Optimal accessibility and safety in winter

WINTER MAINTENANCE MANAGEMENT SYSTEM. ACCIDENT/INJURY RISKS.

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VINTERMODELLEN

Introduction

Investment planning of highways and streets has long included models for estimating different effects. The field of road maintenance and operation, especially winter maintenance and operation, is in this respect very neglected, being a weakness when competing for funds within a limited budget.
The aim of the Winter Model is to estimate and put a value on the most important impacts of the strategies and measures in winter road management for road users, road management authorities and society at large. This will be a tool to find winter maintenance rules with the lowest possible socio-economic costs.

Structure of Vintermodellen

The structure of the model appears in Figure 1 and the Winter model consists of sub-models for assessing the state of the road, the effects and their monetary value and the total cost. The hub of the model is the Road Condition Model. The road condition can be calculated for every hour, in 5 different strips across the road, influenced by the prior road condition, weather, traffic and actions. Actions are depending on what winter maintenance regulations and technique decided for a certain case. In the model, the weather throughout a whole winter season is defined by the Road Weather Information System and other data on an hourly level. The data may be derived from any real winter or be estimated for an average winter. The Road Condition Model controls calculations in the effect models: Accident Model, Accessibility Model, Vehicle Cost Model, Environment Model and Model for Road Management Costs. The Accident Model calculates accident rates, accident types and consequences, all coupled with different road conditions and their duration. The Accessibility Model calculates the effect of different road conditions on mean speed and trip times. The Vehicle Cost Model calculates the costs of fuel consumption and corrosion due to road salt. The Environment Model calculates the impacts on roadside vegetation due to road salt. The Model for Road Management Costs calculates both the direct costs of the measures and the costs of damage to, and wear of, road surfacing, road markings etc as a result of road management measures.

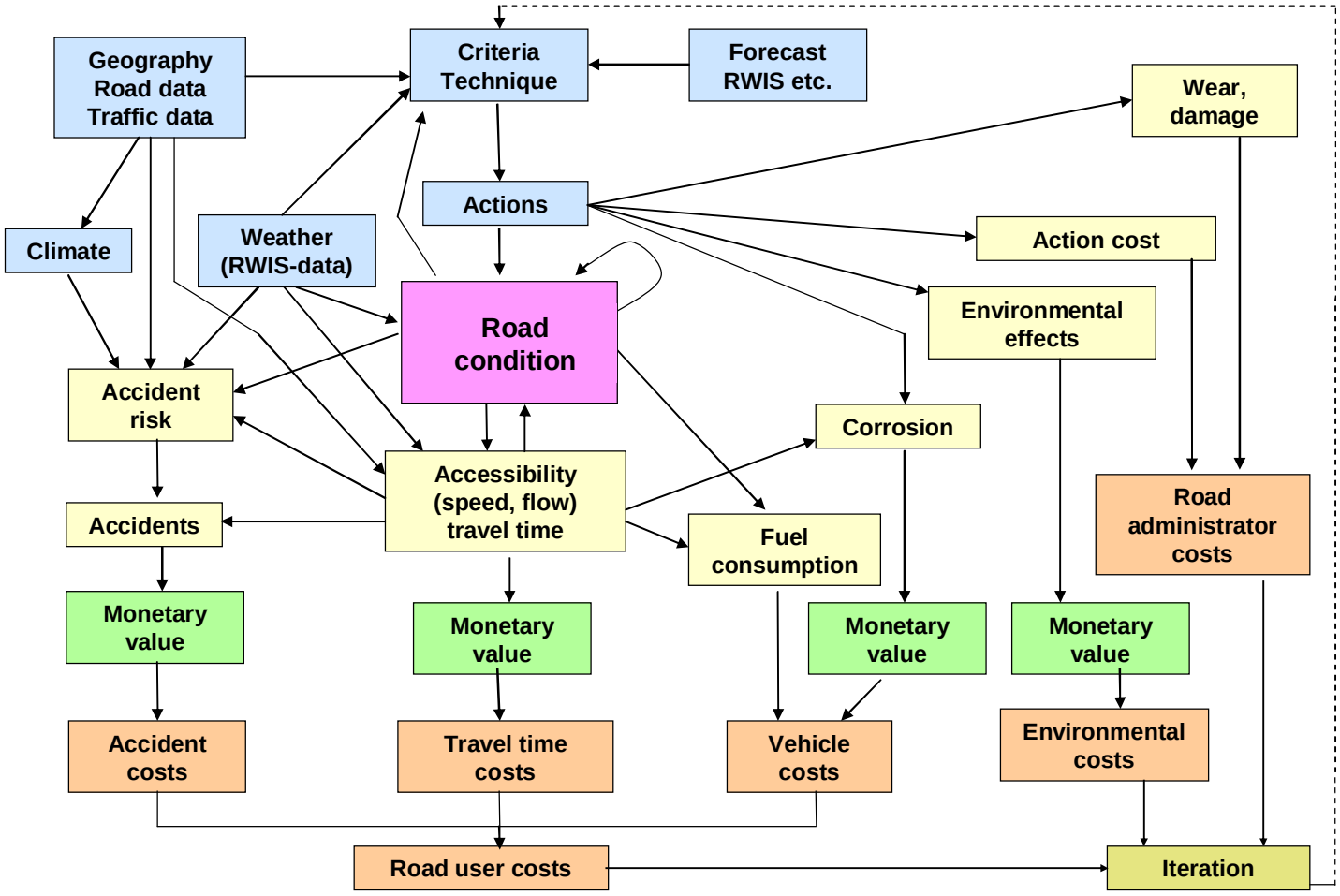

Figure 1. Flow chart of Vintermodellen

Accident Risk Model

To estimate the accident rate in a specific ice or snow condition for a certain road network, two data must be known: the number of accidents on the road condition in question and the vehicle mileage on that condition. There is a major problem in collecting data for the vehicle mileage, the duration of icy and snowy conditions is often very short, and calls for close observations of the road network throughout the winter season.
Swedish Road Administration (SRA) monitored the roadway condition all over Sweden in the four winter seasons of 1993-1994 to 1996-1997. The intention was to check the performance of the winter maintenance contractors. From the data it was possible to estimate the distributions of the roadway conditions under the four winter seasons. Roadway condition data were aggregated for road networks, grouped into the four climate zones, and into the different standard levels of operation. Finally, the vehicle mileage on each roadway condition could be estimated.

The accidents reported by the police during the four winter seasons were used, grouped into the reported roadway conditions. The accidents were linked to the same road networks as the roadway conditions.
The average accident rates vary between the different ice and snow conditions and between the climate zones.
As an example, the accident rates for the salted and unsalted road networks in Central Sweden are displayed in Figure 2.

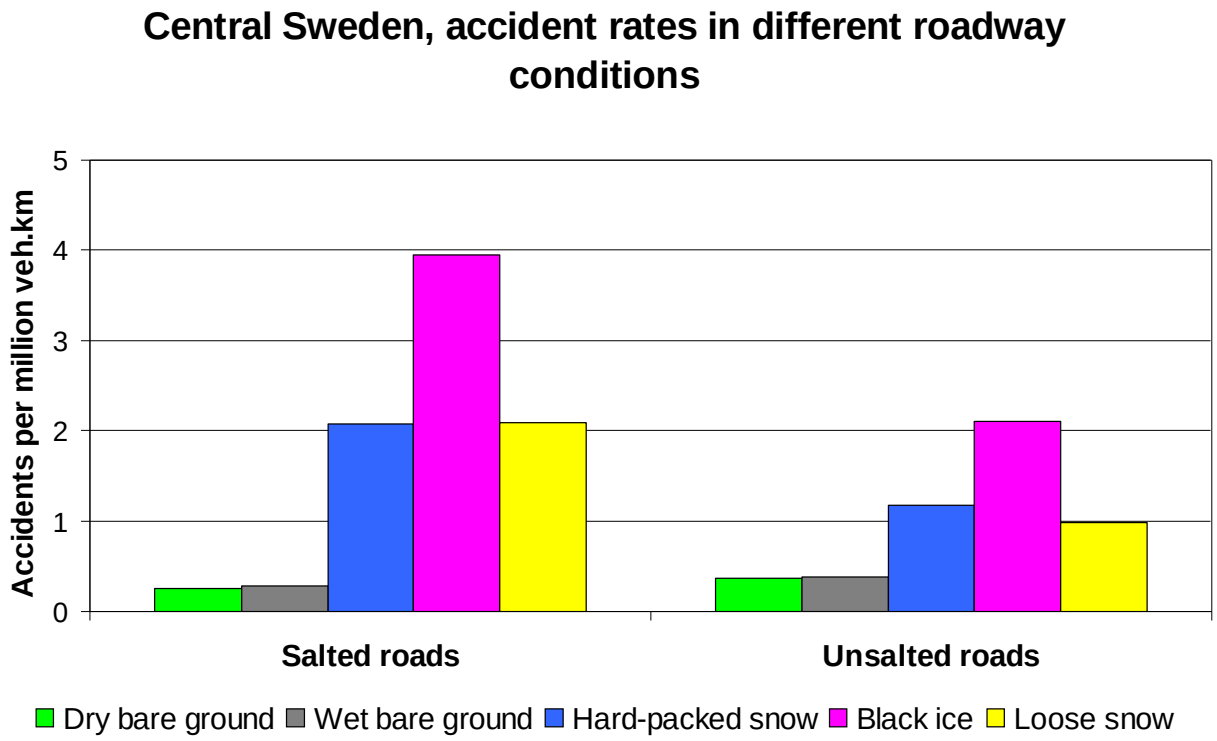

Figure 2. Average accident rates (accidents per million vehicle kilometres) at different road conditions, salted and unsalted roads

The accident rates for ice and snow conditions are much larger for the salted network and still larger if the rates are related to the rate at dry, bare ground. For example, black ice is 16 times more dangerous on salted roads, but "only" about 6 times on unsalted roads.
An interesting question is whether the accident risk is the same for each ice and snow condition, or if the risk varies with the duration of the conditions.
For testing this hypothesis, the same set of data as before could be used. The result shows an exponential relation between the accident rate and the duration for each of the three different ice and snow conditions, reported by the police. Like the average accident rates, this result varies between the climate zones.
The relative duration denotes the vehicle mileage on the particular ice and snow condition related to the total vehicle mileage throughout the winter season. Roughly, the number 0.01 corresponds to the duration of about 2 days of the winter season.
If the accident rate functions are related to the rate at dry, bare conditions, the relations are valid for all climate zones and for all accidents as severe accidents (Figure 3). When ice and snow very common the accident risk is about double the accident risk on bare roads but when

ice/snow uncommon the accident risk on black ice can be 30-40 times the accident risk on bare roads.

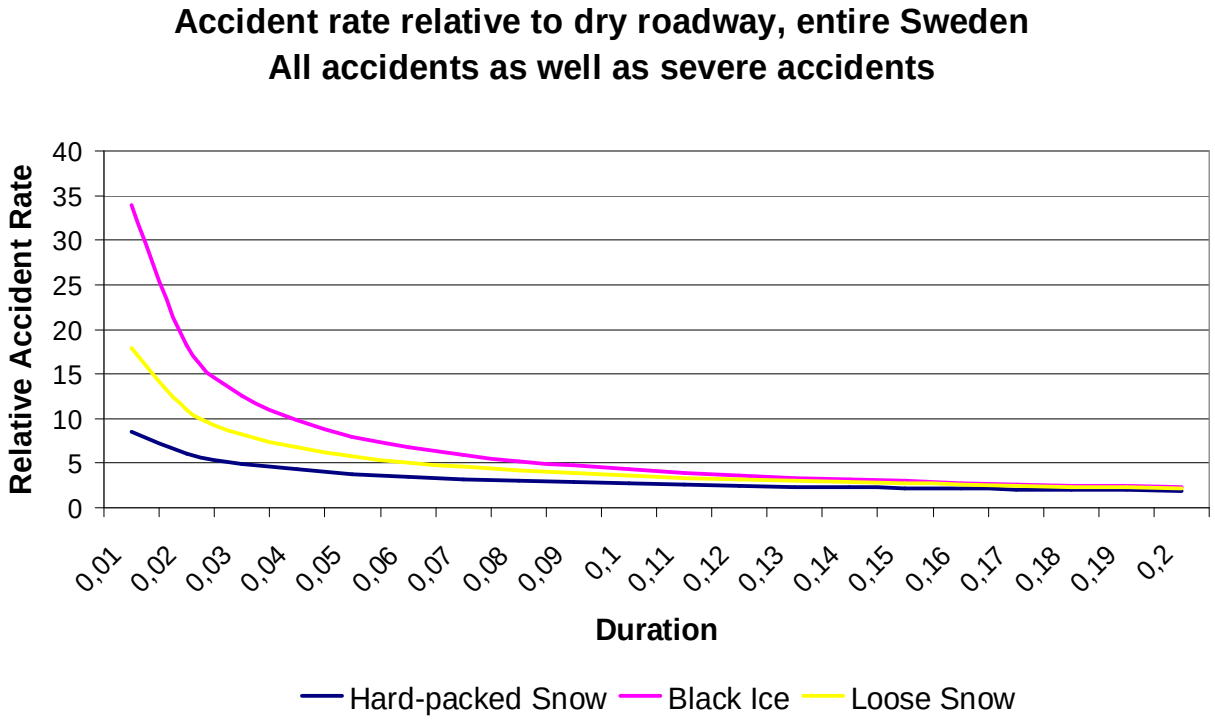

Figure 3. The accident rate (accidents per million vehicle kilometres) as a function of relative duration for three ice and snow conditions. Salted as well as unsalted roads.

The accident rates for varying roadway conditions were analyzed for early and late winter periods compared to mid-winter. Also, the accident rates for single accidents, head-on collisions, and rear-end collisions for varying roadway conditions were analyzed, as well as the average number of persons killed, seriously wounded, and slightly wounded per incident for the three accident types.

The analyses show that, in almost all cases, ice and snow conditions constitute a greater risk during Early and Late winter periods than during Mid-winter. The reason for this could be that drivers are more likely to expect these kinds of road conditions during Mid-winter than at the beginning and end of the winter season.

Moreover, the accident risk was, in most cases, greater during the Late winter periods than during the Early winter periods. Additionally, in many cases, the shorter the Early and Late winter period the higher was the risk.

The percentage of single accidents increases a lot on ice and snow. On bare roads less than one third is single vehicle accidents while on ice/snow more than half of the accidents are single accidents. The percentage of head-on collisions also increases when ice and snow while all other types decrease.

For four types of accidents have the percentage for each of them been calculated for different road conditions, different winter maintenance standard and for different zones. The consequence for each of them has also been calculated. While the consequence decreases for single vehicle accidents when ice and snow, the consequence increases for head-on collision

accidents. One explanation why it is so can be that many crashes when slippery are not really head-on but one car hits the other at the side where people are not as protected as when front collision.

To calculate the accident costs the product of the following data is used:

- Relative accident rate.
- Percentage of different accident types.
- Consequence for different accident types.
- Accident costs as used by Swedish Road Administration.

SINGLE ACCIDENTS AMONG PEDESTRIANS AND CYCLISTS IN SWEDEN

Single accidents among pedestrians and cyclists, especially on days with slippery road conditions, have been considered an important problem in medical care. High proportions of injuries, above all among pedestrians, burden the medical services. Normally, this is not defined as a traffic safety problem since no (motor) vehicle is involved. In principle, this also applies to cyclists' falling accidents. On the other hand, it is a transport safety problem and as such, relating to injuries in traffic environments, considerably greater than for other road users together.
The aim was to elucidate possible differences in injury risks for pedestrians and cyclists depending on the type of surface, the quality of the surface and slippery conditions in the winter. Injury registration, road surface studies and exposure measurements for pedestrians and cyclists were then required.
Three hospitals with existing injury records in different climate zones in Sweden were chosen and consequently also the urban areas where these hospitals are situated.
Prior to the accident study, each day was classified into days with mainly bare ground, mixed road conditions and mainly ice and snow for the pedestrian and cycle areas in each urban area.

There is no significant difference in pedestrian flows between bare ground in the winter and mixed road conditions, but only 75 % of the bare ground flow exists in icy and snowy conditions. The difference is greater for cyclists. In mixed road conditions only fully 60 % and on icy or snow-covered roads scarcely half as many use a cycle compared with bare ground conditions in the winter.
When the temperature is below 0°C the pedestrian flow decreases by 10-15 % for each decrease with 5°C. It is mainly children and elderly people that stand for the decrease. The greatest decrease for cyclists is because of the season winter itself. The winter flow is about half the summer flow.
The pedestrian flow is not depending so much on precipitation, but the cyclist flow is. At slight precipitation the flow decreases by 40 % and at heavier precipitation by 60 %. It is the same for rain and snow.
A total of approximately 450 pedestrians and cyclists per 100,000 inhabitants and year are injured. The injured pedestrians are mostly elderly women, while the injured cyclists are most often young boys. Pedestrian injuries are on an average more serious than cyclist injuries, 30 % and 20 % respectively being hospitalised. The long-term effects of accidents are quite

serious among pedestrians; a year after the accident 35 % still have pain and motion problems and between 5-7 % of the injured need social service.
Pedestrians' falling accidents are more expensive for society than single accidents among cyclists. It should be observed that this is not particularly caused by the fact that many elderly people are injured in pedestrian accidents, but also because the cost of sick-listing is twice as high among pedestrians compared with cyclists.
The classification of days based on observations of road conditions implies that during days with bare ground there may also be icy and snow-covered roads. During the days classified as mainly bare ground, more than half of the pedestrian injuries occurred on icy and snow-covered roads and concerning cyclists approximately one third occurred on ice or snow.
Concerning all urban areas, the injury rate for **pedestrians** on mainly bare ground in winter is twice as high as in the summer. Days with mixed road conditions were slightly more than six times more dangerous, while ice and snow were scarcely eight times more dangerous than summer conditions. All differences are statistically guaranteed except the difference between mixed road conditions and icy and snow-covered roads.
The old pedestrians have a much higher injury risk than the adults. The greatest difference is in the summer when the elderly people have seven times higher injury risk. In the winter the risk is 4-5 times higher. All differences between adults and elderly people are statistically guaranteed.

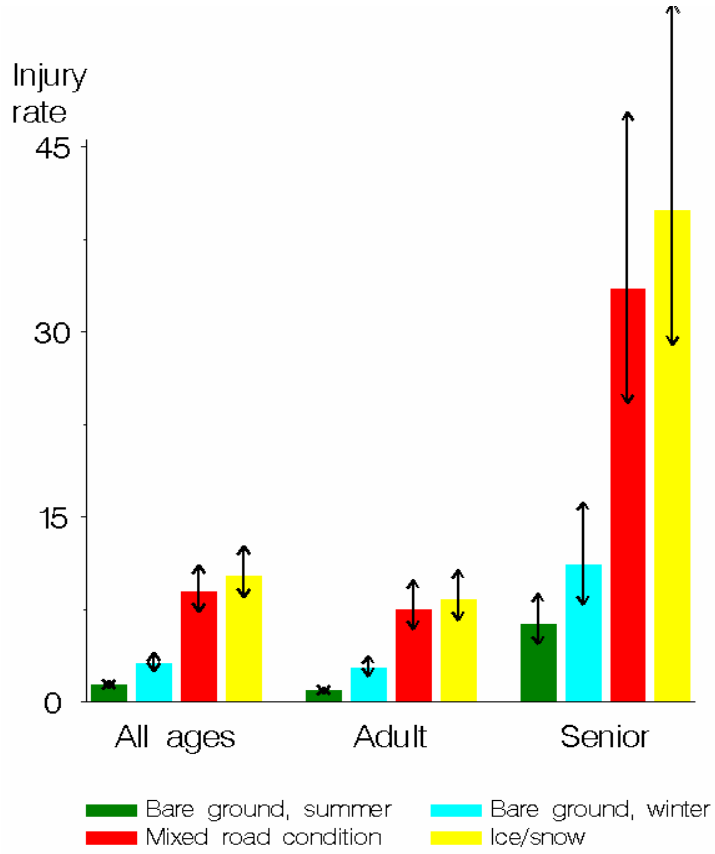

Figure 4 *Injury rates for pedestrians. A confidence interval of 95 % with respect to the uncertainty of the number of injured is indicated by arrows. Adults: 16-65 years old.*

Cyclists have about the same injury risk on bare ground in winter as in summer. Other winter road conditions are slightly more dangerous than summer road conditions. The category of cyclists in the winter differs from that in the summer. Elderly cyclists' injury risk is almost twice as high as that of adults, except on icy and snow-covered roads, where it is considerably higher. No differences are statistically guaranteed, except the difference between adults and elderly on icy and snow-covered roads.
On a 24-hour period with super cooled rain more than 30 times more pedestrians than usual looked up the hospital because they have slipped on the surface. It was extremely slippery and some did not walk they were creeping. As not many did leave their houses the injury risk can be hundred times higher than on bare roads. People in cars were not injured more than an ordinary day.

Recommendations to the road authority

The recommendations to road authorities are based on injury risks among pedestrians and cyclists in single accidents. No other considerations have been applied.
These injuries are worth taking seriously. Compared with those injured in collisions they are

- just as many,
- just as serious measured in number of hospitalised (= seriously injured),
- almost as serious measured as average medical care cost,

and are to a great extent to be referred to the road authority's responsibility (especially regarding pedestrian accidents).

Pedestrian accidents are above all caused by slippery winter road conditions. Elderly people are also affected by falling accidents on bare ground, while such accidents are very rare for other age categories. Furthermore, pedestrian accidents also show several signs of behavioural adaptation. This means that an improved standard of the pedestrian surfaces does not always reduce the number of accidents. A reduction in the number of accidents can only be expected if the standard is even and of high quality. The correspondence between accident number and surface quality for cyclists is simpler: a high standard leads to fewer accidents.
Based on these comprehensive results, the following recommendations can be given to road authorities:

- First, concentrate on improved winter road maintenance for pedestrians and secondly, an improved surface standard in bare ground conditions.
- The winter road maintenance should be of high and uniform standard.
- Provide more heated surfaces for pedestrians.
- Better winter road maintenance (stated in order of priority) should be provided for:
  elderly pedestrians
  adult pedestrians
  elderly cyclists
  adult cyclists
- Sand/gravel should be swept up as soon as possible after winter - above all on hills in cycle areas!

Summer road maintenance should be guided by efforts towards a uniform standard for pedestrians and a high average standard for cyclists.

Behavioural adaptation may also be more frequent than discussed above. In Sweden, the quality of pedestrian and cycle areas is very high in the international perspective. One reason is winter conditions which demand even surfaces for efficient snow and ice removal. As a result, pedestrians' and cyclists' expectations on the quality of surfaces may be too high and minor defects may cause serious problems compared with conditions where pedestrians and cyclists expect general defects.

Acknowledgements

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Sources

1. Wallman, C-G, Möller, S, Blomqvist, G, Bergström, A and Gaunt, H. 2005. 'Vintermodellen, Stage 1'. (In Swedish). VTI meddelande 958. Linköping, Sweden.
2. Wallman, C-G, Möller, S, Blomqvist, G, Gustafsson, M, Niska, A, Öberg, G, Berglund, C M, and Karlsson, B. 2006. 'Vintermodellen, Stage 2. Final Report'. (In Swedish). VTI rapport 531. Linköping, Sweden.
3. Öberg G (editor). PIARC 2006 XII Winter Road Congress 27-30 March 2006, Torino Italy. VTI notat 19 A-2006.
4. Öberg, G; Nilsson, G; Velin, H and Wretling, P
   Swedish National Road and Transport Research Institute
   and Berntman, M; Brundell-Freij, K; Hydén, C and Ståhl, A
   University of Lund
   Single accidents among pedestrians and cyclists
   Swedish National Road and Transport Research Institute (VTI)
   Meddelande 799 A, 1996.
5. Möller, S; Wallman, C-G & Gregersen N P. Winter road maintenance in urban areas – road safety and trafficability. Overview. TFB & VTI forskning/research 2:2A, 1991.