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SRIS - Slippery Road Information System

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SLIPPERY ROAD INFORMATION SYSTEM is a collaborative effort by the following parts:

1. Background

In today's society we have come to rely on our roads to be in perfect condition to get us where we're supposed to be in time. In-real-time reports about the prevailing road conditions are important to be able to make correct decisions about maintenance activities, lowered speed limits or closure of roads. If such information is reached by all different kinds of road users they can plan their routs ahead knowing the conditions of the roads before getting into the car.

In Sweden there are over 700 Road Weather Information System (RWIS) stations in use, along the roads. The system gives detailed information about the road weather in regard of temperatures, both in the air but also on the road surface, precipitation, in amount and type, as well as wind information. Since the temperatures are measured both in the air and on the road surface, different temperature variations can be used to derive the transportation of moist air towards the ground. Such information makes it possible to predict hoarfrost and rime on the roads. Precipitation together with wind information also makes it possible to detect snow drifting.

The probable state of the roads can be estimated by the use of RWIS. The stations give detailed but fixed point information and can not show the state of the roads in-between RWIS stations. Preformed maintenance activities or specific weather situations are not considered in the system, hence the need for improvements, in ways of increased and improved information.

The maintenance personnel in Sweden use the information from RWIS together with information from weather forecasts to plan their work. Figure 1 shows an example of how the information from RWIS can be displayed in a map for the contractor to consider before making decisions about maintenance activities. The red dots indicate precipitation/slipperiness in the area. The question is whether it is slippery on the actual roads or not. It is a difficult question which needs experience and local knowledge. It is difficult to know if the snow will continue further south or if the snow will turn into rainfall or completely cease to fall, from only examining the figure. It is extra difficult to know about the current conditions of the roads and of how they might change.

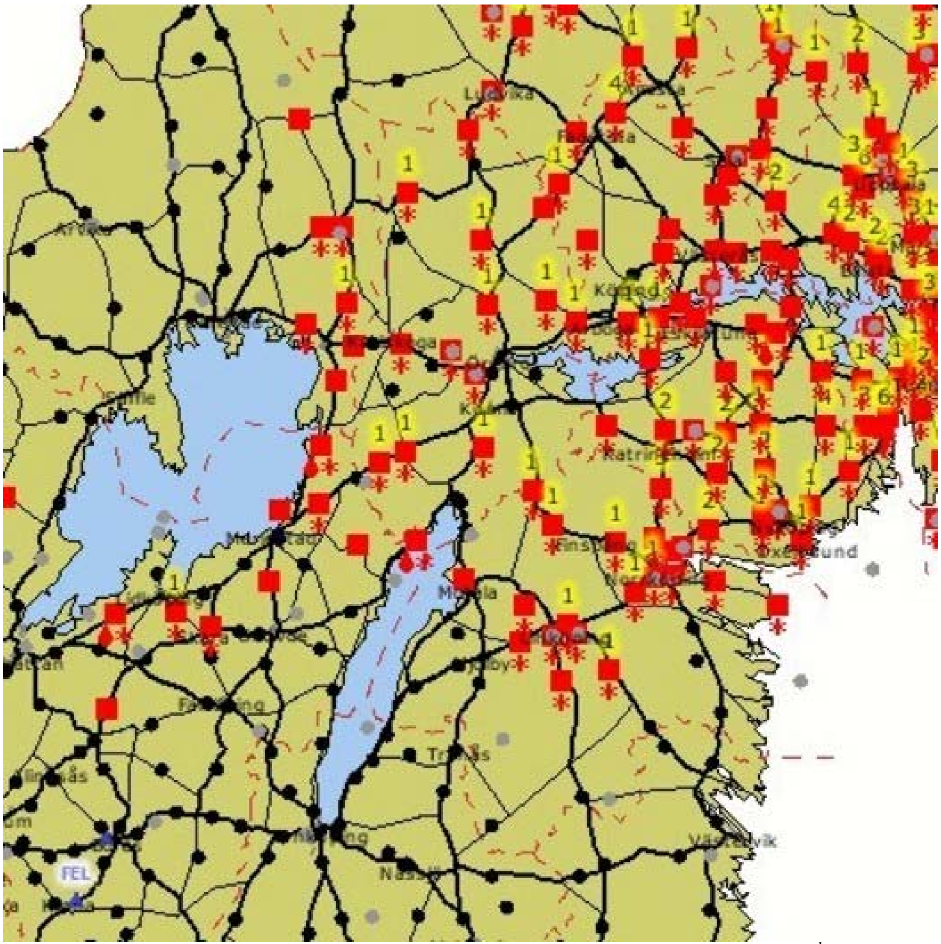

Figure 1. Warnings about snow from the RWIS during the evening of the 19th of February, 2007. The red symbols with stars beneath indicates snowfall.

The lack of information about the actual road conditions makes it difficult to map trends and perform extensive analysis which could visualize the efficiency potential for, for instance, more accurate activities and more efficient rout planning for winter mainten

As mentioned in the earlier section a large portion of the drivers have a poor recollection of where slipperiness occurs on the roads. They have hence limited possibilities to adjust their driving to prevailing conditions. The drivers needs a system that easily and user-friendly can bring them in real time information about where there are slippery conditions on the roads.

2. Vision and Objectives

The vision of SRIS is to optimize winter maintenance in regard of accurate operations as well as affect drivers to adjust their driving according to prevailing road conditions by the help of expanded road information in user-friendly devices and applications. The vision is to save lives and at the same time give a greater sense of security and control, as well as decreased cost for winter maintenance and accident managements. Figure 2 shows how SRIS is supposed to function. Information from cars, maintenance vehicles and RWIS stations will be integrated into a map over the slipperiness in the area and distributed to the user in different ways.

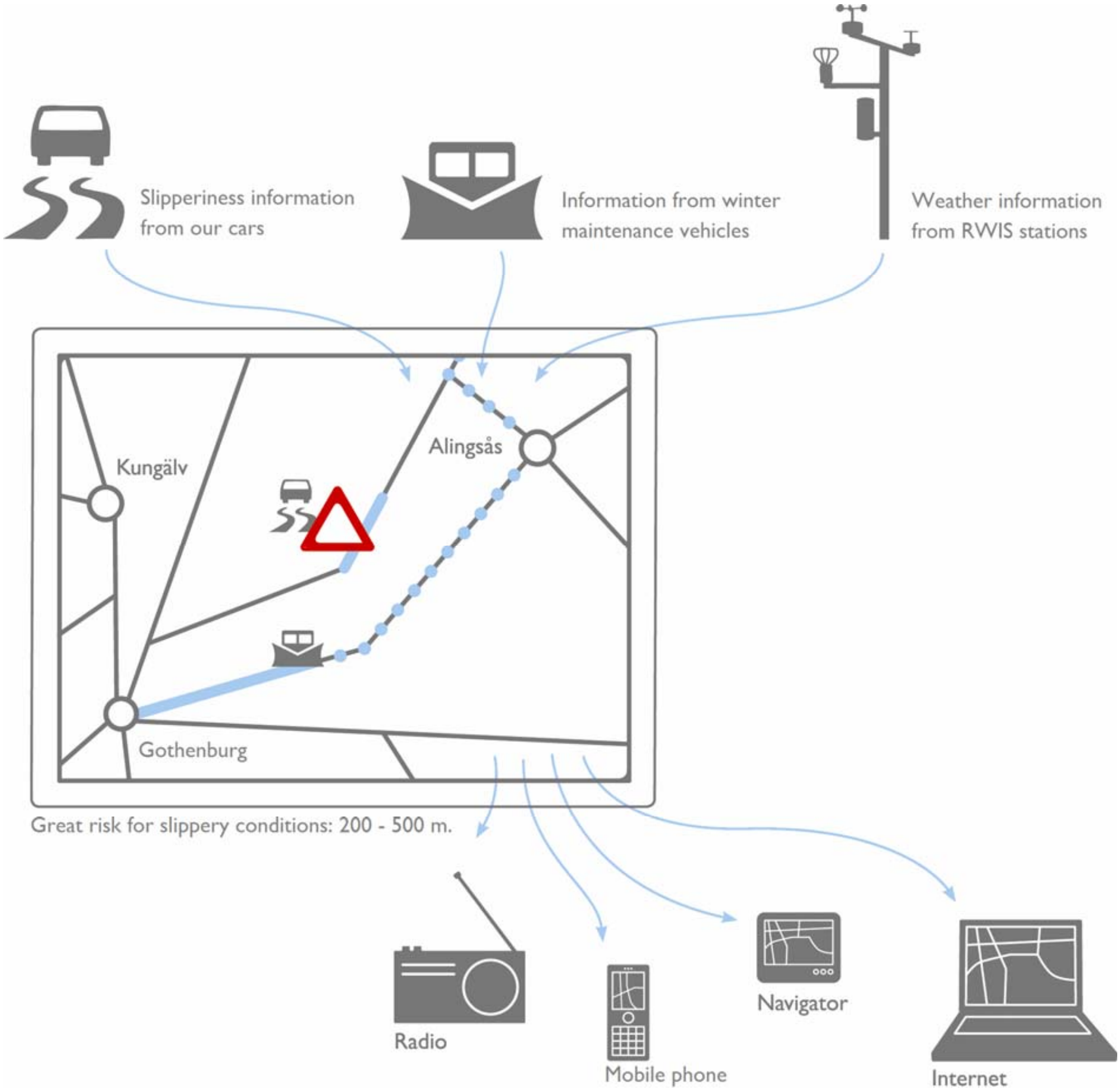

Figure 2. Schematic sketch of how SRIS is supposed to function.

The SRIS-project is a first step towards the vision. The objective with the project is to develop a model which integrates the information from RWIS along with cars and information from maintenance activities. By performing field tests on a fleet of 20 cars during the first test period and 100 cars during the next test period, which will take place during the winter of 2007/2008, the model will be developed, tested and improved.

3. Methods

The SRIS project is divided into three stages. The base of the model is developed in stage 1 and is further developed in stage 2 and 3 completing the knowledge gained from the analysis of the field tests. Field test 1 began in November 2006 and was completed in March 2007, since then the different involved parties have been working on their respective area of responsibility to be ready in time for the start of field test 2. During a few specific weather situations during the field test 1 period some directed measures were conducted on specific road stretches in the field test area. This was done to be able to control the incoming data and to get better knowledge of how the conditions of the road were felt by the drivers.

3.1 Stage 1

3.1.1 Car data

Large amounts of CAN-data (vehicle information) were collected in the beginning of the project to be able to select such information that was interesting. The data was assorted into two different categories; Background data and Event data. The background data is continuously collected every 30 seconds and consists of information such as temperature, precipitation and position. The Event data is information that is sent only when one of the safety systems such as the ABS or the Anti-skid systems in the car is activated.

Several test drives were conducted on slippery conditions in order to understand how the activating of safety systems in the cars work and where their threshold values lies, i.e. how should one drive in order to activate the safety system. This was part of the background in the development of the technical system design used in the cars as well as in the central database.

The system design was divided into two communication channels; the SMS-design which sends text messages through the mobile telephone network and the GPRS channel, where you need a GPRS modem, which sends data in bits.

3.1.2 RWIS

The RWIS is as mentioned earlier a system specifically developed to give information about the road conditions, to help maintenance personnel making accurate decisions about maintenance activities. Information about the actual road conditions is nevertheless rather limited. In the RWIS the different slipperiness risks are classified as follows:

H1 Moderate hoarfrost
H2 Severe hoarfrost
HN Rain or sleet on a cold road
HT Road icing
H* Many different types of slipperiness at the same time

A slippery warning is given every 30 minutes. The idea with the SRIS project is to supplement the information from RWIS with information from the cars to gain a more fitted system. Within the project there are two models used; the Weather model and the Car data model. By the use of the Weather model the RWIS data can be extrapolated to give information about road stretches even though the RWIS only will give fixed point information. Models of topography, land-use and sun exposure are used in the calculations to create such an extrapolation. By this extrapolation it is possible to obtain information about the whole area instead of just a fixed spot on the road.

In the Weather model data is read from the RWIS stations and the risks for slipperiness is calculated according to the boundary values for temperature, precipitation and time of the day as well as time of the year. Different slipperiness situations are further classified into levels of seriousness, which are dependent upon the degree of friction loss on the road.

Class 1 – ***Very slippery***, friction values between 0.1 – 0.2
Class 2 – ***Slippery***, friction values between 0.3 – 0.4
Class 3 – ***Not slippery***, friction values larger than 0.4

The Car data model gives information about the actual position of the cars and the number of signals in form of anti-skidding, ABS etc. which are integrated within a specific road segment. In a final step the Weather Model and the Car data Model are integrated into a third model; the SRIS-model (figure 2). It is possible to compare the calculations in the two sub models and thereby increase the information about the actual conditions of the roads since the divisions of road segments are alike in both models.

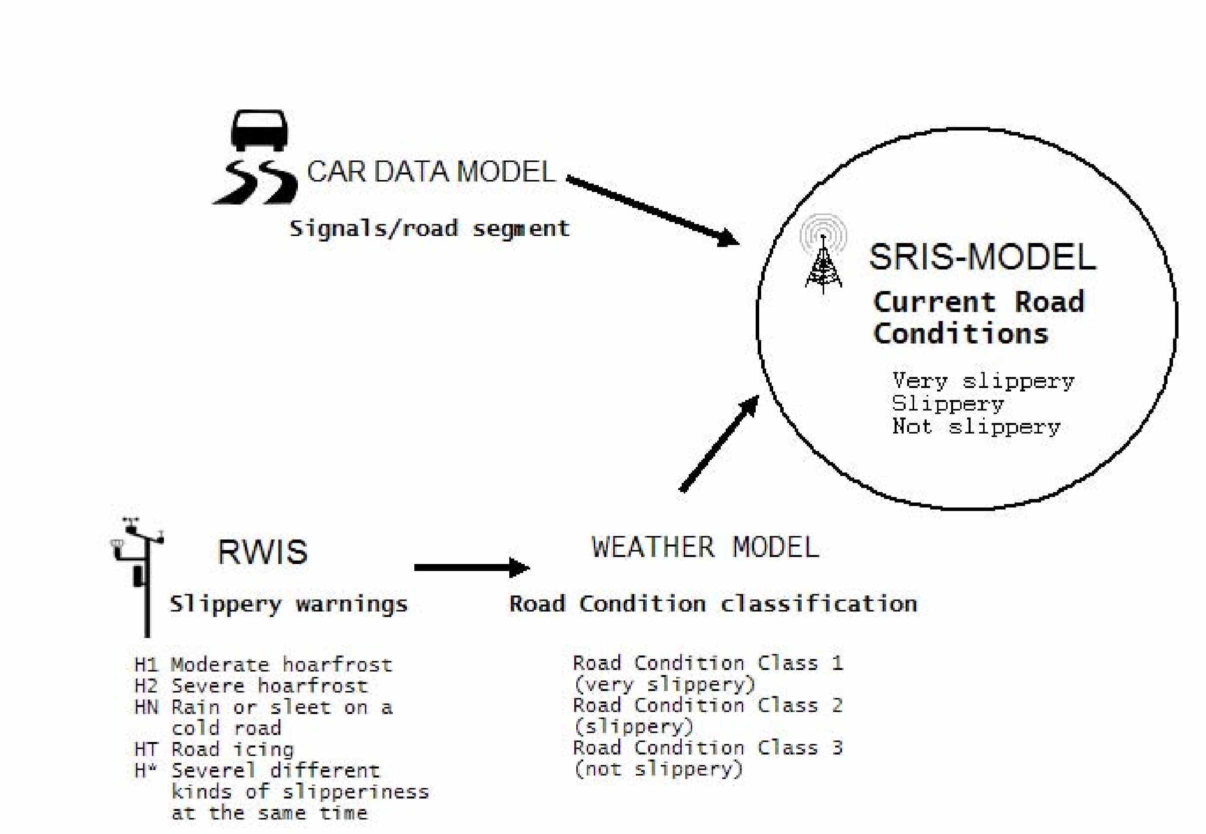

Figure 3. Sketch of how the SRIS model is built and function.

3.1.3 SRIS Model

In the SRIS model the information from the Weather Model and the Car data Model are integrated to give a view of the current condition of the road. In Stage 1 manual test drives of the models are done since the SRIS-model not yet is automatized. Both the Weather Model and the Car data Model are working and were used during the first field test period, but manoeuvred manually. Each event that the car fleet generates gives a signal; these signals are given in amount per road stretch. In the next stage of the development these signals should be reported as amount per road segment instead, to get a higher resolution of the information, and thereby give a more accurate view of the slipperiness in the area. The model can be used to give information to different kinds of road users such as winter maintenance personnel and private drivers about where there are slippery conditions as well as when it is time to lower speed limits or to perform maintenance activities.

Table 1 shows a summation of the relation between data from the Weather Model and the Car data Model during the measurements the 20th January 2007. The example shows how the reactions from the cars can be related to the data from the Weather Model to derive the road conditions in the SRIS-model. The road conditions could be classified according to the three slipperiness classes of the Weather Model during the measurements performed in the winter season 2006/2007. The data from the different models does not always agree with each other, which makes the interpretation of the data a little bit complicated. By the help from the observations of the road conditions made in relation to the measures we could decide upon situations where the Car data Model gave better indications about the conditions than the Weather model, and vice versa. One reason to why the models may give differing results could be that maintenance actions have been performed or that the weather does not create slippery conditions to the extent as theoretical calculations have indicated.

Table 1. The road conditions are classified according tothe Weather Model as well as the driver observations. Based on the classes used in the Weather Model where class 1 = Very slippery, 2= Slippery and 3 = Not slippery.

Car data, number of signals	Weather Model	Observed conditions	SRIS-model prototype
10	Very Slippery	Very Slippery	Very Slippery
8	Not slippery	Slippery	Slippery
2	Not Slippery	Not Slippery	Not Slippery

3.2 Field trials

3.2 1 Car data

There were a total of twenty cars in motion in the trail area during the field trials of the first season; 2006/2007. Ten of them used texting-communication and 10 used GPRS-communication.

The field trials were complemented with controlled measures to get better knowledge of the situations. These controlled measures were conducted during specific weather systems that passed the field area during the trail season. Four such measures took place during the first season, where three SRIS equipped cars drove continuously on a specific road stretch throughout the weather system.

During the controlled field measures there were some complications with the data reports from the cars in motion. At some occasions there were no reports at all for a long period of time. Such complications were localized during the controlled measures and the routines about the data management were updated. The field trials went on without any major technical problems.

General SRIS statistics from 1st of November to 6th of March 2006/2007:

- 3850 hours or 30.6 hours/24 hour period of background information from the cars (SRIS-cars online)
- 6400 signals from cars over 10 km/h
- Daily mean road surface temperatures (from four RWIS stations) 3.4 ^{o}C
- Daily mean air temperatures (from four RWIS stations) 4.3 ^{o}C

3.2.2 RWIS data

A total of 80 RWIS stations within the field area were equipped with GPRS. Four out of these 80 could not deliver data during the field trial. The cars of the fleet mostly used the national roads 42, 44 and 45 in the area around Trollhättan. Data from RWIS stations along these roads are used in the analyses.

The weather data sampling functioned well. Unfortunately there are periods where data was lost as a cause of problems in the GPRS-net.

The transfer of data through the web-service to VM-data a Logical CMG company functioned well. There were a few interruptions in the connection between Combitech and WM-data but data was continuously sampled, hence no data was lost. The problem is still of interest since the system is supposed to give information in real time and delayed data may cause a lack to the credibility of the system. It is thus important to continue the work and development at all aspects of the project.

4. Analysis and Results

4.1. Field Trial 1

Analysis is done on data recorded from the car fleet used during Field Trial 1 to be able to get an understanding of how SRIS can be related to RWIS. Five situations are selected to illustrate the results from the analysis. The situations are 17th and 22nd of December, and 11th, 23rd and 28th of January. These situations are chosen since they represent situations with hoarfrost, where information through SRIS can complement the information gained from RWIS. Hoarfrost occasions are difficult to predict and they were not covered by the controlled measures, thereby the use of these situations in this analysis.

The signals from the cars have been analysed in relation to the slipperiness warnings produced by the RWIS. The car generated signals have been registered and summed over the same period as the warnings indicate the slippery types moderate (H1) and severe (H2) hoarfrost.

All the registered car signals without KeyOut has been used. KeyOut indicates that the engine is turned off and is therefore not of interest at this point. All signals which are generated with speeds below 20 km/h have been disregarded to filter out unnecessary noise such as signals given when parking etc. Signals from cars outside the span of 57-59 degrees north have also been filtered out to limit the area to include the field area only.

The cars will confirm a very slippery situation by giving many signals. This happens for example during the 23 rd of January 2007. RWIS indicates moderate and severe hoarfrost on the roads and the cars register a mean of 13 signals per car every thirty minutes.

In the evening of the 17th of December 2006 between five and eight thirty a few RWIS stations along the national road 45 indicates moderate slipperiness as well as slipperiness cause by a cold surface. There are about 3 cars in motion in the area during this period and they generate 1-3 signals per car every thirty minutes. This type of slipperiness is difficult to interpret since hoarfrost easily can be polished off by the cars. The situation may hence not lead to slippery conditions, but in this case the cars still indicated moderate slipperiness as a result of the few but significant signals they generated.

A similar situation to the one mentioned above occurs on the 11th of January 2007 when the temperature varies around $0^{o}C$. Several RWIS stations indicate slipperiness of the types H1, HN, and HT. The cars generate 1-13 signals per car every thirty minutes. Between 2 and 7 cars are in motion in the area during the day but there are only two at the most that give signals at the same time. These two cars are good indicators of the slipperiness in the area.

At certain occasions during the winter the RWIS stations warn about very slippery road conditions but there are few signals generated by the cars. One such example happens during the 28th of January 2007, where every RWIS warn about moderate and severe hoarfrost between 04.30 and 10.30 am. There are only two signals generated from the cars in the area. There are only two cars in motion at this occasion whereof only one generates signals. Winter maintenance actions have most certainly been taken in the area and it is likely that there is no slipperiness on the roads at that time. It is yet difficult to estimate the road conditions in this situation since there are so few cars in motion.

Other situations during the winter have shown the opposite conditions; where the cars have generated lots of signals but the RWIS do not indicate slippery conditions. The 22nd of December between nine in the morning until nine in the evening did not show any slipperiness warnings from RWIS, the road surface temperature varies between 3 and 7 degrees Celsius above freezing and there was no precipitation yet signalized every motioning car in the area between 1 and 6 signals every thirty minutes during the same period. There were 11 cars in motion in the area, 8 of these gave signals of the types ABS, TC and SC. This shows that the cars can inform about slippery conditions even though RWIS can not.

In this case it was a matter of dewfall, i.e. a transportation of humid air down towards a slightly colder road surface. This means that the air was saturated and that water was deposited on the road surface. This happens during large parts of the day, and it is presumed that large amount of dewfall occurred. Since the temperatures were above freezing there was no hoarfrost on the road, hence no maintenance was needed. Nevertheless there was slipperiness on the roads. This is thus a good example of a type of improvement needed for the system. It is important to consider warm degrees in the SRIS Model since as the example indicates there may be slipperiness even though RWIS do not show it. Figure 2 in appendix shows the temperature development at station 1524 during the 23rd of January 2007. This was also a situation where the surface temperature was lower than the dew point temperature, but since they both were below freezing the dew falls out as hoarfrost instead, this is confirmed both by RWIS and by the signals from the cars (see table 4 in appendix). This situation shows an occasion where SRIS information could be very useful. Hoarfrost situations are difficult to interpret in relation to how slippery the road actually gets. Many signals from the cars specify severe hoarfrost and very slippery road conditions.

4.1.1. Conclusions

The Weather Model and the Car data Model confirm each other in most cases, hence we draw the conclusion that the Car data Model works to show slippery road conditions.

- When the Weather Model indicates Very Slippery the cars generates many signals
- When the RWIS indicates Moderate hoarfrost the cars generate significant but few signals.
- When the RWIS indicates moderate, but varied slipperiness the cars generate a varied amount of signals.

But there are also occasions where the two models contradict each other:

- The Weather Model indicates Very Slippery while the cars do not generate any signals. Our conclusion is that winter maintenance has been performed. These activities are not registered in the Weather Model but are obvious through the Car data Model. The Car data Model is hence an important complement to the Weather Model.
- The Weather Model indicates no slipperiness, while the cars generate signals. Our conclusion is that there are specific weather situations that are not classified as slippery occasions but that in fact creates slippery roads. The Car data Model works as a complement to the Weather Model in this situation as well.

4.2. Controlled measurements

The complementing control measures that were conducted during January and February of 2007 in the Västra Götalands region, were planned measures which were preceded by careful studies of incoming weather systems. These measures were planned as complement to the analysis made on the data from the field trial. The controlled measures made possible to a larger extent a control of the performances, data samplings and results of the measures that was not possible in the Field Trial. By always being able to attend the measures, important observations from the drivers could be used as a complement to the sampled data, to understand how certain road conditions were experienced by the drivers as well as getting information about performed winter maintenance activities on the current road stretch of interest. This information could then be used in the analysis of the sampled data from the measurement. The measurements were performed according to compulsory working model (Procedure at measures – SRIS, season 1) which means that two or three SRIS-equipped cars were driving the pre-set road stretch on road 156 between National Road 40 and Skene/Kinna, continuously during different types of slippery conditions. To be able to measure slippery conditions in other parts of the field area as well, other road stretches were used during two of the measurements.

4.2.1. Measurement the 20th January

RWIS – Weather Model	Warm front Heavy snowfall Temperature: -1°C Slipperiness type: H1, H2, HN, H*, snowfall
Car data Model	10-15 signals/road stretch
Observations	Very Slippery
SRIS-model	Very Slippery

The drivers experienced very slippery road conditions in the area during the measurement. The low visibility and the slippery road conditions lowered the general speeds by at least 10 km/h below allowed speed limits. The RWIS stations in the area indicated high risk of slippery conditions and the cars could confirm this by generating many signals. SRIS classified the road conditions to ***Very Slippery*** during the forenoon but this classification was later on reduced to ***Slippery*** and during the late afternoon and evening to ***Not Slippery***. Immediately after snowfall had decreased signals where still generated by the cars, this because the snow had begun to melt as a cause of the salt and the warmer air temperatures making the roads slushy and slippery. The road conditions were also slightly more slippery right after the salt spreading on the snowy roads.

4.2.2. Measurement the 7th of February

RWIS – Weather Model	Warm front Light Snowfall Temperature: -1°C Slipperiness type: Snowfall
Car data Model	0 signals/ road stretch
Observations	Not Slippery
SRIS-model	Not Slippery

The national road 44 was salted in the area around Vänersborg between 02.00 and 05.00 in the morning, between 10.00 and 13.00 and between 17.30 and 19.45 according to maintenance reports from the date of interest. No signals were reported from the measuring vehicles in the area, but there were about ten signals per car in the rest of the car fleet in motion in the area during this day.

There was no slipperiness on the roads in the area based on the signals generated from the cars even though the RWIS indicated snowfall, which usually may cause slippery occasions.

The roads in the area were probably salted since they were wet even though the temperatures were below freezing and there was therefore no slipperiness on the roads.

4.2.3. Measurement the 20th of February

RWIS – Weather Model	Cold front Snowfall, supercooled precipitation Temperature: -3°C Slipperiness type: HT, HN, H1, snowfall
Car data Model	0 signals/road stretch
Observations	Not Slippery
SRIS-model	Not Slippery

There was no slipperiness on the roads, a conclusion drawn based on the information from the cars along with observations from the drivers. The RWIS indicated risk for slippery conditions. The cold snow had turned into bare asphalt on the larger salted roads, with slush in between the lanes.

4.2.4. Measurement the 21st of February

RWIS – Weather Model	Occluded front Heavy snowfall Temperature: -4°C Slipperiness types: HN, HT, snowfall
Car data Model	5 signals/road stretch
Observations	Slippery
SRIS-model	Slippery

This control measurement showed slippery conditions during the forenoon but not as slippery as might have been predicted based on information from the RWIS. The conditions were classified as Slippery or Not Slippery depending on the lanes driven i.e. the direction of the car. The difference between the lanes was a probable cause of snow drifting. This shows that SRIS is good to discover differences in between lanes, which is not possible by the use of RWIS only. The SRIS can discover differences between different segments of the roads as well as in different directions of the road, dependent upon the resolution of the model.

4.2.5. Conclusions

Conclusions made from the control measurements includes that it can be difficult to decide upon the road conditions base only on RWIS. The observations from the drivers in combination with the signals generated by the cars have given a clearer view of the actual road conditions.

The SRIS model can give information about performed maintenance activities and give indications as to whether these activities are enough to reduce the slipperiness even though the RWIS indicates ongoing snowfall.

The SRIS Model can give information about the degree of slipperiness as well as distinguish the road conditions of different lanes.

The SRIS model can contribute in deciding how slippery a specific road stretch is during an ongoing snowfall, as well as show the development of the road conditions after the snowfall has ceased.

The SRIS Model can give important information about an exaggerated warning level from the RWIS in relation to actual road conditions.

5. Further Developments

5.1. Car data

New software for the telematics module in the cars is under development. This new module is based on the experiences drawn during the first field test in the winter 2006/2007. Along with this module a friction algorithm will be installed in the texting-design, to deliver friction values of the actual friction of the road as a complement to the original signals used during Field Test 1. The new Volvo V70 and S80 will be used in Field Test 2 since these models are required for the new friction algorithm. The car fleet will also be increased to include 100 vehicles.

5.2. SRIS model

During the next stage of the development the SRIS model will be improved in many areas. The Car data Model and the Weather Model will automatically be integrated in the SRIS Model which will generate a user-friendly map over the current slipperiness in the area. There are many aspects to consider in the next developing stage. One aspect is for instance the integration of a maintenance algorithm where information from winter maintenance vehicles is implemented. The number of and distribution of the cars of the car fleet is also important information to consider as well as the integration of road segments to create a higher resolution to the model. These and other improvements to the model will be considered and developed in Stage 2 of the SRIS – project.