extent at least. When VMSs were justified by road authorities using socio-economic cost-benefit analysis (CBA), the automotive makers will simply adopt cash flow analysis (CFA) based on market assumptions. There has been actually a radical "mutation" in the evolutionary process of transferring road condition information to road users on the spot.

Road weather information systems (RWIS) are still needed and they have evolved from road authorities' informative tools to private or commercial road maintenance service providers' business tools which help them to perform their operations more efficiently. The shift from public system towards jointly operated systems, which could be in many cases called to some type of public-private partnerships (PPP), has already taken place. As and if the *new public management* trend is continuing, the RWIS will turn into business tools of these operators and service providers. It should be remembered, however, that this means also that the systems are getting more and more closed, to be managed and hosted in-house only. The development of vehicle technology, vehicles being the monitoring infrastructure, could change this logic though. In PPP arrangements both parties, the public and the private/commercial, will use their own logic of valuation of the "goodness" of the system. The challenge is to combine the interests of both. This is not that easy, which is reported in studies on other type of PPPs too (see e.g. Leviäkangas 2007). Road weather systems are surely no exception to the rule.

Road weather info-services directly to end-users started in the past as public service but very quickly developed into privately supplied information services or PPPs. Even if there is a significant amount of public finance involved, the market pull will dictate how well and widely the information is utilised. And this being the case, the market push will also become more important, respectively. In any other case, there would only be public service without too many users and this is simply not acceptable even from public sector's viewpoint.

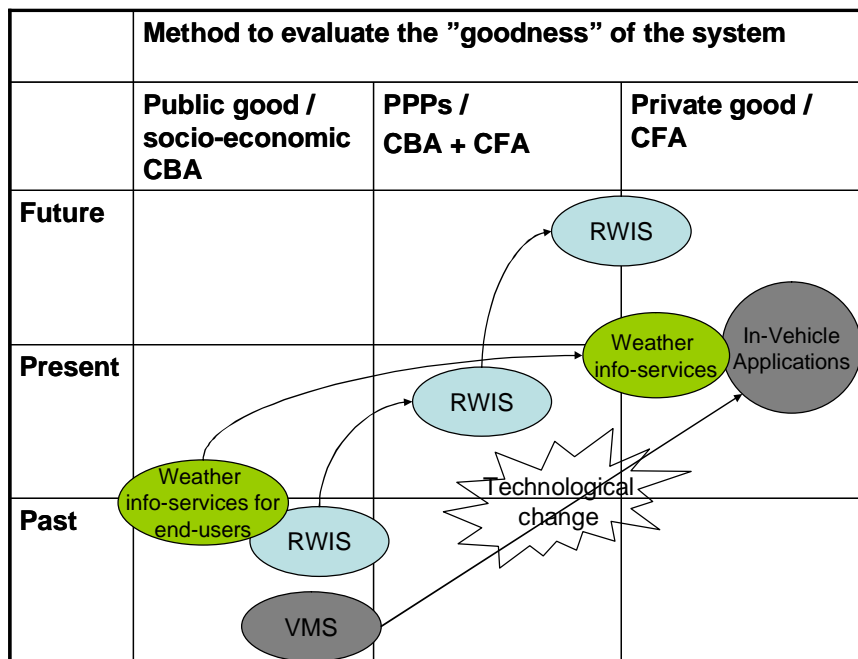


Figure 1. Three example system entities and their evolution

In sum, the whole field of road weather information is under rapid evolution largely because of new public management thinking is reshuffling the roles and responsibilities of road authorities, maintenance contractors, met-service providers and other information service providers. This combined with the aggressive development of vehicle and communication technologies will make future unpredictable. We may perhaps see half a decade ahead but longer-term visions are truly visions in the word's truest meaning.

As to the value of weather information in road management... well, this is easy to put briefly: if there is no business value, the cash value, in the foreseeable future of road weather information, the future will look grimmer to whole road weather community, regardless whether we address the experts, business people or the public sector servants. All the trends are pointing to this direction. The trend is neither good nor bad, though, just to be taken note of. Authorities' role is crucial as they need to make it sure that when the market is offering road weather services to road management value chain (e.g. to maintenance contractors or to road users directly), the services must have the component of socio-economic good in them. The market itself will not do that on people's behalf.

Furthermore, there will most probably a clearer distinction between day-to-day weather information, serving the operational purposes and provided mainly by commercial or private entities, and strategic, long-perspective weather information, which serves public sector dealing with infrastructure placement (where to build) and climate impact mitigation (how to make infrastructure more resilient to weather). This will be reflected also on valuation logic of the information: short-term information is cash valued, long-term information is socio-economically valued.

These questions on time-perspectives of weather information are partly to be answered in EWENT project (Extreme Weather impacts on European Networks of Transport), which has been launched in the beginning of December 2009 under European Commission's 7th Framework Programme. One of EWENT's main tasks is the valuation of extreme weather impacts (contact the 1st author for more information).

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