County-wide variable speed limits?

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ABSTRACT

In Finland several road sections, totalling approximately 350 km, have been equipped with variable speed limits. The aim of the study was to estimate the costs and the benefits of a weather-controlled variable speed limit system that would cover most of the Finnish main roads. The building costs and annual maintenance costs were evaluated based on a quality, up-to-date system. It seems likely that a weather and road condition controlled system of variable speed limits would be profitable in Finland. The benefit-cost ratio calculated with the most likely starting values was 1.1–1.9. As a conclusion, it can be said that it is probably not advisable to build variable speed limit systems very extensively but more of them should be built on highly trafficked road segments.

Keywords: Variable message sign, speed limit, cost-benefit analysis, evaluation

1. INTRODUCTION

In Finland several road sections, totalling approximately 350 km, have been equipped with variable speed limits. Most of these systems are weather-controlled. Speed limit signs and possible attached warning signs are controlled automatically, but they can also be controlled manually if needed. The automatic control is based on data produced by the road weather system. The used speed limits are determined according to the control policy formulated by the Finnish Road Administration. The most recent systems have red, black and white LED-signs.

Depending on the site, the weather and road conditions are classified either into three (normal, poor, very poor) or four (good, normal, poor, very poor) categories. On one-carriageway roads the speed limits used are 100, 80 and 60 km/h. On motorways the speed limits used are 120, 100, 80, and 60 km/h. However, during the wintertime the 120 km/h speed limit has not been used, which is in accordance with the guideline for speed limits in Finland.

The Finnish road authorities have adopted a policy to develop and implement ITS applications gradually during experiments. According to this policy, variable message sign (VMS) systems have been evaluated from different points of view. Road side interviews have shown good acceptance for variable speed limit systems [1–3]. Effect evaluations on driver behaviour have shown that the VMS system on the E18 road affected driver behaviour according to the goals set for the systems [2–3]. During adverse road conditions the motorway VMS system decreased the mean speed and the standard deviation of speed [4]. Variable speed limits were proved to be most effective when slipperiness was difficult to detect. Under good conditions, when higher speed limits were allowed the mean speed increased moderately [2–3]. Drivers seemed to obey the variable speed limits even more than the fixed speed limits. The findings emphasised the importance of the reliability and the error-free control and road authorities' responsibility in control policy.

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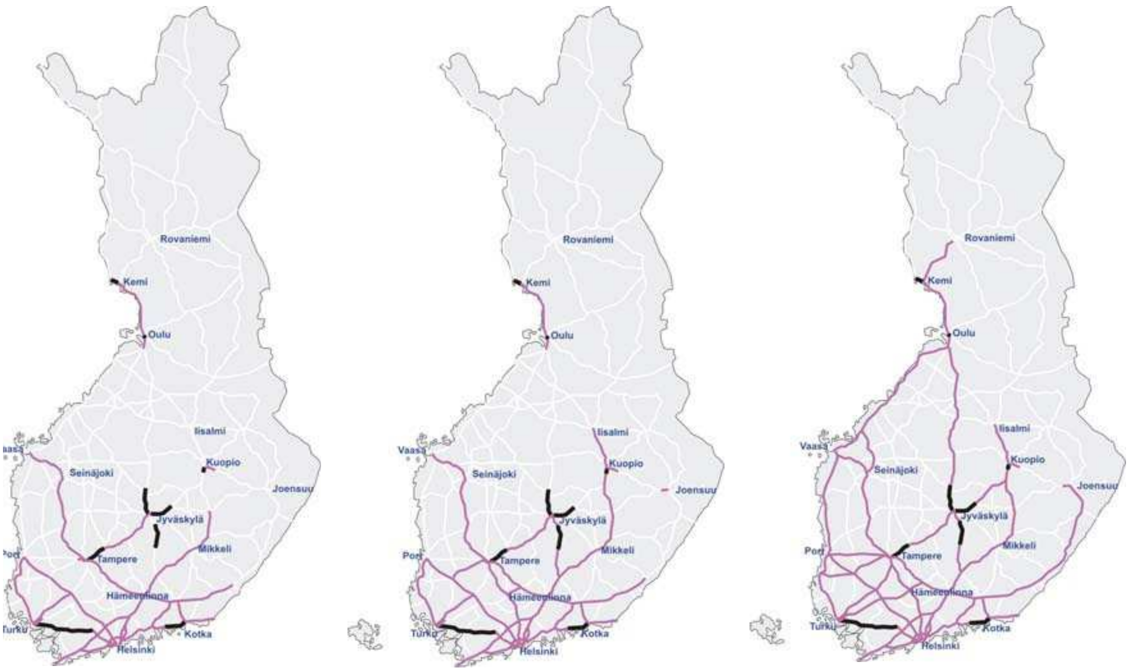
2. METHOD

2.1 Network selection

The starting point of the study was the main road network that is planned to be developed in the future according to the roadmaps of the road authorities. Based on that network, totalling almost 5000 km, three scenarios for the VMS network were created. The lengths of these networks were 2100–4300 km (Figure 1). Road sections belonging to the networks were selected based on set traffic safety and traffic volume criteria. The selection was finalised from a driver's point of view, i.e. the networks were completed in such a way that the VMS-controlled network did not end at an illogical point or did not have gaps between the selected road sections.



Network I, 2118km Network II, 2774km Network III, 4303km

Fig. 1. Suggested different scenarios for the VMS network. The current systems are shown in black.

2.2 Estimation of the safety impacts

The data of an earlier study [4] of the safety effects of the variable speed limit systems was complemented by two years data. The analysis was based on a comparison of the injury accident risk on the road sections before and after implementation of variable speed limits. The same types of roads with fixed speed limits were used to control the general trend in the injury accident risk. In the control data, the fixed speed limits complied with the limits before the variable speed limit systems were implemented.

According to the complemented data, the variable speed limit systems seemed to decrease the injury accident risk by 10 %. Variation in the data was considerable in respect to the amount of injury accidents even though the studied period was 14 years. Therefore, the results were not statistically significant. In this study, an estimate of a six percent decrease in accidents was used for the summer-time.

2.3 Estimation of the travel times

Expected changes on the travel-times were based on three points: current measured mean speeds of heavy and light vehicles on different road types, expected timely proportions of the variable speed limits based on experiences from the current control policies (Table 1), and expected changes on the mean speeds of light and heavy vehicles different road types on different conditions based on research results and expert estimates.

Table 1. Three scenarios (A, B, and C) of the timely proportions of the speed limits played by variable speed limit signs in winter time.

Timely proportions of speed limits (%)	Single carriageway roads				Dual carriageway roads			
	100	80	70	60	120	100	80	70
A (the current policy)	20	65	14	1	10	75	14	1
B	20	76	5	1	10	86	5	1
C	55	39	5	1	20	76	5	1

2.4 Implementation plan

The construction costs of the systems were estimated according to the implementation principles given in Table 2. The speed limit and warning signs use LED technology. The implementing costs and the annual maintenance costs were based on the experience of the most recently built systems.

Table 2. The numbers of signs and monitoring equipment of VMS systems.

Road type	Speed limit signs	Combined information and warning signs	Traffic monitoring stations	Road weather stations	Traffic monitoring cameras
Motorways and dual carriageways	6 units /graded intersection if the spacing between intersections is longer than 5km speed limit repeater signs are required (4 units)	one for each carriageway for each intersection spacing	every graded intersection spacing has one traffic monitoring station	one for every 15 kilometres	one for each graded intersection
Single carriageways	4 units /intersection if the spacing between intersections is longer than 5km speed limit repeater signs are required (2 units)	one for every other intersection spacing	one for each 20 kilometres	one for each 15 kilometres	one for each 20 kilometres

The construction costs of dual carriage way roads are about double that of single carriage way roads. The greatest cost is due to cabling (Table 3).

Table 3. Average implementation costs, 20 year maintenance costs and portions of costs of construction costs.

Road type	Construction (€/km)	Maintenance including replacement investements (€/km/year)	Portion of construction costs (%)		
			Signals	Cabling	Monitoring systems (traffic and cameras)
Motorways and dual carriageways	80 000	3 500	31	60	9
Single carriageways	36 000	1 000	44	50	6

The cost-benefit analysis was made for 20 years of use and took into account the annual traffic increase of two percent and assumed annual decrease of five percent in personal injury accidents. Pollution and noise costs were assumed to be marginal at most and were thus not included.

3. RESULTS

The building costs and annual maintenance costs were evaluated at the 2004 level. The basis was a quality, up-to-date system. As no study data was available on the traffic impacts of traffic situation controlled VMS systems, the building costs of the systems were allocated separately on weather and road surface condition controlled system, for which the benefit-cost ratio was calculable based on financially evaluable benefits. The impacts of weather and road surface condition controlled systems were evaluated based on the speed and safety adjustments and the future use of speed limits.

The impacts of weather and road surface condition controlled systems were evaluated based on the expected effects on mean speeds, the empirical data on the safety effects, and the future use of speed limits (Table 4). Based on these assumptions, variable speed limits the will increase travel time costs both in winter and summer-time. In 20 years period the number of fatalities was estimated to be decreased by 107 on the network III.

Table 4. The 20 years' (2008–2027) benefits and costs of a variable speed limit system discounted to the year 2006, based on the price level of 2004.

The network	Weather-controlled system				Weather- and traffic-controlled system	
	Benefits (M€)		Costs (M€)		Costs (M€)	
	Traffic safety	Travel time	Implementation	Usage and maintenance	Implementation	Usage and maintenance
I	170.0	–18.9	64.5	53.7	101.7	83.7
II	211.8	–27.5	81.3	67.2	129.0	105.3
III	278.3	–36.1	111.2	92.1	181.4	143.6

The benefit-cost ratio was calculated for different safety evaluates and speed limit use principles. With the most likely starting values it was 1.1–1.9. The benefit-cost ratio was higher if the safety assumptions were higher and the higher the use of higher speed limits was assumed to be. The latter is due to decreased time costs.

4. DISCUSSION

In the study, the profitability of a weather and road condition controlled system was evaluated. In Finland, in the current systems the control of the speed limits is typically based on weather and road conditions. However, it was assumed that in the future the control of most of the systems would be based also on traffic situation. Hence, all costs including those due to traffic situation based control were taken into account so that a realistic picture of the costs was able to be given. The systems' costs of building, operating, and maintaining were estimated according to the systems implemented in 2004. However, because there is no research data on the effects on traffic of those systems in Finland yet, the profitability of variable speed limit systems controlled by the traffic situation was not studied. The costs were allocated separately to weather controlled systems, for which it was possible to calculate a benefit-cost ratio on the base of benefits that were financially calculable.

Based on the results, it seems likely that a weather and road condition controlled system of variable speed limits would be profitable in Finland. The benefit-cost ratio calculated with the most likely starting values was 1.1–1.9. However, because the interaction between the safety effects and different control policies of VMS systems is not known, the range can differ from the estimated. In a scenario that best applies to the current practice, meaning that the highest allowed speed limit (100 km/h) is used for about 20 % of the time, the lowest speed limits (70 and 60 km/h) are used for about 6 % of the time and the alleged safety benefit in winter is 10 %, the benefit-cost ratio was about 1.2.

It is significant that by means of ITS there seem to be safety benefits gained from a system that improves traffic flow and speed in good conditions. In addition, it should be remembered that all the benefits of the system are not measurable by means of money and therefore are not included in the benefit-cost ratios. These possible benefits left out of the study include improvement of the driver's comfort, using the monitoring systems for maintenance and information as initial data and using the control system for traffic information services. In the end, it is a question of which kind of services are wanted and are possible to be offered to the road users and what the alternative means to achieve the imposed service level goal are.

According to the estimates acquired, the benefit-cost ratios on different sized networks do not significantly differ. Instead, the benefits not evaluated in this study are probably the most notable on the road segments with the highest traffic volumes. As a conclusion, it can be said that it is probably not advisable to build variable speed limit systems very extensively but more of them should be built on highly trafficked road segments. It is important to study the impacts of those built systems on the type of road in question. It is aimed to use the weather and road condition controlled variable speed limit systems around the year. At special sites, variable road condition warning signs are attached to the system.

The policy of use for variable speed limits should be formulated in a safety-oriented way. This means that the highest speed limit should only be used cautiously and the lowest to be on the safe side. The highest speed limit to be used depends on the road characteristics. In Finland, all variable speed limit systems must be based at least on weather and road conditions. The control has to be based on automated, exact and reliable detection and classification of the circumstances. Manual control is used only when needed. When using variable speed limits, special care has to be taken so that links to roads with permanent speed limits do not produce incoherent changes in speed limits.

An interesting alternative could be enforcing a variable speed limit system on a small part of the most highly trafficked network segment. However, at the moment there is not enough research information on which such a solution could be based. The data of safety impacts, for instance, is from one carriageway roads. In practice, the highly trafficked roads are motorways, on which the results can not be generalised. The data on traffic-based control and its effects as well as the effect of the different use proportions of speed limits is also lacking. An extension of the system should therefore be based on a trial, in which the use, acceptability and effects of the system are studied.

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