# Winter Maintenance Standards on Cycleways

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A high incidence of bicycle usage for personal travel is desirable, provided it is associated with a corresponding decrease in car-based transport. Cycling provides considerable health benefits as well as environmental benefits. During winter, weather conditions figure significantly in a person's decision whether to cycle; whereas road conditions are also important, it is not certain that improved road standards would increase cycling usage. The relationship between improved winter maintenance standards and the benefit to society is complex and merits additional study. During February and March 1999, a pilot study of unconventional methods for snow clearance and skid control was performed in Linköping, Sweden. One method with good results involved a front-mounted sweeper for snow clearance combined with a brine spreader for deicing. This method was further tested in a large-scale field study during the winter of 1999–2000. Both of these studies are presented, with the main focus on how to evaluate road standards (for example, through observation of road conditions and friction measurement). Literature reviews concerning winter maintenance methods for cycleways used in Sweden are also included. Winter maintenance methods on cycleways used today often are adapted to the prevailing conditions on motor traffic roads but are not necessarily the best methods for bicycle traffic. The methods most suitable for cycleways with regard to accessibility and total cost for cyclists are needed. A combination of different methods adjusted to weather and road conditions is likely to be the best solution.

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A high incidence of bicycle usage for personal travel is desirable, assuming it is associated with a corresponding decrease in car-based transport. A reduction of motor traffic, especially in urban regions, would be desirable for environmental reasons. Cycling provides considerable health benefits (*1*).

In Sweden, cycling is an increasingly important mode of transport. Of all passenger journeys in Sweden, approximately 11 percent are made by bicycle and 59 percent are made by car (*2*). Nevertheless, the transport mileage by bicycle is only 3 percent compared to 84 percent by car. Of course, cycling frequency varies between cities due to tradition, attitudes, climate, and topography. Even though cycling for personal travel in Sweden is considered significant compared with many other western countries, the potential for further increasing cycling frequency is high. Most people consider that cycling distances less than 5 km present no difficulty, but approximately 60 percent of all passenger journeys in Sweden are shorter than 5 km, and just over 50 percent of these journeys are made by car. Cycling could increase in response to campaigns that influence peoples' attitudes toward cycling, restrictions for motor traffic, and other means.

Even during winter, bicycles are used for personal travel in Sweden. However, the variation in cycling frequency between seasons is large, and the cycling frequency during the summer is nearly three times higher than during the winter (*3*). The decrease in winter cycling frequency is probably largely due to less favorable weather conditions; low temperatures, strong winds, ice, and snow affect cycling frequency negatively (*4*). Not only current conditions are significant in this respect; weather on the days immediately preceding travel also affects a person's choice of transport mode (*5*).

Road conditions also are important in deciding whether to cycle (*6, 7*). However, it is not certain that an improved winter maintenance standard for cycleways could increase cycling frequency during winter. If it could, then how large is the potential for winter cycling? How can the road standard be improved, and what will it cost? Road conditions are also important for the safety of cyclists. Many single accidents are caused by hazardous road conditions (*3, 8–11*). With dry surface conditions, the chief causes of accidents are ruts, unevenness, and cracks in the surface or sand, gravel, and other debris; during winter, the risk of accident is increased by ice and snow. Obviously, improved winter maintenance standards and benefits to society form a rather complex relationship. Figure 1 is an attempt to portray this relationship. Note that if the directed edges in the graph are quantified, it is possible to carry out cost/benefit analysis for improved winter maintenance standards.

Additional studies (questionnaire surveys, interviews, and field studies) are needed to determine whether it is possible to increase cycling frequency during winter just by improving the winter maintenance standards on cycleways. Field studies include bicycle counts related to different road conditions and comparisons of road standards achieved with altered methods. However, before these field studies can be done, methods for comparing different road conditions on cycleways are needed. It also is important to define good road standards on cycleways from a cyclist's point of view.

## PURPOSE

In this paper, a method is presented for describing winter road conditions on cycleways that will be easy to use for comparing studies and that clearly describe the prevailing conditions. A review of field studies where road conditions on cycleways in Linköping, Sweden, were observed during the use of unconventional methods for snow clearance and deicing is included. Another objective is to present a short review of winter maintenance methods for cycleways normally used in Sweden.

## METHODS

The content of this paper is based on literature reviews and field studies. Literature reviews were conducted to find methods for describing winter road conditions on cycleways and to overview present winter maintenance methods for cycleways. Field studies were conducted mainly to obtain appropriate ideas for improving the available observation methods.

## MAINTENANCE AND OPERATION OF CYCLEWAYS IN SWEDEN

### Snow Clearance

Snow plowing is the method usually used for clearing snow from cycleways in Sweden as well as in Norway, Finland, and Denmark (*12*). Other methods include the use of snowblowers or mechanical sweepers, although these methods are seldom used.

The methods and equipment used for cycleway maintenance are the same as for roadways. However, the large, heavy equipment can cause damage to cycleways and has difficulty passing through tunnels and narrow passages. Its usability is also reduced to a certain degree by low speed. Examples of vehicles specially adapted for paths

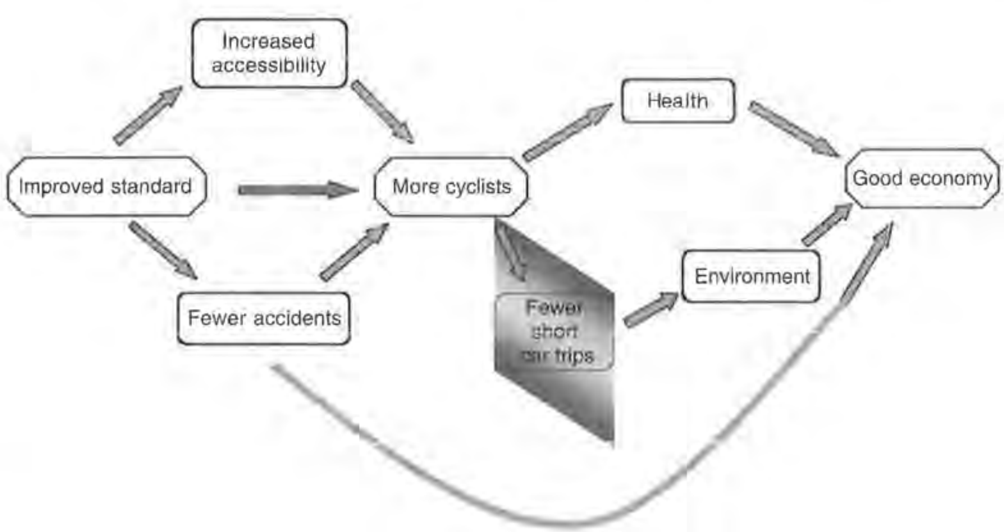


**FIGURE 1** Relationship between improved winter maintenance for cycleways and benefits to society.

FIGURE 2 Mercedes Benz UX 100 equipped with a front-mounted sweeper for snow clearance and a spinner for spreading salt, brine, or grit.

and cycleways are the Multicar and the Mercedes Benz UX 100 (Figure 2). These vehicles are fast, light, and maneuverable and can easily be equipped for various applications (*13*). This kind of equipment is presently available but not in common use. The new vehicles are rather expensive, and functioning old equipment is not exchanged simply because it is old-fashioned.

Furthermore, on some occasions, all available equipment (including farm tractors) is required to clear snow from cycleways and roadways within a reasonable time. Actually, the most common vehicles used for clearing snow from cycleways today are tractors such as the Volvo BM 650 or bucket chargers such as the Lundberg 341 (*12*). In some larger communities, the smaller, newer vehicles are used more frequently. However, the old, heavy vehicles are still in use, and it probably will be decades before the entire fleet is replaced with vehicles better adapted to cycleways.

## Skid Control

Skid control on cycleways in Sweden is normally done through mechanical methods that involve the application of sand, grit, or abrasive (crushed stone aggregate). Sand needs to be heated or mixed with salt to prevent freezing and thus is replaced with grit or abrasive, usually of 2- to 5-mm fraction. Abrasive, like grit, increases friction even when covered by a thin layer of snow but has little effect on black ice. The coarse material also causes punctures in bicycle tires, injures dog paws, and creates a safety hazard in spring until it is swept up. Grit may impose an environmental burden; during a thaw, grit may end up in the street sewers, where it can cause blockages. Grit also is a natural resource (quantities of which are not unlimited), and the production and transport of abrasive consumes energy.

The most common chemical method for deicing is the application of salt, usually sodium chloride (NaCl). Salt is often applied to roads used by motor traffic but rarely on cycleways. Most municipalities in Sweden stopped using salt on footways and cycleways after receiving complaints from cyclists about rust on cycle chains and from pedestrians whose clothes and shoes had been stained. Salt contaminates the environment (Blomqvist and Thunqvist in papers in this proceedings, pp. 179–194) and causes rust and concrete damage, but it is economical and readily available.

Salt can be spread dry, prewetted, or as brine. Brine is a saturated salt solution that contains about 20 to 25 percent NaCl by weight (therefore using only about one-quarter the amount of dry salt over the same area). Brine application on roads decreases the salt concentration considerably and is preferred for cycleways because cycling traffic is too light for dry salt to work effectively. However, brine application is unsuitable during snowfall, on wet roads, or when ice has already formed.

Brine application is extremely effective as a preventive measure (anti-icing) and for dealing with hoarfrost (which is caused by a combination of temperatures below 0°C and high moisture content at the level of the pavement).

In fact, in Odense, Denmark, brine has been used to anti-ice cycleways since 1986 (*14*). It began as an experiment on a few stretches but produced such good results that brine alone is used for skid control on cycleways in Odense today.

## Evaluation Methods

To establish a cost-effective maintenance performance standard and analyze the consequences of different standards of maintenance, it is important to know the snow and ice conditions on the roads. Methods of evaluating road standards are needed to compare maintenance methods for cycleways.

To determine the road conditions during the winter, visual inspection is almost the only suitable method, although it entails considerable manual effort and is subjective. The instructions available are mainly for observing roadways, not cycleways; however, the same instructions can and have been used. The work in this project has revealed the need to modify the instructions to some extent to better describe the road conditions on cycleways. The instructions for observing road conditions normally used in Sweden are described below [from Möller and Öberg (*15*) with some complementary comments by Gabestad (*16*)].

The visual inspections can be supplemented with mechanical methods such as friction measurement. However, the mechanical methods available for judging road condition often involve the use of large vehicles, which can cause overloading damage on paths and cycleways.

### Instructions for Observing Road Conditions

Every observation area is 100 m long. The road surface in the observation area is surveyed and first generally categorized as one of four conditions (Level 1). Then, the general condition is given a more detailed description (Level 2). The logical construction of the road condition classification is presented in Figure 3; see Figure 4 for the survey form that is used (the form has been modified to better describe the condition on cycleways).

### *Level 1*

Level 1 describes four basic surface conditions:

1. Bare surface. At least three-quarters of the roadway is bare. A bare surface is identical to the pavement surface condition in summer.
2. Ice and snow. At least three-quarters of the roadway is covered with ice, snow, hoarfrost, or slush from a continuing or earlier snowfall. The condition may also stem from supercooled rain or moisture that creates ice.

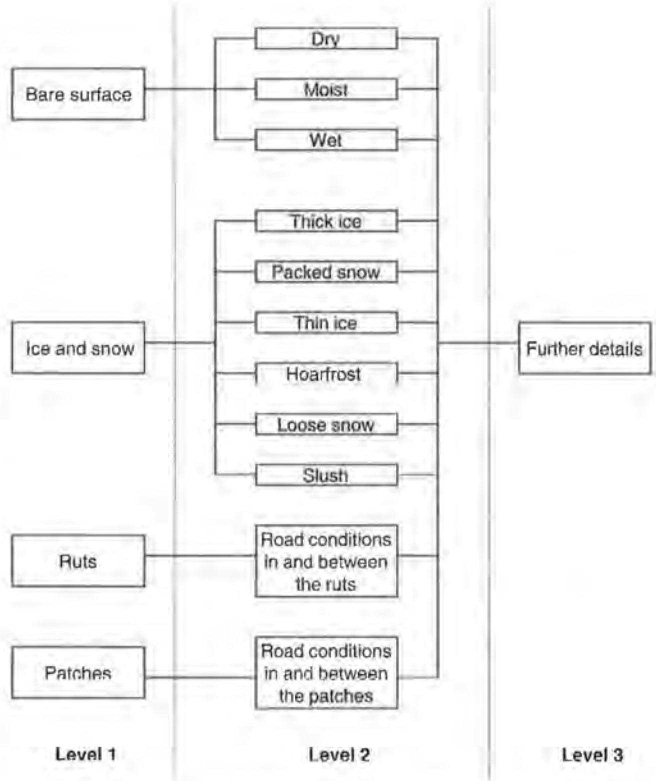


**FIGURE 3 Logical construction of road surface condition classification, whereby every detailed condition is connected to a more general condition.**

3. Ruts. The roadway is covered with ice, snow, hoarfrost, or slush, and wheels have worn the ice or snow layer so that the pavement is clearly visible in the ruts. Ice and snow exist between the ruts. In other words, different conditions occur across the roadway. (If the pavement is not visible, the condition is defined as "ice and snow.")
4. Patches. The roadway has ice and snow as well as bare pavement. If at least three-quarters of the roadway is one road condition, then that condition is considered to be the prevailing one.

### *Level 2*

Level 2 describes the road conditions in more detail:

1. Bare surface. Is the surface dry, moist, or wet? If puddles of water are visible or windshield wipers are needed when following another car, even in absence of precipitation, then the road surface is considered to be wet. Otherwise, it is moist or dry.
2. Ice and snow. Descriptions include thick ice, thin ice, packed snow, loose snow, slush, and hoarfrost. The difference between thick and thin ice is its transparency; pavement is visible through thin ice but not through thick ice. A surface of thick ice may be broken only with an axe

LOCATION:........................................................................................ OBSERVER:........................................................................................

| | | | | DETAILED ROAD CONDITION | | | | | | | | | OCCURRENCE OF | | | | | WEATHER | | | | | | | | TEMP. | | FURTHER INFORMATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | GENERAL ROAD CONDITION | Bare surface | | | | | | | | | Cycle-tracks | | | Sand | | Snowfall | | | Rain | | | | | | | E.g. strong winds, varying road conditions, maintenance methods used, icy tracks. |
| Stretch no. | Date | Time | | Dry | Moist | Wet | Thick ice | Packed snow | Thin ice | Hoarfrost | Loose snow (cm) | Slush (cm) | Number | Width (cm) | Irregu-larities | High friction | Low friction | Light | Medium | Heavy | Light | Medium | Heavy | Super-cooled | Fog | Air | Road surface | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
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**FIGURE 4 Protocol for describing the road surface condition on cycleways survey.**

or other such implement. Packed snow is distinguished from thick ice by its white color. Loose snow may be scraped from the pavement by one's fingers, whereas the surface of packed snow is hard and cannot be scraped off without the use of a tool. Slush contains more water than loose snow and does not compact but remains soft on the road surface. If slush or loose snow is present, its depth shall be determined. Hoarfrost occurs on the pavement and usually is white.

3. Ruts. The two conditions are "in the ruts" (where the only possible conditions are bare ground and thin ice) and "between the ruts."

4. Patches. The two conditions are "in the patches" and "between the patches."

### *Level 3*

Level 3 gives more information about the road conditions, such as the presence of irregularities, sand, and grading tracks. Irregularities appear as potholes or waves in a surface of thick ice or packed snow. Sand is considered to be present if the friction level is increased. Thick ice or packed snow is required for grading tracks to occur. Other relevant information such as weather conditions and road temperature also should be observed.

## Adjustments Needed for Describing Cycleway Conditions

As mentioned earlier, the instructions for observing road conditions are created mainly for roadways, not cycleways. Not all parameters included in the method for roadways are relevant for cycleways. Other parameters are of greater importance for cyclists than for motorists and therefore should be highlighted and described in more detail when observing cycleways. Although there is no need to differentiate between roadways and cycleways when describing the general condition (Level 1), it is advantageous to shorten the observation area from 100 m to 50 m.

Ruts, a common condition on roadways—especially in countries that allow the use of studded tires—are not as common on cycleways. However, where cycling traffic is high, ruts often appear 1 or 2 days after a snowfall. They develop when many cyclists choose the same track when traveling on the cycleway. If the cycling frequency is high in both directions, the cyclists are more or less forced to choose the same track. At first the rut is just a few centimeters, but it can grow to about 40 cm, depending on temperature, the amount of snow, and the cycling frequency. Ruts represent a potential danger for passing maneuvers and are a larger hindrance for cyclists than for motorists. It is therefore important to note this condition. Even when the pavement is not yet visible in the tracks (which technically is the definition of "rut"), the number of tracks as well as their width should be determined. In such a case, the general road condition would be "snow and ice," and the tracks would be presented only in the detailed description (Figure 4).

Detecting other kinds of tracks is also important and should be described in the detailed description of road conditions. Icy tracks are often formed on cycleways when wet snow freezes. Interviews and comments in a questionnaire survey performed early in this project indicated that these kinds of tracks are what cyclists fear most. Icy tracks are considered to be both troublesome and dangerous.

Other detailed information important for cycleways includes the occurrence and amount of grit on the surface. In the instructions for observing roadways described earlier, the occurrence of grit was to be noted when it was judged to increase the road surface friction. However, for cycleways, it is important to distinguish whether grit increases or decreases friction. If the amount of grit is more than needed, the friction level on the surface is decreased rather than increased, which is the fundamental purpose of grit application. (Such is often the case during mild winters, when the general road condition is often bare ground.) On roadways, friction level is almost never decreased, because air turbulence from motor traffic quickly transports the grit off the road surface.

## Measurement of Coefficient of Friction

Surface friction is one of the most important features concerning road conditions. It is particularly important during winter, because snow and ice on the road surface decrease friction considerably. When the friction level on the pavement surface is lower than what may be considered safe, the surface is considered to be slippery or seriously slippery. In Operation 96 of the Swedish National Road Administration's General Technical Description of Operation Service Levels (*17*), a surface with a coefficient of friction below 0.25 is considered "slippery" (Table 1).

The friction coefficient can be measured with several methods and devices. One method normally used to measure friction on roadways in Sweden is the Saab Friction

**TABLE 1 Friction Coefficients Defining the Road Conditions in Terms of Slipperiness, According to Operation 96 (*17*)**

| Class | Friction coefficient |
|---|---|
| Satisfactory friction | $\mu \geq 0.25$ |
| Slippery | $\mu < 0.25$ |
| Seriously slippery | $\mu \leq 0.15$ |

NOTE: The friction coefficient is defined as the average value over a 20-m stretch, as measured with a Saab Friction Tester or analogous equipment.

Tester. This device uses the wheel-slip principle, whereby a slipping wheel is installed in a car (a Saab), enabling a continuous measurement of friction at a moderate highway speed. Table 2 presents friction coefficients representative of different road conditions measured with the Saab Friction Tester. As Tables 1 and 2 show, a roadway free of snow and ice is always considered to have satisfactory friction, whereas the presence of ice almost always creates a slippery or seriously slippery condition. Packed or loose snow provides a friction level that can be either satisfactory or slippery.

The Saab Friction Tester can be used on cycleways as well as on roadways. However, because of limited space and for the safety of cyclists when performing the measurements, other devices are preferable. A portable instrument for measuring friction over short distances (down to 1 m) has been developed at the Swedish National Road and Transport Research Institute (*19*). The Portable Friction Tester (PFT; Figure 5) is a three-wheeled hand-pushed cart of which one of the wheels has a variable slip. Friction is measured in terms of the force on this wheel, sampled with variable frequency. This equipment was originally designed to measure friction on road markings in wet conditions, but it also can be used on cycleways.

The PFT has not been scientifically compared with the Saab Friction Tester. However, it has been compared with the British pendulum (*19*); it is possible to predict friction values measured by the PFT into British pendulum units. Thus the PFT has high validity, if it is assumed that the pendulum shows the "true" friction. Furthermore, the repeatability of the PFT measurement has been good and the measurement less time-consuming than with the pendulum.

## FIELD STUDIES

### Purpose

The main purpose of the field study was to test an unconventional method for snow clearance and deicing of cycleways. The field study surveyed, through questionnaires, the users' opinions of the tested maintenance method compared with traditional methods with respect to degree of snow clearance, surface friction, and so forth.

**TABLE 2 Friction Coefficients Representative of Different Winter Road Conditions Obtained with a Saab Friction Tester (*18*)**

| Road condition | Friction coefficient |
|---|---|
| Dry bare ground | 0.8–1.0 |
| Wet bare ground | 0.7–0.8 |
| Packed snow | 0.2–0.3 |
| Loose snow/slush | 0.2–0.5 |
| Thin ice | 0.15–0.30 |
| Loose snow on thin ice | 0.15–0.25 |
| Wet thin ice | 0.05–0.10 |

NOTE: For loose snow or slush, the higher values represent the occasion when the slipping wheel is in contact with the pavement.

FIGURE 5 Portable friction tester, constructed at the Swedish National Road and Transport Research Institute for measuring the friction over short distances.

To compare different road conditions, an evaluation method for cycleways was needed. Therefore, another purpose of the field study was to develop a method for describing road conditions on cycleways.

### Methods

Instructions for observing road conditions on roadways, found through literature reviews, were developed to better describe cycleway conditions (described under Evaluation Methods.) A preliminary study was conducted to obtain information for an extensive study on how to improve the instructions for observing road conditions on cycleways and the problems that certain maintenance methods could expect.

Two frequently used cycling paths in Linköping were chosen for the study, which was carried out in February and March 1999. Observations of the road surface conditions on the cycling paths were conducted after each snowfall or hoarfrost. On two occasions, in addition to the observations, friction was measured with a PFT, which was considered practical in this case because it was difficult to use other measuring devices. To obtain an idea of the cyclists' opinion of the condition of the cycling paths included in the study, roadside interviews were carried out on four occasions.

Two different and unconventional methods of snow clearance and skid control were tested on the selected cycling paths in the pilot study. The front-mounted sweeper for snow clearance combined with a brine spreader for deicing (Figure 2) showed good results and therefore was used in the large-scale study the following winter. The snow sweeper was meant to reduce any remaining layer of ice and snow so that the salt dosage needed to achieve an acceptable standard could be minimized.

The large-scale winter study was carried out between October 1999 and March 2000. In this study, part of the network of cycleways in Linköping was used as a test area. In the test area, cycleways received a higher level of service than usual; the front-mounted sweeper and brine (for deicing) were used to achieve the higher standard. Snow was cleared and skid control applied more frequently than on other cycleways. Snow clearance was begun at a depth of 1 cm of loose snow, and deicing at every occasion of ice, snow, or hoarfrost. (In Linköping, snow clearance is usually started at a depth of 3 cm, using a traditional steel plow and abrasive for skid control.)

The large-scale study was evaluated in much the same way as the pilot study. Throughout the winter, observations of the road conditions on cycleways in the test area and on reference stretches were carried out whenever necessary, at least after every snowfall. Interviews and measurements of friction were conducted on a few occasions. The large-scale study will be evaluated through an extensive survey of users' opinions of the new methods. A total of 850 questionnaires have been sent out to inhabitants in the test area and to reference groups.

## Results

Because the pilot study was completed quickly, its results were limited. However, the maintenance method using a sweeper for snow clearance and brine for deicing gave such good results that it was considered interesting to study further. Friction measurements showed that the friction level on the cycling paths where this method had been used was considerably higher than on reference paths (Figure 6). At the time of measurement, the cycling path included in the test was wet and bare, whereas the reference path was covered with snow. It is not surprising that the snowy surface is more slippery than the bare ground. Nevertheless, it shows that the test method resulted in a surface less slippery than did the maintenance methods normally used.

The instructions for observing road surface conditions on cycleways proved to be adequate for the purpose. Only a few adjustments in the protocol for the inspections were needed (described under Evaluation Methods). However, visual inspections needed to be done more frequently than during the pilot study.

The roadside interviews conducted during the pilot study indicated that cyclists' opinions were more positive than expected toward the use of brine in eliminating ice on cycleways. Of the 122 persons interviewed on five different occasions, a majority (53 percent) thought it was acceptable to use brine on cycleways. Only 30 percent were against its use, and the remainder were unsure.

The large-scale study has not yet been fully evaluated. However, observations of road surface conditions showed that the ground in the test area was almost always bare and dry, moist, or wet throughout the winter, no matter what the conditions were on other cycleways in the municipality. These observations imply that the test method provides a better level of service than methods traditionally used in Linköping. However, winter was unusually mild during the test period, which means that the results may not apply to all kinds of winter conditions in this region. Also, in a few stretches in the test area, the pavement was in such bad condition that it was difficult to clear the snow completely.

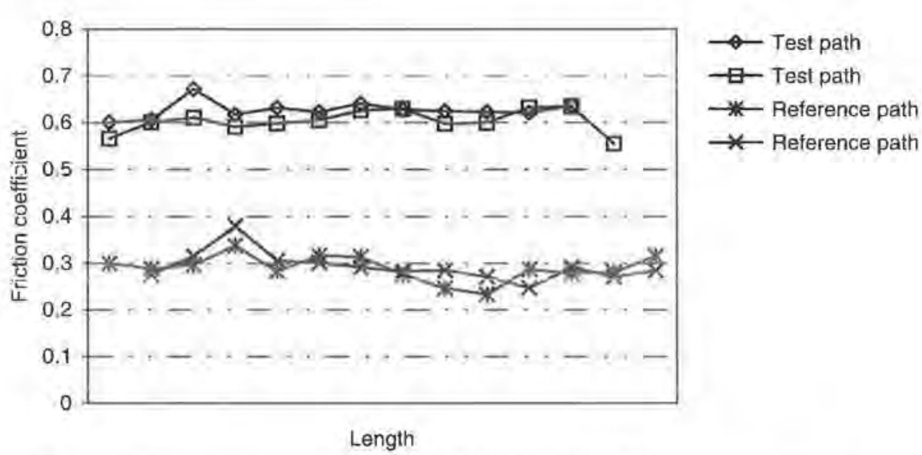


**FIGURE 6 Measurements of friction performed in the pilot study conducted in Linköping.**

## Conclusions and Additional Studies

Winter maintenance methods for cycleways are often adapted from those for roadways, and as such, they are not necessarily the best methods for cycleways. However, equipment and methods are available today that are better adapted to cycleways. Because the surface condition is very important for the safety and accessibility of cyclists, it is important that appropriate methods be widely used. It is also important to improve the methods available to better suit their purposes and also to become more cost-effective. A combination of different methods adjusted to weather and road conditions is likely to be the best solution.

The front-mounted sweeper for snow clearance combined with brine for deicing is probably a good method for regions with low snow accumulations and major ice problems. Linköping and many other municipalities in southern Sweden have winter conditions of this kind. Also, in regions with colder climates, such as in 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 probably are better suited.

The use of salt always should be as moderate as possible because of its adverse effects on the environment. However, its advantages and drawbacks have to be compared with alternate methods, such as the use of abrasives. On some occasions, salt can be more cost-effective despite its environmental effects. Additional studies comparing abrasives and salt with respect to environmental effects, traffic safety, and total cost are necessary to make the right decisions about the winter maintenance of cycleways and footways.

It is also important to consider the needs of the road users. If we want people to use their bicycles whenever possible, they must have safe and trafficable cycleways. Additional studies to clearly define a good road standard from a cyclist's point of view are needed. Such methods could include, for example, surveys or bicycle counts at several occasions under varied road conditions. When the parameters important to cyclists have been identified, methods for evaluating winter road standards on cycleways can be improved even more. When striving for good winter maintenance standards, the structural standards of the pavement should not be overlooked. Potholes and other irregularities that create an uneven surface can prevent adequate snow clearance.

The PFT seems to be a good instrument for measuring friction on cycleways, especially for comparing measurements. However, additional evaluation of the instrument is needed to be able to define the road conditions more specifically based on the PFT measurements. For example, a comparison study with the Saab Friction Tester would be valuable.

## Acknowledgments

This paper is part of the Ph.D. project "Effects on Cycling of Road Maintenance and Operation." The main purpose of the project is to evaluate the possibility of increasing the number of cyclists during winter by improving the operation service level on cycleways. The project started in August 1997 and is planned to result in a doctoral thesis in 2001. The project is being carried out in the Department of Infrastructure and Planning, Division of Highway Engineering, Royal Institute of Technology, Sweden. However, most of the practical work is being performed at the Swedish National Road and Transport Research Institute.

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