

**Summary:**

# **Evaluation of variable message signs in Trondheim**

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*Against the background of increasing use of ITS, this report presents the results from a project in the programme “ITS on the road towards 2020”. The effects of six variable message signs (VMS) in Trondheim (on travel times, road safety and the environment) were investigated using simulations, user surveys and analyses of speed data. According to the results from traffic simulations, travel times are likely to be reduced and crashes to increase when incident information is shown on VMS. However, the reduction in travel times is not sufficient to outweigh the increased costs of crashes. No positive safety effects were found of congestion warnings, possibly because the VMS were not working as intended. Most road users regard VMS as useful, even though only a few change route as a result of the information given on them. Some will change route in the case of an incident, but not necessarily when travel times or information on congestion is given. Using VMS to provide information about alternative routes and driving conditions would improve their usefulness.*

# 1 Introduction

The aim of the present project was to investigate the effects of six variable message signs (VMS) on travel times, road safety and the environment, and on road users' attitudes and experiences in Trondheim. Operation and reliability of the VMS were also studied. The project was part of the Norwegian Road Directorates programme "ITS on the road towards 2020".

The VMS that were investigated give information on travel times, incidents and congestion (the sites can be seen in figures 1 and 2).

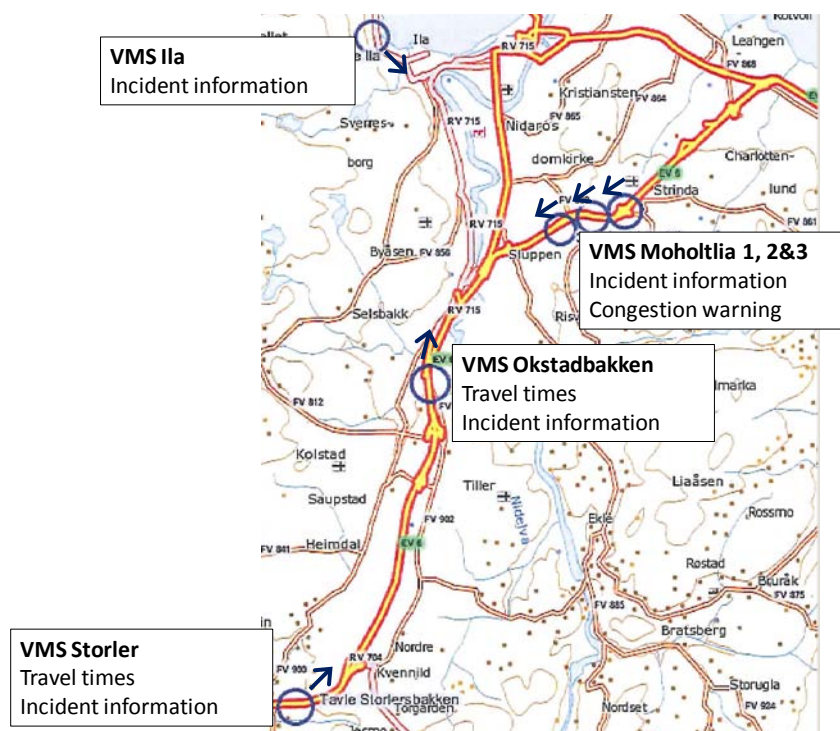


Figure 1: Sites of the VMS in Trondheim.



Figure 2: VMS with travel time information at Okstadbakken.

## 2 Summary of international studies of VMS

*In international studies of VMS there is a lack of methodologically strong studies of their effects on safety, travel times and the environment. Although there may be some positive effects on road safety, information on VMS can cause drivers to brake or to change lane unexpectedly, thereby increasing the risk of crashing. Congestion warnings were found to increase property damage only crashes. There is also a lack of reliable algorithms for programming VMS, especially congestion warnings, and of knowledge about how messages are interpreted by road users.*

The survey of international studies of several types of VMS includes the following studies: The Handbook of Road Safety Measures, project E18 Oslo, freeway Ring 3 Kopenhagen, FASAN-project Stockholm, DynamiIT and several EU projects conducted within the TEMPO framework.

**Effects on road safety:** In the studies summarized by means of meta-analysis in the Handbook of Road Safety Measures, it was found that crashes are for the most part reduced on roads where VMS have been installed. However, because of methodological weaknesses it is likely that most crash reduction figures are overestimated. Crash reductions were found for incident information and fog warnings. Congestion warnings reduced the number of injury crashes and increased property damage only crashes. No effects on crashes were found for travel time information.

In only a few of the other studies summarized in the literature survey have safety effects been investigated, and those indicate that VMS are likely to have positive safety effects. The results, however, are based on small numbers of crashes and

methodologically weak study designs. In some studies it was found that information on VMS can increase crash risk by causing drivers to brake or to change lane. These problems may possibly be limited by improving the readability and comprehensibility of VMS messages.

**Effects on travel times and the environment** were investigated in only a few studies. For the most part, the results indicate positive effects, most of which are not investigated empirically, but instead estimated based on the potential effects of reduced frustration and improved choice of driving routes.

**User surveys:** Several surveys among road users have shown that drivers' attitudes to VMS are generally positive. For instance, most prefer driving on a road where travel time information is given than on a road with no information at all (all else being equal). There is a lack of knowledge about how drivers interpret VMS messages and about the ways these can be misunderstood. Messages are sometimes difficult to read or to understand and the amount of information is often too much. Another problem is the choice of terminology. For example, different drivers have different interpretations of the word "congestion", so congestion warnings might be better given in the form of information about the average speed downstream of the VMS.

**Other findings:** Algorithms for identifying congestion vary in quality and reliability, especially at times when congestion is forming or dissolving, and there seems to be room for improvement in the competence and training of operators at traffic monitoring centres.

### 3 User survey

*Two user surveys were conducted with a total of 330 respondents: a roadside survey and an online survey. Although most drivers are generally positive towards VMS, about half of all drivers consider them of little use. VMS would be of more use if their readability was improved by the use of less text and by the provision of information about alternative routes and difficult driving conditions. Time, date and weather information might be shown when there are no delays instead of travel times continually. In the case of incidents, 14% of drivers say that they would use an alternative route. However, questionnaires do not provide reliable information on how many drivers would change route or in what situations, and there is a lack of knowledge of the effects of VMS among heavy vehicle drivers.*

Two user surveys were conducted in which drivers were asked about their perception of and attitudes towards VMS, the effects on driver behaviour and route choice and about general experiences with VMS:

- a roadside survey at VMS Storlersbakken on which travel time information was displayed during the morning peak traffic (N = 124 drivers who had noticed the information on the VMS)
- a web-based survey (N = 206)

**Design of the VMS and messages:** Only a few drivers reported that they had problems reading messages on VMS: variously, too much text, too many letters, too few letters or too little space between letters. Some suggested that "travel time

information” ought to be shortened to ”travel time”. If a message on a VMS is difficult to read, drivers can be distracted and react by braking to give themselves more time to read the message. Braking may be a safety hazard. Only a few drivers brake because of difficulty reading a message on a VMS, but those that do force other drivers to brake to avoid rear-end collisions, especially in dense traffic. All drivers who participated in the user survey correctly understood the term ”travel time information”. However, there is large variation among drivers in comprehending what is regarded as ”normal” travel time.

**Messages on the VMS:** When asked about what types of information should be shown on VMS, over 80% of all respondents answered ‘incident information’ and ‘congestion warnings’. Only half answered ‘travel time information’ (even though travel time information is regarded as useful by more respondents than are congestion warnings).

More than half of all respondents would appreciate being given information on VMS about alternative routes in the case of incidents and difficult driving conditions. Results from the present study and others indicate that incident warnings are likely to be more effective in re-routing traffic when information about alternative routes is given.

Over half of all respondents believe that information on travel times should be given rather than information on delays. The question whether travel time information should be shown continually or only when there is a delay is still to be answered. Irritation arises when the displayed information “never” changes, resulting in it being less trustworthy.

About half of all respondents would appreciate traffic information on the web or as a text message in addition to VMS information.

**Local effects on road safety:** Almost 10% of all respondents said that they are sometimes distracted by messages on VMS, some because they find it difficult to read the message. Erratic driver behaviour has been reported, such as braking and lane changing, but no one gets stressed or considers that other drivers get stressed. Distraction and braking increase the risk of crashes. Otherwise the effects are likely to be positive in terms of safety. Effects of congestion warnings on headways could not be investigated because too few drivers had seen a VMS with congestion warning.

**Effects on route choice:** Of drivers who had passed a VMS carrying incident information, 14% said that they had changed route, which corresponds with findings from other studies. No drivers who had passed a VMS with travel time information or a congestion warning had chosen an alternative route. Drivers who do not trust VMS information are less likely to choose an alternative route than other drivers.

When asked in what situations drivers would change route, their answers were inconsistent with actual behaviour. In a hypothetical situation where the travel time shown on a VMS is 30 min. (compared to 14 min. without delay), between 50% and 70% said that they would change route. In fact, the percentage would probably be far less. Surveys do not yield reliable information on how many drivers actually would change route.

**Attitudes towards VMS:** Most drivers are generally positive about the information on VMS. About 8% do not trust it and only a few believe that VMS are totally unnecessary. About half of all respondents find that VMS are useful. There are more who find incident and travel time information useful than who find congestion warnings useful. There is no strong relationship between the subjective usefulness and whether or not drivers are likely to change route based on VMS information.

**Method:** The results from both surveys can be taken as representative of private car drivers in Trondheim. Heavy vehicle drivers and other commercial drivers, on the other hand, are underrepresented. Reliability and validity of the surveys could only be tested up to a point, but as far as this was possible the answers to most questions are consistent with each other. Statements about when drivers would change route appear inconsistent with actual behaviour. Traffic counts cannot readily be replaced by surveys investigating effects on route choice. Valuation studies could provide more detailed information about ways in which VMS information could be useful to drivers.

## 4 Technical evaluation

*Up until now, the messaging of VMS has depended mainly on the subjective judgements of individual operators. Therefore, in order to ensure consistency, operators should be given explicit criteria concerning what messages can be displayed and in what situations. Operators should also be confident that the VMS function as intended, and ensure that their logging of incidents and messages on VMS is in the standard form.*

The technical evaluation is based on interviews with central persons at the traffic monitoring centre in Trondheim. Taking the VMS into operation was delayed by several technical problems, in addition to a truck crashing into and demolishing one of the VMS at the start of the project. To begin with, incident and congestion warnings in particular were largely dependent on the judgement of individual operators. Not all operators were convinced of the reliability and usefulness of the VMS and not all used the same criteria concerning when to display particular messages.

If use of VMS is to be consistent, all operators will have to follow standardized procedures for logging incidents and adopt the same criteria concerning when to display particular messages.

## 5 Network effects – traffic flow and travel times

*Traffic simulations show that a VMS message about an incident lasting for half an hour re-routes between 0.02% and 1.9% of all traffic in Trondheim. The total amount of travel time is reduced by between 6 and 344 hours. The effect on travel times is greatest at the VMS Okstadbakken and least at the VMS Ila. The extent to which the results from simulations are valid indicators of the effects in real traffic is dubious.*

For the most part, network effects have been evaluated with the help of the traffic simulation tool CONTRAM. Traffic in central Trondheim is modelled for several types of incident, both with and without incident information being displayed on VMS. All incidents last for half an hour during a peak period. Road sections where the incidents are located are chosen such as to be relevant for one of the VMS Okstadbakken, Moholtlia or Ila. Different assumptions about the proportions of drivers changing route when incident information is displayed on a VMS are used in the simulations: between 3% and 25% for medium incidents (one of two lanes in one direction closed for 30 min.) and between 30% and 95% for major incidents (all lanes in one direction closed for 30 min.).

**Re-routing of traffic:** Displaying incident information on VMS re-routes between 50 and 60,000 vehicle kilometres, or between 0.02% and 1.9% of all vehicle kilometres in the entire road network in Trondheim. On average, the greatest amount of traffic is re-routed when incident information is shown on the VMS Moholtlia and least on the VMS Ila.

**Effects on travel times:** There is large variation in the reductions of the total travel times, i.e. between 6 and 344 hours. During a whole year, it is assumed that incident information on VMS will reduce travel times by 255 hours at Okstadbakken, by 36 hours at Ila and by 241 hours at Moholtlia. These estimates are based on information about incidents in 2009 and 2010.

In addition to simulations, an experimental evaluation of the effects of travel time information on travel times has been conducted, the results indicating that travel time information as such, when there are no incidents or delays, does not affect travel times.

**Method:** The validity of traffic simulations measuring the effects of VMS in real traffic is doubtful. For example, simulations do not take into account the fact that not all drivers know the road network in Trondheim and that not all behave rationally with respect to choice of route; the different effects on light and heavy vehicles are not taken into account either. A formal validation of the simulation results has been attempted through comparing traffic volumes with and without incident information on VMS (both in CONTRAM and in real traffic), the results indicating that simulations may yield realistic results. However, insufficient data were available for conducting a methodologically sound validation.

In future studies, it is recommended that traffic counts be conducted in advance to simulations in order to investigate the proportions of drivers who change route in different situations, and to use the results from the traffic counts as input in the simulations.

## 6 Network effects – road safety

*According to traffic simulations, the number of crashes can be expected to increase when incident information is displayed on VMS. Fatal crashes in the entire road network in Trondheim may increase by up to 6.3%, while injury and property-damage-only crashes may increase by up to 3%. These figures are based on simulations and are therefore uncertain. However, the general finding that crash numbers increase is likely to be realistic.*

Based on the traffic simulations in CONTRAM, it has been estimated how incident information will affect the number of crashes in the entire road network in Trondheim. The safety effects were estimated based on the effects of VMS information on the total number of vehicle kilometres, traffic volumes, the number of vehicle kilometres of traffic re-routed to roads with a lower standard, speed and the number of vehicle kilometres in congestion.

None of these variables was found to change to any great degree, i.e. in most scenarios below 1%. The total number of vehicle kilometres and the average traffic volume were found to increase in most scenarios. Changes in average speed and the number of vehicle kilometres in congestion seem to vary unsystematically between scenarios.

Considering changes in all variables, the number of crashes is expected to increase in all scenarios when incident information is shown on a VMS – fatal crashes more so than less serious crashes. At one incident, the number of fatal crashes increases by up to 6.3%, the number of injury crashes by up to 3.3% and the number of property damage only crashes by up to 3.0%. There is large variation in the estimated effects at different VMS.

During the course of a year, the number of fatal crashes is expected to increase by 2.9%, 1.6% and 0.3% at Okstadbakken, Moholtlia and Ila, respectively. This is in central Trondheim during daytime on working days.

Travel time information is unlikely to affect choice of route so long as there are no incidents and is therefore assumed not to have any network effects on safety.

**Method:** The estimated network effects on safety are based on traffic simulations and are therefore uncertain. The effects on the numbers of crashes estimated based on all traffic indicators seem fairly consistent between different scenarios. However, when looking at safety effects estimated based on a single traffic indicator, the results are for the most part highly inconsistent between scenarios. The general finding that crashes, especially fatal crashes, will increase is assumed to be realistic.



## 7 Local road safety effects

*An evaluation of the local effects of congestion warnings indicates that no effects on safety can be expected. However, the results may be explained by methodological weaknesses and by the fact that congestion warnings did not work as intended (all three VMS with a congestion warning always display the same information).*

Local effects on road safety were investigated based on speed data and video observations. Average speed, variation in speed, average headways and the proportion of headways below 1 and below 2 sec. and of vehicles changing lane were compared between periods during which the three VMS at Moholtia displayed a congestion warning and periods when they did not. Two periods were used: (1) periods without congestion warnings being displayed on days when congestion warnings were shown and (2) periods on days on which a congestion warning was turned off and which are comparable to the periods during which congestion warnings were displayed with respect to duration and volume. It is doubtful whether the VMS would have displayed congestion warnings if the VMS had not been turned off.

When using the first type of comparison period, the results indicate that the proportion of headways below 1 sec. is possibly reduced when congestion warnings are shown. When using the second type of comparison period, no differences were found between periods with and without congestion warnings.

**Method:** One possible explanation for the lack of effects of congestion warnings is that all three VMS always display the same information, based on traffic cameras a considerable distance downstream of the first two. Drivers may therefore have little confidence in what is displayed on the VMS. Had the VMS worked as intended, each would have displayed a congestion warning only when traffic was actually congested immediately downstream of the VMS.

Another possible explanation for the lack of effects is that the traffic conditions in the comparison periods are not actually comparable to the conditions during the periods with congestion warnings.

## 8 Network effects – environmental effects

*According to traffic simulations, the display of incident information on VMS leads to an increase of emissions in the entire road network in Trondheim of below 1%, and to an increase of societal costs for noise of less than NOK 30,000. The effects may be overestimated because the simulations do not take into account the different effects of VMS on light and heavy vehicles.*

How the re-routing effects of displaying incident information on VMS affect emissions and noise has been investigated (based on the simulated effects on the total number of vehicle kilometres, and on speed and congestion). In reality, there are many more factors that affect emissions and noise (e.g. temperature, vertical grades, proportion of heavy vehicles), but only minor effects were found.

Emissions do not increase by more than 1% in any of the scenarios and societal costs for noise increase by a maximum NOK 27,500.

**Method:** The same uncertainties are associated with these results as with other results from traffic simulations. Since a number of relevant factors have not been taken into account and the environmental effects that were found are only small, it is unlikely that the results would have changed substantially had more variables been taken into account. However, not taking into account the different effects of VMS information on light and heavy vehicles may have led to an overestimation of the actual effects.

## 9 Cost-benefit analysis

*Cost-benefit analyses were conducted based on the network effects of incident information on VMS estimated with the help of traffic simulations (re-routing, travel times and environmental effects). The analyses show that none of the VMS that were investigated produce greater societal benefits than costs. The greatest societal costs are associated with increased crashes.*

Societal benefits and costs of each VMS are estimated based on the simulated effects on the numbers of fatalities and injuries in road crashes, travel times, vehicle operating costs, congestion, noise and emissions. The societal costs associated with these effects are estimated based on available valuation studies. All effects are estimated for a period of one year (see table 1).

*Table 1: Annual societal benefits and costs of the VMS at Okstadbakken, Ila and Moholtlia in NOK (pos. = costs; neg. = benefit).*

	VMS		
	Okstadbakken	Ila	Moholtlia
<b>Network effects</b>			
Travel times	-152,795	-21,314	-144,497
Crashes	1,805,134	239,813	2,380,509
Noise	114,623	12,590	40,405
Emissions	3,319	623	9,171
Vehicle operating costs	2,725	656	9,372
<b>Sum network effects</b>	<b>1,773,006</b>	<b>232,368</b>	<b>2,294,960</b>
<b>Costs for VMS</b>	<b>125,000</b>	<b>125,000</b>	<b>375,000</b>

The greatest costs of VMS are associated with increasing numbers of crashes. The decrease in travel time costs is not sufficient to compensate for the increasing costs of crashes. Other effects are minor and have little influence on the general results.

**Method:** The cost-benefit analysis is based on results from traffic simulations and the results are therefore uncertain. A sensitivity analysis indicates that the general result that costs by far exceed the benefits remains unchanged even under the most optimistic assumptions. If the road users' valuation of VMS information had been included in the analysis it is possible that the benefits would exceed the costs. This is uncertain, however, because no relevant valuation studies are available.

## 10 Conclusions

The most important results from the present study, i.e. possible improvements to VMS in Trondheim and methodological considerations, are summarized in the following.

### **Results:**

- User surveys indicate that most drivers are positive towards VMS information, even though only a few use it in their choice of route or in experiencing reduced travel times.
- The information shown on the VMS corresponds largely with the needs of road users needs. Incident information is regarded as the most useful type of information.
- The re-routing effects of incident information shown on VMS lead to an increased number of crashes. Although travel times are reduced, the time saving is not sufficient to compensate for increased crash costs.
- The environmental effects of VMS information are minor according to traffic simulations.
- Although highly uncertain, the general results from traffic simulations are likely to be realistic.
- Travel time information and congestion warnings have no re-routing effects so long as there are no incidents. Information of this type is therefore not expected to have any network effects in normal traffic.
- No local road safety effects of congestion information were found. This is most likely due to methodological weaknesses and to the fact that the congestion warning system did not work as intended.

### **Possible improvements to the VMS in Trondheim:**

- Showing information on alternative routes in the case of incidents or delays and on difficult driving conditions would be regarded as improvements by many drivers. Information on alternative routes would also improve the re-routing effects of VMS.
- The readability of VMS could be improved by as little text as possible being used to get the message across.
- Larger letters and stronger contrasts might also be an improvement for some drivers.

***Possible topics in future studies of VMS:***

- When investigating the effects of VMS on re-routing, traffic counts cannot entirely be replaced by surveys or simulations. Simulations may still be used to estimate effects on a number of variables in the road network under standardized conditions. The results will be more realistic if the proportions of drivers choosing alternative routes in different situations are estimated in an experimental study with traffic counts in real traffic, and if the results are used as input to the simulations.
- Incident and travel time information are likely to affect light and heavy vehicles differently. Effects on heavy vehicles could be investigated in a separate user survey and in an experimental study of the re-routing effects of VMS.
- The subjective usefulness and valuation of VMS information could be investigated in a valuation study, where it would be possible to include the valuation of VMS information by road users in a new cost-benefit analysis.
- In order to investigate local safety effects of VMS it is a requirement that measurements of, for example, speed, volume and driver behaviour, can be compared between periods where information is displayed on the VMS and periods during which no information is displayed, but which otherwise are comparable. This requires some kind of manipulation of the VMS information.