ID: 0019

BiFi - Bearing information through vehicle intelligence

T. Gustavsson & J. Bogren
Department of Earth Sciences
Klimator
Gothenburg University, Sweden
Anders Johansson, Pär Ekström & Magnus Andersson
Semcon AB
Gothenburg, Sweden

ABSTRACT

The BiFi project "Bearing information through vehicle intelligence" is an ongoing project in Sweden with the aim of studying if it is possible to map the load/bearing strength of roads by a vehicle-based method. The basic idea is that through combining the vehicle data with weather observations and forecasted weather data it is possible to model and forecast the road status according to bearing strength. The results from the project so fare are based on field tests in a rough and real environment for determining the load-bearing strength of the roads.

Roads with a high load-bearing capacity are essential for harvesting natural resources in and to help keep the countryside open and prosperous. During periods in the spring when the ground frost thaws the load bearing capacity of the forest roads is greatly reduced, leading to road closure. Subsequently it is not possible to use the roads for transporting heavy goods such as lumber. In order to decrease the costly consequences of road closure the lumber industry needs to build up large stocks and to plan their transport in such a way that secondary stocks can be used. It has been calculated by that these measures cost the industry an extra 650 million a year only in Sweden. And therefore there is a need for a tool for judging the load-bearing capacity of the road network in a detailed and dynamic way would considerably help to change the current strategy and possibly save the industry significant amounts.

The results from the BiFi-project have so far been very successful. The technology to use vehicles to detect the bearing strength of gravel roads has been found very promising. In part 1 of the BiFi-project an algorithm has been developed based on collected real-time data from a vehicle's standard sensors. Through data analysis, a method of determining the load bearing capacity of the roads that were driven on with cars was established. To test the algorithm and model - extensive field trials have been carried out together with reference measurements. Using the well proven method based on DCP- Dynamic Cone Penetrometer a comprehensive set of reference data was established. This method was also complemented by measurements using a FWD - falling weight deflectometer. A conclusion from this was that the FWD as a method is not very useful during the thawing period since high water content in the road bed gives rise to errors for the FWD. To ensure the quality from the cars additional sensors were used by reference accelerometers that were fitted to the vehicle in order to give an indication of the quality of the vehicle's own accelerometer data.

Using the information available within modern cars and data from RWIS – road weather information systems makes it possible to find solutions for detection of different kinds of maintenance needs. BiFi and two more models models are presented – SRIS and SSWM.

Introduction

In order to have information about road condition and traffic data for road stretches is necessary to have access to comprehensive and reliable data that are frequently updated. In many areas RWIS – road weather information systems are established to give information about the prevailing weather conditions at certain locations along the roads. However, this system is limited to certain spots along the road net work meaning that there is insufficient coverage of the road network. For this reason, road traffic engineers are making increasing use of intelligent vehicles as mobile sensors, so-called "floating cars", to determine the actual condition that is prevailing. In modern vehicles, the data available include a wide variety of variables that can be acquired in digital form from the vehicle's data buses. Using these data as a base, research and developing work have been carried out to construct models which could be applied for maintenance use and information to the drivers. Three models are presented – SRIS, BiFi and SSWM.

SRIS -Slippery Road Information System

SRIS is an example of a project carried out in Sweden with the aim of doing research within traffic safety using existing in-vehicles technology together with infrastructure in a new and innovating way. In the SRIS-project data were collected from existing sensors in vehicles about the road condition (ESP, ABS) and other useful information (temperature, windshield wipers etc), and transmitting to a central database. The information was combined with weather information from a road weather model and data from road weather stations and as result, improved and increased information about the road condition were provided. One of the real benefits with SRIS was that it covers a spatially larger area compared with the fixed positions of the road weather stations and also gives a denser temporal resolution.

The data was transmitted from the Controller–area network (short CAN-bus) which is a vehicle-bus standard designed to allow microcontrollers and devices to communicate with each other within a vehicle without a central computer. CAN is a message-based protocol, designed specifically for automotive applications, but the technique is now also used in other areas such as industrial automation and medical equipment. CAN is one of five protocols used in the vehicle diagnostics standard. This standard has been mandatory for all cars and light trucks sold in the United States since 1996, and a similar standard has been mandatory for all petrol vehicles sold in the European Union since 2001 and all diesel vehicles since 2004.

A modern car may have as many as 70 electronic control units (ECU) for various subsystems. Typically, the biggest processor is the control unit that is related to the engine of the car. Other examples are used for transmission, airbags, antilock braking (ABS), etc. As modern cars constantly record all these variables it opens up for new improvement and uses of this type of data. The following section describes some projects where the two techniques are used together, FCD-data and CAN-bus data, in order to evaluate how good this type of information can be for example from a road maintenance point of view. Information that can be achieved via the CAN-bus are signals from all the electrical equipment in a modern car, such as wipers, radio and air condition. It is also possible to get information about lateral and longitudinal acceleration, speed, engine speed, steering angle, throttle position, etc. which can be used to analyze the road and its condition. By using an external computer, with usable software, the CAN-bus signals can be logged and analyzed. By analyzing the data with different algorithms and methods, it is possible to get comprehensive information about the state of a road. When comparing signals from the anti-lock braking system (ABS) and the electronic stability control (ESC) together with the surrounding temperature, it is possible to evaluate if there is a risk of icy roads or if some types of pavements are more slippery than others. The quality of the pavement can also be evaluated when analyzing signals from the acceleration sensors. The data from the CAN-signals can also be used to analyze driver behavior. This can in turn be used to improve road intervals where accidents are more frequent.

Approximate 90% of all new cars in Sweden have ESP (Electronic Stability Program). By using only existing sensors in vehicles, a greater coverage can be established. All vehicles in the SRIS field-test had a special equipment to transmit the signals from the vehicles to a central database. More important is that many new cars has integrated telecommunication equipment, so the real big task in the future, is integrate SRIS in the electrical architecture of the vehicle so the vehicles can send information without the extra equipment that has been used now.

SRIS experienced a field-test in the winter 2007/2008 with 100 cars and the result was successful. The result showed that in most cases, the information from the vehicles corresponds with the information from the road weather stations. But there were also situations when SRIS detected slipperiness without warnings from the road weather stations.

In a worldwide perspective, the idea and scenario is to increase SRIS to more countries and technically, many of the new vehicles have ESP and telephone, so it's more a political challenge.

The SRIS test in Sweden was performed by use of 100 cars, 90 of them were located in the Gothenburg area and 10 cars in Stockholm. The car models used in the test were Volvo V70s and Saab 9-5s. The used cars were both company cars and taxis to get a high frequency of usage and driving distance of the cars.

The weather information is collected by 80 Road Weather Stations and transmitted to a central database, located in Borlänge, Sweden. At the same time, vehicles are reporting background data or events of slipperiness from the existing in-vehicle sensors to the same database.

The relation between the signals from vehicles and actual road conditions

The actual road weather has been collected from road weather stations during the season 2007-2008 and has been sorted by an expert system to classify the different types of slipperiness. The signals from the vehicles have been sorted due to the type of slipperiness that was registered in relation to the closest road weather stations.

	NOT SLIPPERY	RAIN	RAIN ON COLD ROAD	SNOW	FROST
Probability of slipperiness	1	1,03	10	14	3

Table 1. An important conclusion is that the weather has a major impact on how often the vehicles are reporting event of slipperiness. This means that it is possible to detect and determine the risk and level of slipperiness on the roads. Note that i.e during snowy conditions on the road the signals increases 14 times compared to not slippery.

The performed field tests show that collected data was possible to combine in a useful way to get an increased usability of the provided information. SRIS increases the possibilities to identify severe road conditions. The field test with 100 cars has shown a good result and that SRIS is possible to apply to more vehicles and gain a growing profit for the society, both for drivers and road maintenance.

The result from the SRIS field-test showed a good result is the test area. An external social economic report has been made in a Movea report where the conclusion is that the system gives a very high social economic outcome when compared with the cost for SRIS. The economic benefits would be for the road administration who pays for the road maintenance and insurance companies who can lower their costs. But most important of all is that SRIS has a potential to increase the traffic safety which can save lives. SRIS also has a potential to give benefits for the environment avoiding unnecessary road salting [1].

BiFi - Bearing information through vehicle intelligence

The BiFi project "Bearing information through vehicle intelligence" is an ongoing project in Sweden with the aim of studying if it is possible to map the load/bearing strength of roads by a vehicle-based method. The basic idea is that through combining the vehicle data with weather observations and forecasted weather data it is possible to model and forecast the road status according to bearing strength. The results from the project so far are based on field tests in a rough and real environment for determining the load-bearing strength of the roads.

Roads with a high load-bearing capacity are essential for harvesting natural resources in and to help keep the countryside open and prosperous. During periods in the spring when the ground frost thaws the load bearing capacity of the forest roads is greatly reduced, leading to road closure. Subsequently it is not possible to use the roads for transporting heavy goods such as lumber. In order to decrease the costly consequences of road closure the lumber industry needs to build up large stocks and to plan their transport in such a way that secondary stocks can be used. It has been calculated by that these measures cost the industry an extra 650 million a year only in Sweden. And therefore there is a need for a tool for judging the load-bearing capacity of the road network in a detailed and dynamic way would considerably help to change the current strategy and possibly save the industry significant amounts.

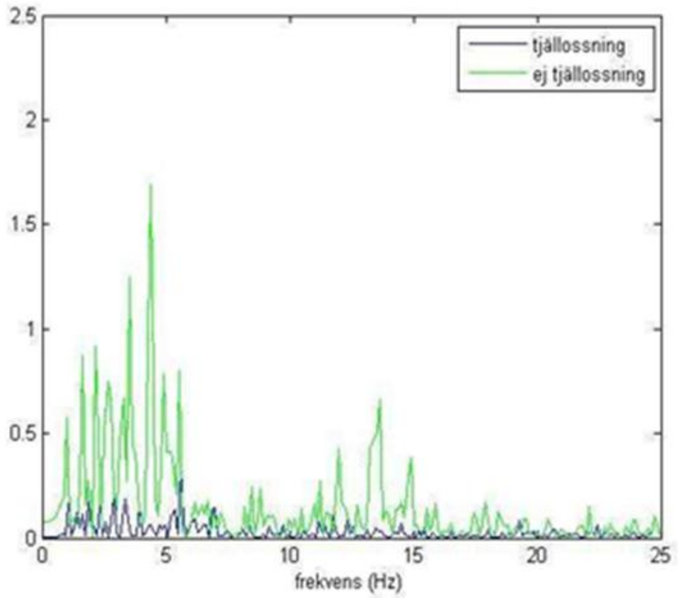

Figure 1. Detection of lateral acceleration in the vehicle reveals the road conditions.

The results from the BiFi-project have been very successful. The technology to use vehicles to detect the bearing strength of gravel roads has been found very promising. In the first part of the BiFi-project an algorithm has been developed based on collected real-time data from a vehicle’s standard sensors, figure 1. Through data analysis, a method of determining the load bearing capacity of the roads that were driven on with cars was established. To test the algorithm and model - extensive field trials have been carried out together with reference measurements.

Using the well proven method based on DCP- Dynamic Cone Penetrometer a comprehensive set of reference data was established. This method was also complemented by measurements using a FWD - falling weight deflectometer. A conclusion from this was that the FWD as a method is not very useful during the thawing period since high water content in the road bed gives rise to errors for the FWD. To ensure the quality from the cars additional sensors were used by reference accelerometers that were fitted to the vehicle in order to give an indication of the quality of the vehicle’s own accelerometer data. The BiFi-system detects the bearing strength in a way that is in accordance with reference measurements [2].

The BiFi-results from the measurements and model are presented in a web-based application, figure 2.

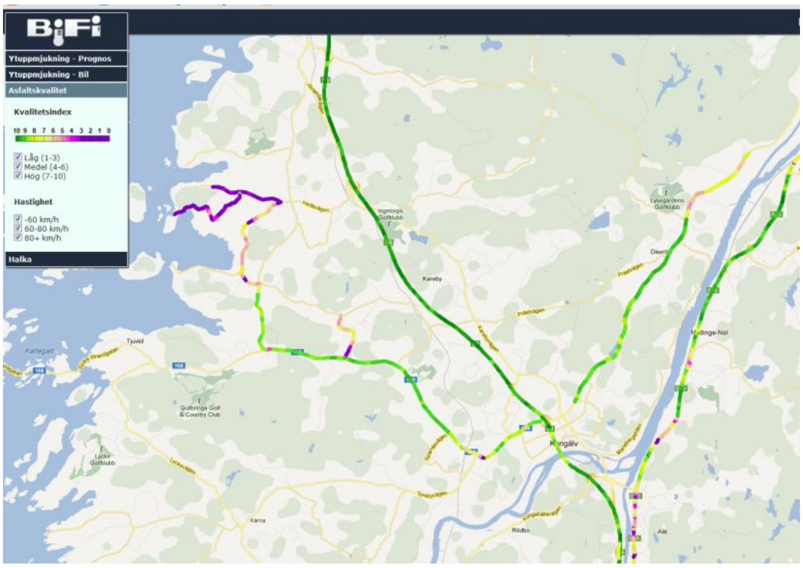

Figure 2. Example on how the BiFi – data can be presented on the web-site.

SSWM - Support System for Winter Maintenance

Road weather Information Systems (RWIS) is used for helping maintenance personal to take the right decision regarding salting and ploughing activities. These types of systems have been in use for many years and have been shown to be a very good help for the maintenance people. However, the system was originally designed and built for a maintenance system consisting of small surveillance areas, well trained personal that also had good local knowledge both of field station environments as well as the local road network. Today most National Road Administrations need to lower costs associated with winter maintenance and therefore small surveillance areas are lumped together forming bigger ones. In doing so the local knowledge of roads and field stations among other things are often lost and forgotten.

RWIS-systems normally forms a very good tool for taking decisions regarding maintenance activities but to be used in its full potential it is very important that the user are well trained and experienced to interpret all the data that are produced by the system. An interview study among maintenance personal performed in Sweden [3] clearly showed that the personal experienced their work to be very stressfull and they where often afraid to take the wrong decision as the consequences could be so fatal. What the personal asked for was some help to make better use of the system and also to help taking the right decision regarding type and timing of activities.

In order to meet these demands research and development regarding a decision support system has been conducted at the University of Göteborg, Sweden, for several years. The aim of these studies have been to develop the present RWIS into a system which gives INFORMATION not only data regarding the present and upcoming need for winter maintenance activities [4]. The result of this is the SSWM – Support System for Winter maintenance i.e., a tool for taking the right decision regarding:

- when to perform activity
- where to perform activity
- type of activity

Forecast of the upcoming weather and road conditions are a very important part of a SSWM. Several different forecast models have been developed during the past years [5] and [6]. In the present SSWM, the RoadCast-model which we have developed, is used for road condition prediction. It differs from previous models as it includes a neural network part. This model also contains a combination of an energy balance part and a statistical part which has been shown to be successful for producing good forecasts of both road surface temperatures and road conditions.

Another important tool for being able to predict the variation in road slipperiness is a model that can calculate the variation in road surface temperature and road conditions along roads, figure 3. A local climate model is used for this which makes it possible to calculate temperature and road condition variations based on input information from thermal mapping, road segmentation and RWIS-data [7] and [8].

A development that has increased the performance of the SSWM is that input comes from the maintenance personal where their experiences and knowledge are taking into account for the actual area covered by the SSWM. Rules regarding when to perform activities in respect of road standards and "allowed" road conditions forms an important link between the processing unit and the output from the SSWM. Performed activities such as salting and ploughing together with online feedback from thermal measurements by the trucks makes the model very dynamic and adjustable to prevailing conditions.

Trials and experiences from the Czech Republic starting during the winter 2007/2008 of the SSWM in full operation including first and second class roads have proven cost effective delivering reliable results [9].

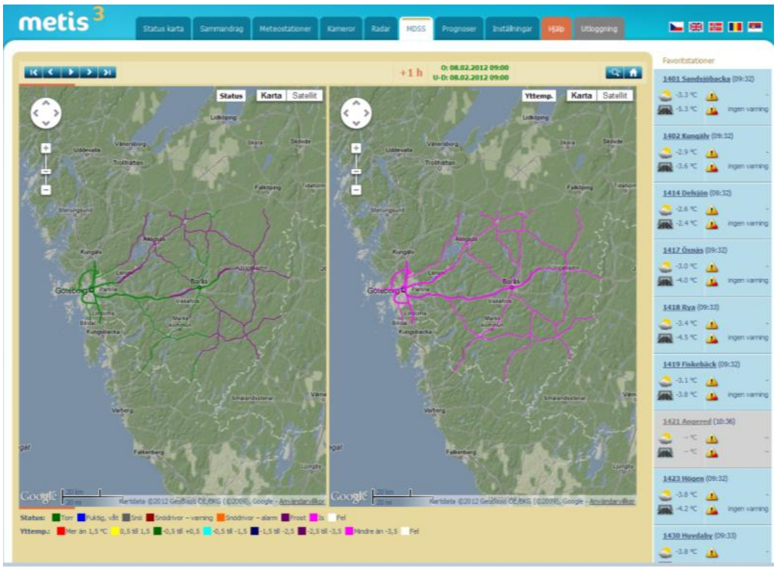

Figure 3. Forecast of road surface temperature and road conditions by SSWM in the metis3 presentation.

The SSWM is now available in three different levels depending on the users need: Entry level – forecasts road conditions which can be used for ahead planning of maintenance activities; Advanced level – includes feedback about performed activities making and Professional Level – includes dynamical segment by use of online thermal mapping.

References

[1] Web sites - www.sris.nu
[2] Web sites - www.bifi.nu
[3] Ljungberg, M. 2002: Expert system for preventive salting operations on winter roads. KTH, Research report TRITA-VT FR 02:03.
[4] Web sites - www.klimator.se
[5] Gustavsson, T. & Bogren, J. 2000: Automatic speed regulation on highways by use of climate data. Proceedings of the 10th SIRWEC, Davos , Switzerland.
[6] Bogren, J., Gustavsson, T., & Postgård, U. 2000: Local Temperature Differences in Relation to Weather Parameters. *Int. J. Climatol. 20: 151-170.*
[7] Bogren, J, Gustavsson, T, & Lindqvist, S, 1992: A Description of a Local Climatological Model Used to Predict Temperature Variations Along Stretches of Roads. *Meteorological Magazine*, 121, 157-164.
[8]Gustavsson,T, & Bogren , J. 1993: Evaluation of a local climatological model – test carried out in the county of Halland, Sweden. *Meteorological Magazine,* 122 (1456):257-267
[9] web site – www.cross.cz