WINTER MAINTENANCE STANDARDS ON CYCLEWAYS
- Appropriate Road Condition for Increased Cycling During Winter

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1. Abstract

From an environmental perspective, a reduction in motor traffic would be desirable. In urban regions, this could be achieved by increasing cycling as a means of personal travel. Improved winter maintenance of cycleways could lead to more winter cyclists. In this paper, the results of a Swedish PhD project, with the purpose of studying the effects of winter road maintenance on cycling, will be summarised. Included in the paper are the results from a literature review focusing on winter maintenance of cycleways, an introductory questionnaire survey to improve the knowledge about travel behaviour during winter, and a field study to see whether it was possible to attain an improved service level. Focus is set on the field study where "new" equipment for snow clearance and de-icing of cycleways was tested.

Results are presented indicating that there seems to be a prevailing discontent among the public concerning winter maintenance of cycleways, and that better winter maintenance could lead to increased cycling. Although slippery surfaces are of great importance for the safety of cyclists, cycleways not cleared from snow seem to be more important for the mode choice.

The results presented from the field study will show that a test method using a broom for snow clearance and brine for de-icing, provided a higher maintenance service level than methods normally used on cycleways.

2. Introduction

Car-based transport has a wide range of impacts upon society and the broader environment. Air pollution, congestion, noise, road accidents, and extensive land use for parking facilities and road constructions, are some of the effects generating large costs for the society. A reduction in motor traffic especially in urban regions would therefore be desirable. This could be achieved by increasing cycling as a means of personal travel, leading to a more economical use of resources such as materials and energy. Regular cycling also contributes to keeping people fit and healthy. From an environmental perspective it is especially important to reduce the number of short car trips since they are responsible for a relatively large amount of the emissions caused by traffic. This is particularly true in winter due to all the cold starts.

Half of all the car trips made in Sweden are shorter than 5 km (Riks-RVU, 1998), and since most people consider there is no difficulty in cycling distances less than 5 km (Herrstedt et al., 1995; Nilsson, 1995), there is a potential for an increased cycling. However, in Sweden, the cycling frequency during the winter is only about a third of that during the summer (Öberg et al., 1996). This decrease during winter is probably largely due to the less favourable weather conditions; low temperatures, strong winds, and precipitation all have a negative influence on cycling (Emmerson, Ryley and Davies, 1998). But, road conditions are also of importance. A cycleway with poor snow clearance means limited accessibility, and a slippery cycleway increases the risk of fall accidents, which deters many from cycling during winter.

In seeking to promote cycling in winter, it is important to know the significance of maintenance service levels of cycleways for travel behaviour. Even though bad road conditions affect cycling negatively, it is not certain that improved winter maintenance standards could lead to more winter cyclists. If it could, it would be desirable to identify the potential for winter cycling. There is also a

need to identify current winter maintenance service levels of cycleways, and the possibilities for making improvements at a reasonable cost.

Considering this, a PhD project with the objective of studying the effects of winter road maintenance on cycling was initiated in 1997 by the Centre for Research and Education in Operation and Maintenance of Infrastructure (CDU). The project is presently being conducted at the Swedish National Road and Transport Research Institute (VTI), and supported financially by the Swedish National Road Administration The project will result in a doctoral dissertation, which is planned for December 2001.

The objective of this paper is to summarise the results of the PhD project, including a literature review, an introductory questionnaire survey, and field studies. The main focus is set on the field study where "new" equipment for snow clearance and de-icing of cycleways was tested. The field study included a pilot study, and a two-year large-scale study, and was evaluated through road condition observations, measurements of friction, traffic censuses, and a questionnaire survey. In particular the results from that questionnaire survey, which aimed to get the users' opinion of the method tested, will be presented in this paper.

3. Literature Review

Throughout the PhD project relevant literature has been reviewed. The literature review focused on winter maintenance of cycleways, such as methods for snow clearance and skid control, requirements of road operation service levels during winter, and methods of monitoring road condition and evaluating the level of service. Other factors associated with winter cycling were also of interest, in particular those related to the mode choice, but even more general topics, such as accidents involving cyclists, were included. Reports representing results not relevant to Swedish conditions were excluded, implying that most of the literature studied was Swedish. Unfortunately, there was not much to be found concerning winter maintenance of cycleways. Most studies in relation to cyclists and cycleways involve accident studies or travel surveys from a summer conditions perspective.

Nevertheless, in the literature it was found that the methods and equipment used for cycleway maintenance are usually the same as for roads and streets (NVF, 1984). Therefore, in many cases, the equipment is too large and heavy for this purpose, and can cause damage to cycleways; it is also difficult for it to pass through tunnels and narrow passages. Its usability is also reduced to a certain degree by low speed. In recent years, however, a new generation of vehicles, for example the Multicar and the Mercedes Benz UX 100 (Figure 1) have become available on the market. These vehicles are light, manoeuvrable, and fast (although engendering high safety), and can be easily equipped for a variety of applications (NVF, 1999). The possibility of changing the application of the vehicle by alternating the equipment makes for good economy, since it enables the same vehicle to be used for both winter and summer maintenance operations. Consequently, these smaller vehicles are becoming more and more popular for municipal use, although they are not yet common in all Swedish municipalities. The new vehicles are rather expensive to purchase, and functioning old equipment is not exchanged simply because it is old fashioned. The most common vehicles used for snow clearance on cycleways today are several kinds of tractors such as the Volvo BM 650 or bucket chargers such as the Lundberg 341 (Lindmark and Lundborg, 1987; NVF, 1984).

There seems to be no specific methods of monitoring road conditions on cycleways. The methods available were developed for roads and street (Gabestad, 1988; Möller and Öberg, 1990), and although some of them can be used for cycleways, they are not well adapted for it. During winter the road condition changes continuously with the weather, as well as being influenced by traffic. Therefore, a visual inspection is almost the only suitable method of monitoring road conditions during winter, although the assessment is subjective and entails considerable manual efforts. Measurement of friction is one of few objective methods of evaluating the level of service on roads during winter. However, the friction measurement devices available, like the methods for maintenance, are usually too large and heavy to be suitable for the use on cycleways.

In the literature review it was also found that there seems to be a prevailing discontent among the public concerning winter maintenance of cycleways. In a survey performed among citizens in 12 Swedish municipalities (SALA, 1998), only 29% of the respondents thought that snow clearance and

skid control of facilities for cyclists and pedestrians were “very good“ or “rather good”, while 68% were satisfied with winter maintenance of motor traffic roads in central areas. This indicates that there is a need to improve winter maintenance on cycleways. However, it is unclear if the dissatisfaction is due to insufficient service level requirements, or if the requirements in reality are poorly met.

According to Möller, Wallman and Gregersen (1991) the accident risk for cyclists increases 5 to 10 times during icy and snowy road conditions compared to bare surfaces. Single accidents in particular are more prevalent during winter. Besides ice and snow, grit from winter maintenance also constitutes a safety hazard for cyclists. According to Binderup Larsen et al. (1991), 10% of all single accidents are caused by loose grit on the road surface. Although slippery surfaces are of great importance for the safety of cyclists, cycleways not cleared from snow seem to be more important in the choice to cycle or not during winter (Giæver, Øvstedal and Lindland, 1998).

4. Questionnaire Survey

To improve the knowledge about travel behaviour during winter, a questionnaire survey was conducted in the PhD project, in 1998 (Bergström 1999, and 2000). The survey focused on journeys to work, and questionnaires were answered by a total of 499 employees at three large companies in two Swedish cities, Luleå and Linköping. The survey aimed to clarify the importance of winter maintenance service level of cycleways for the choice of mode, and to get the respondents opinion concerning the current service level of cycleways.

In the survey it was found that the total number of bicycle trips to work decreased by 47% from the summer period, April to October, to the winter period, November to March. During summer 36%, and during winter 19%, of all the trips to work were bicycle trips. At the same time the number of car trips increased by 27% from 53% during the summer period to 68% during the winter period. In total, 38% of the respondents stated that they would cycle more during winter if the maintenance service level of cycleways was improved. A majority of the respondents, 57%, thought that winter maintenance on cycleways needed to be improved, 9% thought that it was satisfactory, and 30% were uncertain or had no opinion. The survey also concluded, in accordance with the literature review, that snow clearance is more important than skid control for the choice of mode.

Another conclusion from the questionnaire survey worth mentioning is that distance seems to be more important for the mode choice during winter than in summer. In summer, one can hope to transfer some of the car trips up to 5 km to bicycle, while it seems that the critical distance is shortened to about 3 km during winter.

5. Test of Unconventional Methods for Winter Maintenance on Cycleways

Both the literature review (SALA, 1998) and the questionnaire survey (Bergström, 1999; Bergström, 2000) indicated that the public is unsatisfied with the service levels provided on cycleways during winter, and that improved winter maintenance on cycleways could lead to increased cycling. However, it is uncertain whether it is possible to improve the service level of cycleways at a reasonable cost, what maintenance methods are to be used, and how much they are able to affect the choice of mode during winter. Further studies are therefore needed, and in the PhD project it was decided to conduct field studies to test unconventional methods of snow clearance and skid control of cycleways. The methods tested were compared to traditional maintenance methods with respect to service levels achieved, such as the degree of snow clearance and the surface friction. Interviews and questionnaire surveys were also done, to see if the road users noticed any difference in the level of service achieved with the equipment tested. To see if an improved standard would lead to an increase in cycling, bicycle censuses related to different road conditions were also conducted.

5.1 Method

To find a winter maintenance method that could improve the service level of cycleways, and to get experience, with a view to a large-scale study, of the problems resulting from certain maintenance methods, a pilot study was carried out in Linköping (Sweden) in 1999. Traditionally, in Linköping cycleways are cleared through ploughing and skid control is attained by abrasives in 4 to 8 mm size. In the pilot study, two different and unconventional methods of snow clearance and skid control were

tested on two selected cycleways. One of the methods used a traditional steel plough for snow clearance and graded gravel for skid control. The graded gravel consisted of natural granular stone particles washed and processed to obtain a size of between 2 and 5 mm. This test method was similar to the method normally used on cycleways in Linköping, but was still meant to produce a higher service level by having a tougher starting condition and by using the graded gravel with the purpose of reducing cyclists' problems with punctured tyres. The other test method used a front-mounted broom for snow clearance combined with a brine spreader for de-icing. Using the snow broom was meant to reduce any remaining layer of ice and snow so that the salt dosage needed to achieve a bare surface could be minimised. The idea of this "brine method" originated from Odense in Denmark (Mikkelsen and Prahl, 1998), where a similar method had been used for winter maintenance on cycleways for several years. However, it was uncertain if this method was applicable to the Swedish winter climate.

The results achieved in the pilot study were limited and uncertain, since the test was performed for only a little more than a month. However, it was concluded that the method of using a broom for snow clearance and brine for de-icing produced a higher level of service compared to a traditional method, and was therefore considered of sufficient interest for further research in a large-scale study. The method using the graded gravel did not notably improve the service level, and although graded gravel might reduce cyclists' problems with punctured tyres, it may also increase the problem with poor friction on bare surfaces. Therefore it was decided not to go on with that method.

The large-scale study was carried out during two winters, between October 1999 and March 2001. In this study a housing area, *Ekholmen*, within cycling distance of a large workplace, *Saab AB*, in Linköping, Sweden, was used as a test area. In addition to all the cycleways within Ekholmen, three major routes from Ekholmen to Saab AB were included in the test area, resulting in a total of about 23 km of cycleway. In the test area the cycleways were given a higher level of service than usual in Linköping by using the front-mounted broom for snow clearance and brine, or on some difficult occasions pre-wetted salt, for de-icing. The equipment used was almost the same as that used in the pilot study, but instead of a Multicar used in the pilot study a new vehicle, a Mercedes Benz UX 100, was purchased for the large-scale study (Figure 1). Another modification before the large-scale study, was the use of a spinner, instead of a spraying boom, for brine spreading. As in the pilot study, snow clearance and skid control were performed more frequently than on other cycleways, starting snow clearance at a snow depth of 1 cm loose snow and de-icing on every occasion ice, snow, or hoarfrost occurred. In Linköping snow clearance is normally started at a depth of 3 cm.

In the large-scale study, as well as during the pilot study, observations of the road surface conditions were conducted after each occurrence of snowfall or hoarfrost. For these observations, a method for roadways (Möller and Öberg, 1990) modified to better describe the prevailing conditions on cycleways (Bergström, 2000) was used. Observations were done on both cycleways included in the test and maintained with the "brine method", and on cycleways used as controls and maintained traditionally. As a complement to the observations, measurements of friction were conducted on a few occasions. These measurements were performed with a Portable Friction Tester (PFT), developed at the Swedish National Road and Transport Research Institute (VTI) to measure friction on road markings in wet conditions (Lundkvist and Lindén, 1994). Since the PFT is reasonably small and handy, it was considered practicable in this case when measuring friction on cycleway surfaces where it can be difficult to use other measuring devices (Bergström, 2001).

To get the users' opinions of the test method, interviews were carried out on a few occasions, especially in the pilot study. The large-scale study was also evaluated through a questionnaire survey, performed in 2000. A total of 570 questionnaires were answered by employees at Saab AB living in the test area of Ekholmen, and by reference groups. The large-scale study was also evaluated by counting cyclists, particularly during the second winter of 2000/2001.

Figure 1. The Mercedes Benz UX 100 Used in the Large-scale Study, Equipped with a Front-mounted Broom for Snow Clearance and a Spinner for Spreading Brine, or Pre-wetted Salt.

5.2 Results

In the pilot study, and in the first winter of the large-scale study, the weather conditions were not ideal for the purpose of testing new winter maintenance methods since it was fairly mild, with high average temperatures and less snow than normal. During the second winter of the large-scale study, there were periods of high snow intensity, but overall one could say that this winter was also milder than normal. Unfortunately, this means that the results cannot apply to the typical winter conditions in this region.

The large-scale study has not yet been fully evaluated. Bicycle censuses related to different road conditions are not yet analysed, and a financial evaluation of the test method still remains to be made. Nevertheless, both in the pilot study and in the large-scale study, the observations of road surface conditions showed that there was almost always a dry, moist, or wet bare surface on cycleways in the test area, no matter what the conditions were on other cycleways in the municipality. This implies that the test method using a broom for snow clearance and brine for de-icing provides a higher maintenance service level than the methods traditionally used in Linköping. At the end of each study period, the effect of the midday thaw in combination with the “brine method” showed it to be very efficient for clearing the cycleways. If brine had been spread in the morning during a day of sunshine, the road condition on the cycleways in the afternoon was almost always dry bare surface.

During the pilot study, and the first winter of the large-scale study, on occasions with a snow depth over 2–3 cm of loose snow, and if the snow was very wet, the broom had problems clearing the snow. The effect of the broom was therefore improved by adding an extra hydraulic engine before the second winter of the large-scale study. This improved the snow clearing results considerably and at almost any snow depth, the snow could swiftly be swept away. Still, the operator had to maintain a slower speed than during traditional ploughing. Also, in a few stretches in the test area, where the pavement was in very bad condition, it was difficult to get good snow-clearing results, although the broom was likely more effective on such stretches than traditional ploughing.

The friction measurements, performed both in the pilot study and in the large-scale study, showed that the friction level on the cycleways maintained with the “brine method” was considerably higher than on cycleways maintained traditionally. At the time of the measurements, the surface on the cycleways included in the test was bare and wet and there was snow on the cycleways used as control. It is not surprising that a snowy surface is more slippery than a bare surface. Nevertheless, this showed that the test method using a broom for snow clearance and brine for de-icing resulted in a surface less slippery than would be the case with the maintenance methods normally used.

In the questionnaire survey conducted within the large-scale study (mainly to evaluate the winter of 1999/2000), 43% of the respondents stated that they would cycle more during the winter if the maintenance service level of cycleways was improved. A total of 62% thought that winter maintenance on cycleways needed to be improved, 12% thought that it was satisfactory, and 25% were uncertain or without an opinion. Naturally, most of those who were uncertain or without an opinion were those who did not cycle to work. This also applied to those who were satisfied with the winter maintenance. However, there were a number of winter cyclists who thought that winter maintenance on cycleways did not need to be improved. In the questionnaire the respondents were given the opportunity to specify how winter maintenance on cycleways should be improved. Most of the answers (162) suggested improved skid control, for example: "gritting should be done more often", "prevent slush from creating frozen tracks", and "use salt on cycleways". Many (141) also suggested better snow clearance, such as "clear the cycleways more often", and "clear the cycleways earlier in the morning".

According to their mode choice for journeys to work in summer and winter, the respondents were divided into different categories of "cyclist": "winter cyclist", "summer-only cyclist", "infrequent cyclist", and "never cyclist". A *winter cyclist* is defined as a person who uses a bicycle for travelling to work in at least two cases out of five during the period from November to March. A *summer-only cyclist* is defined as a person who uses a bicycle for travelling to work in at least two cases out of five during the period from April to October, but less during the period from November to March. An *infrequent cyclist* is a person who cycles only occasionally, fewer than two cases out of five, when travelling to work, no matter the season; and a *never cyclist* is a person who never uses a bicycle for a journey to work. In the survey, 51% were winter cyclists, 24% summer-only cyclists, 9% infrequent cyclists, and 16% never cyclists. It should be noted that the large number of winter cyclists in this survey is probably a lot higher than for an average Swedish workplace.

Of the 570 respondents, 214 lived within the test area of Ekholmen, and of those 128 were classified as winter cyclists. Winter cyclists within the test area were found to be more satisfied with the maintenance service level of cycleways during the winter of 1999/2000, compared to winter cyclists in the control areas (Table 1). This indicates that, in accordance with the measurements of friction, and the road condition observations, the test method did produce a higher maintenance service level than traditional methods.

Table 1: Respondents Satisfied with the Maintenance Service Level of Cycleways Concerning Different Road Conditions in the Test Area Compared to the Control Areas.

Road Condition:	Satisfied respondents in the:	
	Test Area	Control Areas
Slush	49%	28%
Loose Snow	62%	44%
Black Ice	50%	25%
Packed Snow/ Thick Ice	50%	24%
Total Average:	53%	30%

In addition, a majority of the winter cyclists in the test area thought that the maintenance service level during the large-scale study in 1999/2000 was higher compared to earlier winters (Figure 1). Also in the control areas, many winter cyclists thought that the service level of cycleways had improved during the test winter of 1999/2000. However, the number was not as striking as for the test area, in Ekholmen. It should be mentioned that winter cyclists in the control group in Hjulsbro, the first control group in Figure 2, were to some extent affected by the test, since the last part of their cycle route to Saab AB was located within the test area.

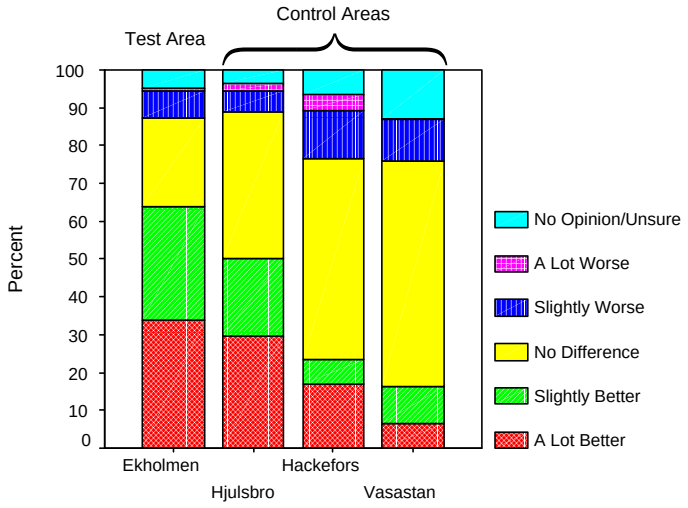

Figure 2. The Respondents' Evaluation of the Maintenance Service Level of Cycleways During the Test Winter of 1999/2000 Compared to Earlier Winters.

Even though most of the winter cyclists living in the test area, Ekholmen, were satisfied with the maintenance of cycleways provided during the winter of 1999/2000, and thought that it had been better compared to earlier winters, 44% were against the use of salt on cycleways. However, the attitude towards the use of salt on cycleways to combat icy conditions was more positive within the test area compared to the control areas. Of winter cyclists living in the test area of Ekholmen, 43% were positive to the use of salt compared to 23% of winter cyclists in the control areas. In total, all respondents included, 26% were positive to the use of salt on cycleway, 53% were against its use and 20% were unsure. A majority (52%) of those who were positive lived in Ekholmen, and thus had experienced the use of salt on cycleways, which was not the case for those who lived in the control areas.

The results from the questionnaire survey, concerning the use of salt on cycleways, can be compared to interviews conducted in the pilot study. Of the 122 people interviewed, on five different occasions, a majority (53%) thought that it was acceptable to use brine on cycleways, while 30% were against its use and the remainder were unsure.

6. Conclusions and Discussion

There seems to be a prevailing discontent among the public concerning winter maintenance of cycleways. This indicates that there is a need to improve winter maintenance on cycleways. However, it is unclear if the dissatisfaction is due to insufficient service level requirements, or if the requirements in reality are poorly met. If we want people to use their bicycles whenever possible, they have to be provided with safe and accessible cycleways. Wet snow freezing and creating icy tracks is the road condition cyclists fear most, and slippery surfaces of all kinds, including grit on bare surfaces, create a safety hazard for cyclists. Although slippery surfaces are of great importance for the safety of cyclists, cycleways not cleared from snow seem to be more important in the choice to cycle or not during winter. Further studies need to be carried out to clearly define a good road standard from a cyclist's point of view. When striving for good winter maintenance standards, the structural standards of the pavement should not be forgotten. Potholes or other irregularities that create an uneven surface can negatively affect the results of snow clearance.

Surveys presented in this paper indicate that improved winter maintenance on cycleways could lead to increased cycling. Since distance seems to be more important for the mode choice during winter than in summer, the critical distance of which one can hope to transfer some of the car trips to bicycle is shortened from 5 km in summer to about 3 km during winter.

Winter maintenance methods used on cycleways today are often adapted to the prevailing conditions on motor traffic roads. Consequently, they are not necessarily the best methods for bicycle traffic. However, there are equipment and methods available that are better adapted to cycleways. Since the surface conditions are very important for the safety and accessibility of cyclists, it is important that these methods are more widely used. It is also important to improve the methods available to better suit their purpose and also to become more cost effective. A combination of different methods adjusted to present weather and road conditions is likely to be the best solution.

Measurements of friction, road condition observations, and a questionnaire survey, presented in this paper, showed that a method using a front-mounted broom for snow clearance and brine for de-icing produced a higher maintenance service level than methods normally used on cycleways. In particular during spring, in combination with the midday thaw, this method proved to be efficient for clearing cycleways. Thus, the method using a front-mounted broom for snow clearance and brine for de-icing, is probably a good method for regions with low snow accumulations but with major ice formation problems. Linköping and many other municipalities in southern Sweden have winter conditions of this kind. Also in regions with a colder climate such as northern Sweden, this method is probably advantageous during spring and fall when the temperatures are higher and the amount of snow is less; during winter, however, other methods are likely to be better suited. A drawback with the method using a front-mounted broom for snow clearance was that the operator had to maintain a slower speed than during traditional ploughing. This increases the time to operate and hence increases the cost.

A majority of the winter cyclists living in the test area were satisfied with the maintenance service level achieved with the method using a front-mounted broom for snow clearance and brine for de-icing, and thought that it was improved compared to earlier winters. Nevertheless, many were still against the use of salt on cycleways. The fact that the attitude towards the use of salt on cycleways was more positive within the test area compared to that in the control areas indicates that the advantages of using salt become more evident for the road users when experienced directly. However, if the common opinion of the public is that salt should not be used on cycleways, it can be difficult introduce such a method. The use of salt should always be as moderate as possible due to its environmental side effects. Its advantages and drawbacks need though to be compared with alternative methods such as the use of abrasives. On some occasions the use of salt can be more cost effective, even when the environmental effects have been taken into consideration. Further studies comparing the impact of abrasives and salt on the environment with security and economy are necessary to be able to make the right decisions concerning winter maintenance of cycleways and footways.

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