THE USE OF REAL-TIME GPS IN RE-OPENING HIGH MOUNTAIN WINTER ROADS IN NORWAY

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1 Abstract

In 1998 it was decided to use a real-time Global Positioning System when re- opening a high-mountain road in Norway after the winter season. Preparations of recording fixed positions along the road started in the summer of 1999 on the trunk road (Route 55) Sognefjell. Installing a GPS recording instrument in a vehicle did an overall recording of the road possible after identifying fixed position marks in the landscape nearby the road, and by using a local positioning transmitter on the fixed mark as a reference.

The white roadside marking line was measured every ten meter, and all safety fences, bridges lay-bys and parking areas were recorded on the actual road. All the data were processed and recorded into a map-software designed by the Norwegian Public Road Administration. An accuracy of +/- 5cm is possible to obtain when using 5 available satellites combined with data from the reference station to the recording unit bearing the GPS receiver equipment.

When the road was to be re-opened after the following winter season, a GPS receiver and a computer containing the recorded road-data were installed in a rotary snow cutter, and also the local reference positioning station was reinstalled and activated. Thus, the local position of the snow cutter was always known. The engineer driving the equipment was continually updated of his position on the road by using a computerised screen map displaying the distance to the edge of the road and any known obstructions recorded from the data entry session. Several snow cutting units operating simultaneously on the actual road can use the same GPS system, and the system can be used regardless the quantity of snow.

The benefits of using real-time GPS as hereby described are many. The experiences from the re-opening of the high mountain roads have so far been positive.

Benefits are first of all the reduction of damage costs to the heavy snow cutter equipment as the equipment can navigate by high accuracy and precision on the road. Damage costs are also reduced related to safety fences and other road furniture not being hit by the heavy machinery. Our mountain roads can from now on also be re-opened without extensive use of roadside installed winter poles. The quantity of snow to be removed is also considerably reduced as the snow removal equipment is working more precisely.

The Norwegian Public Roads Administration has also started to use GPS equipment in the road construction sector. The use is based on experience from using the GPS in re-opening the winter roads with the same procedure of identifying the fixed points of reference. When this procedure is fulfilled, it is possible to use the GPS in various road construction processes.

Since the elements of road construction such as earth cutting, rock-out, ditch, road embankment and road surface all have their defined surface identity, it is possible to import different procedures of measurement into different construction plants such as excavators and graders.

2. Introduction

The road network connecting the Western- and Eastern part of Norway comprise of several high-mountain roads of various length. Some of the roads are open for traffic all seasons, also during the winter season. However, some minor trunk roads are closed during the winter season due to heavy snow-conditions in the mountains and the lack of possibility of serving these roads frequently with ordinary snow clearing equipment. These roads are of minor importance for the main traffic between the eastern and western part of the country since alternative and less difficult routes are available. In the summer season these roads are of great importance for the tourist industry.

The roads in question are the Route 55 Sognefjell, the Route 13 Vikafjell, the Route 258 Old Strynefjell and the route 243 from Lærdal to Aurland, also called the Snow-Road. These roads are all passing the mountains at an altitude between 1200 meter and 1400 meter above sea level, and they are normally blocked by snow from the beginning of December to the beginning of May, which is defined as the winter season in Norway. The snow depth varies considerable on the various roads from 2 meters up to 10 meters in the snowdrifts. On a trial basis, the Norwegian Public Roads Administration established a fully operational GPS orientated system on the Route 63 Geiranger - Oppland Border in 1997.

The preparation for the winter-season has up to recent days been to install a considerable number of winter poles to identify the roadside when re-opening the roads in the springtime. The distance between the poles installed is approximately 15 to 20 meter, which gives an inaccurate indication of the roadside.

When navigating the heavy snow cutter equipment, the visual sight of the poles has been the only possible remedy assistance to the machine-engineers. Severe damage to the snow-cutter machinery has often been the result as the machinery easily hits rocks or stones beside the roadbed due to lack of sufficient navigating facilities. Sometimes the poles are moved from their positions due to avalanches or heavy wind. These circumstances make it even more difficult to navigate exactly within the defined roadside marking.

3 Searching for alternative solutions

An option for using alternative methods of navigating the heavy snow cutting machinery has been under consideration for some years in the Norwegian Public Roads Administration (NPRA).

Land survey has for a long time been used under the road construction process and for property acquisition. For these purposes traditional land survey equipment has been used for static measurements. Up to the 1970, the theodolit was in common use.

This is an instrument measuring the horizontal and vertical angles but it was unqualified for distance measurement. Since 1980 up to 1990 the total station enable to measure both angles and distances was in common use. Since 1990, the performance of land survey by using the Global Positioning System (GPS) are carried out in two modes:

a) **Static measurements**

This is a mode where the GPS equipment is fixed to one point and the vectors are calculated in posterity.
This mode of operation is very exact, and gives precise measurement up to one millimetre.

b) Real-time measurement

This is a mode where one receiver is fixed to a known point of reference, and one receiver (called the rover) is floating. The distance between the two stations is calculated in real-time. When 5 satellites are serving the two receivers and they are connected to a mutual radio link, it is possible to identify the distance to the rover within an accuracy of 5cm. even if the rover is in motion. From one single fixed point of reference, it is possible to measure the distance to many rovers simultaneously.

Both the two principles of measurement are used as the basic standards for the development of a GPS system for the purpose of re-opening High Mountain winter roads in Norway.
The real-time mode is the basic principle used for navigating snow cutters on the road and where the snow cutters are defined as the rovers. This is also the basic idea for development of a practical operational system using two GPS receivers in both the fixed point of reference and in the snow cutter.

4 The basic principle of function

The system in use is based on NAVISTAR, an American system for GPS developed by the USA Defence Authorities. The satellites are operating at an altitude of 20.000 km with a global time cycle of 11 hours and 58 minutes. The numbers of operational satellites are from 28 to 30.

The GPS receivers are functioning in principle as a distance measurer calculating the distance between the two GPS receivers and at the same time the distance to the satellites. The accuracy of measurement depends on the number of satellites in use. Normally 5 satellites are needed simultaneously for accurate calculation. Between the two receivers a radio link is established. The radio link, representing a correction beam with a frequency of 419 MHZ, updates the rover 10 times pr. second with data from the fixed point of reference. The high updating frequency enables the rover to orientate to an accurate position within 5cm even if the rover is in motion. Due to atmospherically conditions, the distance between the fixed point of reference and the rover should not exceed 10 km to obtain the high accurate position. This explains the fact that several fixed points of reference are needed on each route in question.

5 The procedures of establishing an operational system

On a trial basis, the Norwegian Public Roads Administration established a fully operational GPS orientated system on the Route 63 Geiranger - Oppland Border in 1997. Using this trial system to our satisfaction, the winter-closed road was re-opened in 1998.

The preparation of using the GPS navigation system in an extended scale, started in 1999. After the procurement of two sets of GPS receiver equipment, decision was made to do the preparatory work on Route 55, the highest trunk road in Norway situated at an altitude of 1400 meter above sea level. In the midsummer of 1999, all the fixed points of reference have been established. These points of reference are defined as the basis for the measuring-in of the road, and later for snow-cutter operation at the same defined road. The fixed points of reference are selected on spots with minor quantity of snow, with good visibility to the road and within radio range to the selected point of reference. Six points of reference were selected on this particular route, and precise identification is performed by static measurement calculated in Euref 89, our superior system of co-ordinates.

The roadside is measured-in by using the GPS attached to the right hand mirror on a truck. The measurement is performed with a speed of 30 kmh, and the receiver is programmed to plot every 10-meter of the road. In addition to the roadside marking, the guardrails and lay-bys are recorded as well. The receiver representing the fixed point of reference is accordingly removed and re-installed to new fixed points of reference as the measurement proceeds along the road. Experiences show that the ideal distance between the plotted records should be 5 meter, especially on roads with sharp curves.

A computerised map-editing program is used for the process of the plotted co-ordinates and the data is stored into a laptop computer. The program is based on the DOS operational system, which later will be converted into a Windows based program. After the processing of the co-ordinates, the system is ready for use.

6 The procedures of installing the equipment on the snow cutter

The GPS antenna is installed at the centre of the cabin on the snow cutter and a laptop is attached to the antenna. Receiving data from the GPS antenna activates the map-orientated database. The processed co-ordinates are recognised by the computer-program, and the position of the antenna is shown in the map.

Due to the frequent updating of co-ordinates, it is now possible to navigate the snow cutter by solely using the computer screen. It is possible to navigate the snow cutter within the prescribed accuracy of 5 cm to the roadside marking or guard rails. It is even possible to determine the distance to the road surface when the snow cutter is working on top of a snowdrift.

7 Operational experiences

After two seasons of operation, the system seems to operate in accordance to the intentions.
In the beginning, some minor technical justifications had to be sorted out. The established procedures are simple, making it possible for the engineers of the snow cutters to install the equipment and run the system without using any external consultancy.

During the operation of the snow cutter, the engineer running the equipment feels safe and comfortable. He knows his exact position on the road. This probably is the most important benefit obtained by introducing the system. Under heavy snow weather conditions with wind, snow and fog, it is normally difficult to orientate the heavy machinery even if it is located only a few meters from a winter pole. Now the operation can go on without any interruptions due to lack of sight. Since the introduction of the GPS system, the winter poles have no significant importance for the purpose of re-opening the roads in the springtime.

The critical issue for a good performance seems to be the radio transmission between the fixed points of references and the snow cutter equipment. If the radio-link is down, it has an impact of the accuracy of the co-ordination of the snow cutter. Thus it is important to equip the units with powerful and sustainable radio transmitters. To avoid the snow cutter to operate inaccurate, the engineer needs to attend the radio link information.

We have also learned the need of procuring sustainable and durable equipment since the operational environment of the equipment is characterised by oil, dust and highly variable temperatures. A minor part of the equipment available on the market to day, gratify the challenging operational environment.

8 Operating expenses and economic benefits

Since the system only has been running for one year on a few of the selected routes, we have not yet achieved a complete picture of the operating expenses and economic benefits.

However, the initial procurement expenses of a basic unit, comprising the GPS units with radio sets and computer, is estimated to about $40.000. We estimate the cost saving to about $18.000 a year. The amount saved is due to reduced operational costs, less damage to road furniture as guardrails and curbstones, and less breakdown of the snow cutter machinery.

9 The use of GPS equipment for other purposes in the road sector.

The Norwegian Public Roads Administration has also started to use GPS equipment in the road construction sector. The use is based on experience from using the GPS in re-opening the winter roads with the same procedure of identifying the fixed points of reference. When this procedure is fulfilled, it is possible to use the GPS in various road construction processes.

Since the elements of road construction such as earth cutting, rock-out, ditch, road embankment and road surface all have their defined surface identity, it is possible to import different procedures of measurement into different construction plants such as excavators and graders. The GPS method has been used to obtain exact width and level to the road under construction. The possibilities are many, and we have just seen the start of using the real-time GPS in the road sector.

10 Map showing the high mountain roads where GPS are used