ENCOURAGEMENT OF BICYCLE TRAFFIC IN WINTER BY OPTIMISED WINTER SERVICE

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ABSTRACT

The provision of continuous, safe and comfortable bicycle facilities is one of the essential requirements for a broad acceptance of the bicycle as an everyday means of transport. In recent years and decades, numerous municipalities have begun a transformation of transport networks and have been able to achieve considerable changes in the modal split within manageable periods of time by focussing bicycle traffic. But cyclists are much more exposed to weather conditions than public transport passengers and car users, especially in winter time. Latest studies show clearly the increase of bike accidents under wintry conditions. The risk of falling for cyclists is substantially higher in icy conditions than in that of snowy surface conditions.

The objective of the research project, funded by the German Federal Ministry of Transport and Digital Infrastructure, is to make recommendations on how to promote bicycle traffic in winter, in particular through optimised winter service.

The recommendations of this study are based on differentiated cost-benefit analysis of different measures, which may include not only the conception and implementation of appropriate winter service treatments but also aspects of planning and design of bicycle facilities. The design of bike lanes should allow an efficient winter service. Furthermore, the project deals with the conditions of legal framework and the management of decision making, especially in case of different road owners (i.e. municipality, county, state).

Next to national enquiry, the research project includes international research with interviews and best practise studies in cities like Vienna or Copenhagen. The measures to be developed will be based on comprehensive surveys and studies on winter services and bicycle traffic in winter weather in 3 selected cities in Germany (Karlsruhe, Cologne, Munich). That means the studies include the view and needs of cyclists as well as the requirements from winter service side. An important question is the use of the best gritting material on bike paths and lanes (brine, pre-wetted salt, dry salt or other) to ensure traffic safety and to reduce environmental impacts. Several measurements on bike paths show the behaviour of different gritting materials according time and areal distribution.

The realisation of the recommendations and requirements of this project opens the possibility to encourage bicycle traffic as a whole year type of transport, an important step towards a climate friendly mobility.

1. WINTER SERVICE ON BICYCLE FACILITIES

A high number of municipalities in Germany has invested in the transport system and infrastructure to encourage the transformation of a sustainable traffic system. You can see already the results by shifting of the modal split. The part of cyclist is increasing rapidly in several cities with attractive bike facilities, for example in city of Karlsruhe the part of cyclist has been increased from 16% in 2002 over 25% in 2012 to over 30% nowadays.
However, cyclists are much more exposed to weather conditions than public transport passengers and car users, especially in wintertime. Latest studies show clearly the increase of bike accidents under wintry conditions. Safe and comfortable bicycle facilities is one of the essential requirements for a broad acceptance of the bicycle as an everyday means of transport
By increasing importance of the bicycle as a means of transport, it becomes more and more the focus of interest by public administration and on political level. Due to the increase in bicycle traffic, not only attention is being paid to winter road maintenance, but also to bicycle traffic infrastructure and their users. Cycling is becoming a part of everyday life in many cities, but it has become apparent that cycling is not promoted enough in winter due to various problems and influences. This research project is preparing recommendations and requirements for winter service treatments and for aspects of planning and design of bicycle facilities. Furthermore, the project deals with the conditions of legal framework and the management of decision making, especially in case of different road owners (i.e. municipality, county, state).

1.1. Gritting materials

There are two types of gritting materials that are used in winter maintenance on bike paths: abrasive materials or de-icing materials. In Germany in several municipalities, it is not allowed to spread de-icing materials on bike paths or walkways.
Abrasive materials mostly consist of natural materials such as sands, grits or foamed clay. With a snow layer, these materials can form a bond with the snow and ice, thus increasing the grip in winter conditions. But the disadvantages of this type of gritting is that they have little effect on icy and slippery conditions and must be removed frequently after thawing [1]. Cyclists are complaining the use of abrasive materials on bike paths because of the sharp edged materials, which can damage the tyre and the danger of slipping in curves or in case of harder breaking.

The use of de-icing materials like salt and brine prevent slippery conditions on bicycle paths and other traffic areas in winter conditions [2].
Chlorides such as sodium chloride (NaCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) are particularly suitable for this purpose. The most common form of application for winter service in Germany is sodium chloride because of mild climate conditions [3].
Salt can theoretically also be spread in dry form. However, it should be applied pre-wetted or in a completely liquid form (brine) to avoid loss during spreading, to ensure a good spreading pattern, and to optimize effectiveness. Actually the application of pure dry salt is recommended only in exceptional cases [3].

The designation of the spreading material is based on the mass ratio of dry salt to salt solution (FS 30 corresponds to 30 % salt solution, 70 % dry salt). Solutions of sodium chloride, calcium chloride or magnesium chloride can be used for moistening. On roadside pre-wetted salt should generally be spread in all weather conditions.
Compared to pre-wetted salt, pure salt solutions (brine, "FS 100") offer a more uniform distribution and longer lying time. Brine spreading is useful when roadway temperatures are not too low (down to approx. -6°C) and large amounts of precipitation and temperature drops

are not expected. Pre-Salting can prevent snow or ice from sticking to the surface during snowfall or freezing rain. Brine is spreaded by special nozzle constructions or spray bars. When spreading via a spreading disc, special attention must be paid to a uniform distribution. The question is, what kind of treatment should be recommend on bike facilities (brine, pre-wetted salt or dry salt), because the circumstances on bike paths are different compared to road conditions with car traffic and higher driven velocities.

1.2. Winter maintenance

Along with the choice and use of gritting materials, the implementation of winter maintenance on bicycle paths represents the second important component for bicycle-friendly use of bicycle facilities in winter and wintry conditions.
This winter maintenance consists of clearing the road surface and bike lanes in case of snowfall and spreading gritting materials, both preventively and immediately after clearing as an additional safety measure to avoid slippery conditions [4].

Due to different widths, changing surfaces, obstacles such as barriers and posts, problems often arise in the implementation of winter maintenance, especially on bike paths. For this reason, more and more so called narrow gauge vehicles are being used for winter maintenance on cycle paths. These are both smaller and more manoeuvrable and are therefore ideally suitable for smaller widths, narrow places and tight curves [5].

Figure 1 – Narrow conditions on bike path for winter service [picture source Cypra, 2021]

As a desired goal of proper winter road clearance on bicycle routes, snow removal, which mostly uncovers the trafficked area, has become established in Germany. The aim is to remove all snow and ice from the surface of cycling routes permanently. The decisive factor for this objective is the minimization of the risk of accidents for cyclists, but also an economically, politically and environmentally justifiable clearing of these cycling routes. Due to the increasing number of cyclists and the change in mobility in many cities and municipalities, cycle paths and especially everyday cycle routes are becoming more and more important. The year-round use of bicycles is highly dependent on optimized winter road maintenance on important bicycle routes. [6].

Depending on the height of snow, best results for snow removal is achieved by using a sweeping broom. Plows are required for significantly higher snow amounts and, in combination, can significantly improve the result of clearing a surface of snow and ice as the first clearing operation before clearing with a sweeping broom.

1.3. Winter service equipment

Narrow gauge vehicles are more and more used nowadays in winter service on cycle paths in many cities. The vehicles differ depending on the manufacturer, brand and model in the dimensions, weight, steering or drive technology.

All these small vehicles can be equipped with a front and a rear attachment. The front attachment can vary between a plow and a broom, for example, depending on the application and the amount of snow. The rear attachment is a spreader with appropriate spreading material and a distribution device such as a spreader disc, spray bar, etc.

Figure 2 - Narrow gauge vehicle with front sweeping broom and spreader for pre-wetted salt treatment [picture source Cypra, 2021]

The picture shows a narrow gauge vehicle in operation on a cycle path with a sweeper broom and a spreader for pre-wetted salt. The result of snow removal behind the winter maintenance vehicle is clearly visible. The objective of creating a cycling-friendly and generally cycling compatible surface on the cycle paths is fulfilled by the use of these narrow gauge vehicles.

In some cities and countries, alternatives to narrow gauge vehicles are also used for winter road maintenance on cycle paths. For example, some municipalities use small tractors with appropriate attachments or trailers for gritting materials. In Montreal, pickup trucks are also increasingly being used as winter maintenance vehicles for narrower stretches of road and cycle paths.

1.4. Winter bicycle network in major German cities

In many major German cities, there has been an increased focus on cycling and the expansion of cycling infrastructure in recent years. Climate protection, improved ecological balance and the promotion of personal health have led to a steady increase in the number of cyclists as a percentage of total traffic. This also affects the use of cycling routes in winter. Several large German cities are joining the trend and promoting cycling all year round. This is made possible by ensuring winter road maintenance on certain bike routes. The winter bicycle network is treated with a level of service like road network. One of the challenges is, how to communicate to cyclists, that a winter bicycle network exists and which parts of the cycling facilities belongs to the winter bicycle network. One of the best ways is a visualisation on a map [7], like in Karlsruhe published in internet.

Figure 3 - Winter bicycle network in city of Karlsruhe [9]

However, several cities and municipalities in Germany do not have a defined winter bicycle network or an appropriate communication is missing.

2. STUDIES ON WINTER ROAD MAINTENANCE IN SELECTED MUNICIPALITIES

2.1. Selected municipalities for studies

During the research project, three municipalities were examined as examples of the initial situation with regard to winter maintenance on cycle paths in major German cities. The selected municipalities are Karlsruhe, Munich and Cologne. In all three cities, studies were carried out on winter maintenance of cycle paths and the rideability of cycle paths on the main traffic routes in relation to everyday traffic in the city itself. These investigations took place on the one hand by means of own cycling on a sensor bike of the University of Applied Sciences Karlsruhe and on the other hand the winter service operations were filmed and documented with support of the operational staff.

Through the following evaluation of the determined data, problems, difficulties and also suggestions for optimisation measurements, different recommendations for municipalities and also for winter service outside of cities on bicycle facilities will be developed.

2.1.1 Karlsruhe

Karlsruhe has already a designated winter bicycle network, which covers a total length of about 220 km. The winter bicycle network has existed for about 10 years and is constantly being renewed and expanded with the assistance of the city planning department of

Karlsruhe, the ADFC (General German Bicycle Club) and the VCD (Traffic Club Germany). Figure 3 shows the winter bicycle network of the city of Karlsruhe. The routes marked in blue show the cycling routes treated in winter by winter service.
The designated winter cycle routes are mainly managed by the Waste Management Office of the City of Karlsruhe (AfA) and are supplemented by service providers in certain areas. The city itself has four narrow gauge vehicles in use for the maintenance of the bike routes. Normally, these are equipped with the sweeping brooms and a spreader (see Figure 4) in winter. Additionally there are 10 more winter service vehicles of the private winter service provider. For spreading treatment, pre-wetted salt or brine is used.

Figure 4 – Winter service vehicle for bicycle facilities [picture source Cypra, 2020]

2.1.2 Munich

In the city of Munich, the municipal building department of the city and service provider is responsible for winter services. This includes winter services on bike paths and especially winter services on the bike paths of the winter bicycle network. In Munich, the cycle path links are divided into two categories in winter. Bike routes of category 1 with a total length of about 150 km are cleared and maintained with priority in winter conditions. Munich relies on small tractors with gritting material containers for the maintenance of the cycle paths and plows are used as a front attachment. Unlike in Karlsruhe, Munich uses abrasive gritting material for treating the bicycle facilities.

2.1.3 Cologne

The Waste Management Company Köln GmbH (AWB) is responsible for winter services on bike paths in Cologne. Unlike in the other two cities, Cologne does not have a tendered winter bicycle network, but it does have a classification of all bicycle connections and bicycle routes in the entire city area. AWB divides the winter service into three temporal stages. The first stage contains approx. 100 km of cycle routes, the third planning stage approx. 260 km. The second stage does not include any cycle routes.

For the maintenance of the described cycle routes, the AWB relies on approx. 34 narrow gauge vehicles with a sweeping broom as front attachment. In the event of large amounts of snow, the vehicles are converted with plows.

2.2. Cycling in wintry conditions

Approximately five bicycle routes are selected for each municipality for cycling in wintry conditions. These cycling routes should be among the most frequently used everyday cycling routes and should be signposted.
Furthermore, the cycle routes should be selected in such a way that the form of guidance varies along the route and even the border marking, i.e. the responsibility for winter service, changes.
As much as possible, the EcoSensorBike of the Karlsruhe University of Applied Sciences was used for the bicycle tours. This is a bicycle developed at the Institute for Information Management and Media (IMM) with the option of installing various sensors.

Figure 5 - Sensor Bike of the university of Karlsruhe

A camera with high resolution and image stabilization was installed. The video recordings are used to divide the trips into sections to which certain trafficability classes are assigned. In this way, it will be possible to check at which points poor trafficability is particularly frequent, how trafficability changes depending on the time after any winter maintenance operations, how transitions between areas of responsibility affect trafficability, and whether certain characteristics (type of guidance, etc.) could have an influence. The trafficability is divided into 5 classes (see Table 1).

Table 1 - Classes of trafficability under wintry conditions on bicycle facilities

Class	Description
1	Trafficability without restrictions
2	Trafficability with minor restrictions (minor reduction in speed, reduced grip, increased concentration, but still safe to ride on; snow accumulation, but safe to ride on).
3	Trafficability with restrictions (significant reduction in speed, significantly reduced skid resistance, generally safe to ride on, but also with restrictions at certain points; significant snow deposits, e.g. on the bike lane or on a cycling path that has not been cleared for a long time)
4	Trafficability significantly limited (rather walking speed, bike slides in places; no winter maintenance, but closed, rideable snow cover)
5	Not trafficable (dismounting and pushing required; too slippery, e.g., snow-covered bridge ramp).

The procedure for the visualization of guidance forms as well as the width of the cycling infrastructure was carried out analogously based on the GPS data of a ride on this route. The recording and visualization of the navigability on the selected routes is carried out by the steps listed below:

- The ride
- The protocol
- The evaluation of the GPS data
- The evaluation of the videos and the entry in the Excel spreadsheet
- The import into QGIS
- Verification by the drivers

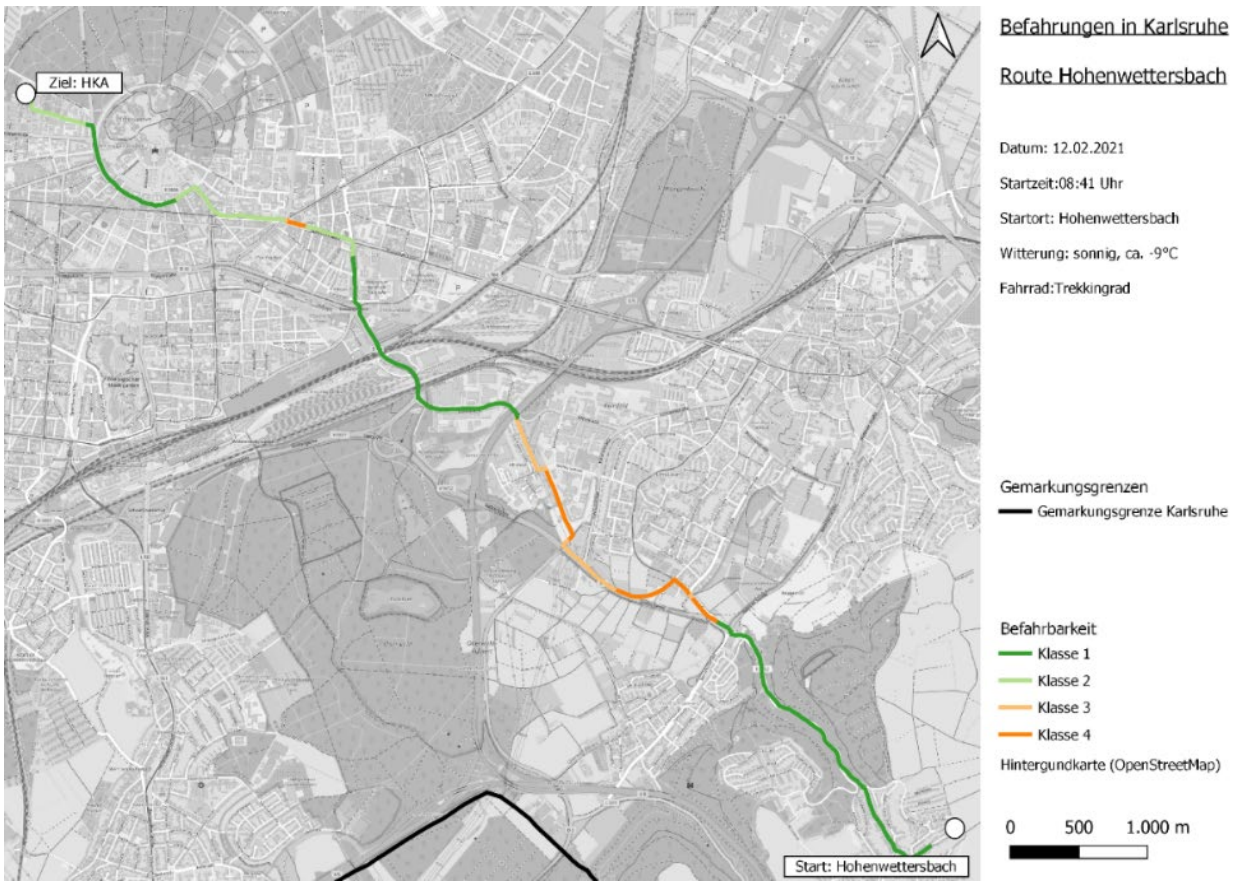

Figure 6 - Example of how to show the rideability of bike lane connections in winter weather

2.3. Analysis of performed winter service operations

For the documentation with subsequent evaluation and assessment of the current situation in winter road maintenance on cycle paths, the three previously selected municipalities were contacted and the winter service operations were filmed and documented with the help of cameras after consultation with the operational personnel. The cameras were fixed and aligned on the corresponding maintenance vehicles both to the front and to the rear. This allowed the entire operation to be filmed. The videos show the types of clearing and the corresponding clearing images as a result, the cleared routes with the corresponding clearing times and, above all, the problem areas in the execution of the winter service.

With the help of the GPS data of the cameras installed in the vehicles, the service trips could be reconstructed and so the problem areas, the forms of guidance, the speed and the clearing pattern could be assigned to specific sections of the route. The following picture shows an example of filmed winter service operation in the city.

Figure 7 - Example of winter service in operation to detect problems

Most of the problems, which have been evaluated during winter service operations are known problems in winter service both nationally and internationally. The most common causes are time lost due to barriers, posts or road signs. In some cases, there are also problems with the width of the roadway, which is artificially narrowed to protect it from other traffic. This often results in problems for winter road maintenance vehicles in passing through and in winter road maintenance in general. In many cities, the problem of snow deposits is also one of the main problems in winter road maintenance. Due to the lack of space in the cross-section of the roadway, bike lanes on the roadway or even bike lanes in the side space are often filled up or partially narrowed by the snow removal of the roadway. Simple solutions has to be found to minimize, if not completely eliminate, the problems in winter road maintenance on bicycle facilities.

3. MEASUREMENT OF THE SPREADING OF GRITTING MATERIALS ON CYCLE PATHS

3.1. Analysis of surface temperatures on cycling paths and the roadway

In order to optimize the application rate and the application method of gritting materials on cycle paths, the surface temperatures of cycle paths and adjacent carriageways are investigated with the help of a road weather station in Karlsruhe. This road weather station measures a variety of parameters such as air and pavement temperature, relative humidity, precipitation intensity, etc., which serve as a basis for the final assessment. The following questions are to be conclusively investigated:

1. How does the surface temperature of the bike path compare to the roadway?
2. When are there significant fluctuations here?
3. How significant are fluctuations in air temperature on the surface temperature?
4. Does the surface of the bike path remain wet longer after precipitation than the surface of the road?

3.2. Study methods for temporal and spatial distribution of gritting materials on cycle paths

Based on BASt (Federal Highway Research Institute) field tests with the flushing-suction device and the investigation of the temporal and spatial distribution of gritting materials on the road surface, a similar test will be carried out within the framework of the research project, related to the investigation of the temporal and spatial distribution of gritting materials on cycle paths. This trial is intended to provide new insights into factors influencing the distribution of gritting materials and the recommended gritting technique for cycle paths, taking into account boundary conditions. These include, among other things, the type of spreading by cycle traffic, the duration of the spreading and the residual salt content on the surface. In the course of the test, the grit distribution of dry salt, pre-wetted salt and brine applications on a test route is examined at defined time intervals with the flushing-suction device and subsequently evaluated.

The 'flush-suction device' is a specially developed device for measuring the lying time of de-icing agents on traffic roads [8].

Figure 8 - Flush-suction device

Each test section has three measuring fields for the test. These measuring sections are located in the center, on the left and on the right side of the cycle track in order to investigate the distribution on the entire cycle track. Between the measuring sections a 10 m safety distance is considered to avoid an influence between the test sections. It is important that the entire surface in the measurement area is cleaned before the start of the test.

4. EVALUATION OF THE POSSIBLE MEASURES BASED ON COST-BENEFIT ANALYSES

Due to the existing problems and difficulties in different areas, differentiated recommendations and requirements will be developed for an optimized winter service on bicycle routes in the future. These recommendations will be evaluated and finally assessed based on a cost-benefit analysis. Based on this analysis, cities and municipalities as well as states can decide which of the proposed recommendations and requirements should be implemented.
The realisation of the recommendations and requirements of this project opens the possibility to encourage bicycle traffic as a whole year type of transport, an important step towards a climate friendly mobility.

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