

Measuring the Surface Evenness of Cycle Paths

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In trying to promote cycling, the maintenance service level of cycleways is significant since it affects the safety, the accessibility and the riding comfort of cyclists. Condition assessment of cycle paths is important for determining the need for maintenance and for planning and prioritising treatments of improvement. Objective measuring methods are needed for effective assessment with better repeatability, and are essential in order for measurable performance requirements to be specified. In this study, a method for measuring the surface evenness of cycle paths has been tested and evaluated. The method is based on measurement of the cycle path's longitudinal profile with two laser sensors mounted in the rear of a small car. To associate the measurements of the longitudinal profile with cyclists' riding quality, cyclists were asked to assess their impression of the surface of cycle path sections of variable surface condition.

Introduction

VTI research is carried out on how to improve cycleway maintenance in order to promote cycling. The maintenance service level of cycleways is important for the safety, the accessibility and the riding comfort of cyclists. For example, in Sweden more than 70 % of bicycle accidents are single vehicle accident and about 40 % of those are maintenance related (Thulin & Niska, 2009).

Models describing the quality of service to cyclists mainly include factors related to motor traffic and hence are usually valid for cyclists in the shared-roadway environment and not on separate cycle paths (Schneider et al., 2005). Only a few models include pavement condition though studies confirm that it plays an important role in cyclists' assessment of the service level (Wigan & Cairney, 1985; Landis et al., 1997; Guthrie, Davies & Gardner, 2001). In addition, requirements and recommendations regarding maintenance of cycleways are based on experience and common knowledge rather than on the effects for cyclists, and it is usually the requirements for roadways as well as budget restraints, that set the limits.

Condition assessment of cycle paths is important for determining the need for maintenance and for planning and prioritising improvement measures. In spite of this, it is relatively rare today that maintenance surveys and condition measurements are carried out on cycle paths. Manual surveys do occur, but to a limited extent. For more reliable and effective condition assessment, objective measuring methods are needed. Objective measuring methods are also essential in order for measurable performance requirements to be specified regarding the cyclists' needs. Condition indicators and measuring methods then need to be related to cyclists' assessment regarding the road surface and not only to the technical life of the cycle path pavement. For the riding comfort of cyclists, the surface evenness of the cycle paths is probably the parameter that has the greatest importance.

Method

With the objective to provide information for road management authorities as to what characterises an attractive cycleway from the standpoint of infrastructure maintenance, several studies have been performed at VTI over the last 15 years. In the study that the presentation

will focus on, a method for measuring the surface evenness of cycle paths was tested and evaluated. The method is based on measurement of the cycle path's longitudinal profile with two laser sensors mounted in the rear of a small car that is also equipped with a GPS and a camera (Figure 1). The camera automatically takes pictures of the cycle path surface and its environment every ten meters during measurement. There was also a control board in the vehicle with a set of buttons that the driver could push to manually record surface defects or other features that could affect the measurement.



Figure 1. The small car equipped to measure the longitudinal profile of cycle paths

Several measurements were made on sections of variable quality on cycle paths in the town of Malmö. A commission from the municipality of Lidingö to perform a condition assessment of the entire pedestrian and cycle path network of the municipality made it possible to carry out further tests on the equipment. Complementing measurements with another system were also made in order to have an idea of the variation in pavement evenness of cycle paths in the transverse direction. These measurements showed that quite a good description of longitudinal evenness along cycle paths is obtained even if measurements are made with only two lasers.

In order for the measurements of the longitudinal profile to be associated with the riding quality perceived by cyclists, a test was carried out in which three groups of cyclists, a total of 21 individuals, were asked to cycle along a loop and to assess their impression of the surface of eight test sections of variable surface condition. The loop was in total 2.3 km long and each test section (marked from A to H) was 50 meters. The test sections were chosen pairwise in order to represent fairly equal surface conditions within a pair and noticeable different conditions between pairs. Sections A and B were representing a smooth and even surface, C and D surfaces with minor defects such as coarser texture and unevenness due to patching. Sections E and F had several visible defects such as alligator cracking and G and H had many unevenness's and cracks due to roots from adjacent trees. Each person was to assess each section individually on a six grade scale from "very comfortable" to "very uncomfortable". They were also asked to compare each section with the one previously passed.

In order to obtain a clearer description of the significance of the magnitude of a single unevenness for the cyclists' perceived riding quality, yet another test was performed – inspired

by a similar Australian study (Cairney & King, 2003). A number of cyclists were asked to cycle over some bars of metal of varying thickness and to assess their impressions on riding over these.

Results and analysis

The riding quality perceived by cyclists

It was found that it was difficult for the cyclists to ignore the surroundings and to assess only the surface itself, and that there was a large individual difference in the assessments done by different cyclists. It is therefore difficult to draw conclusions on what the "average" cyclist thinks, but it was nonetheless possible to make a distinction between assessments of the different sections (Figure 2).

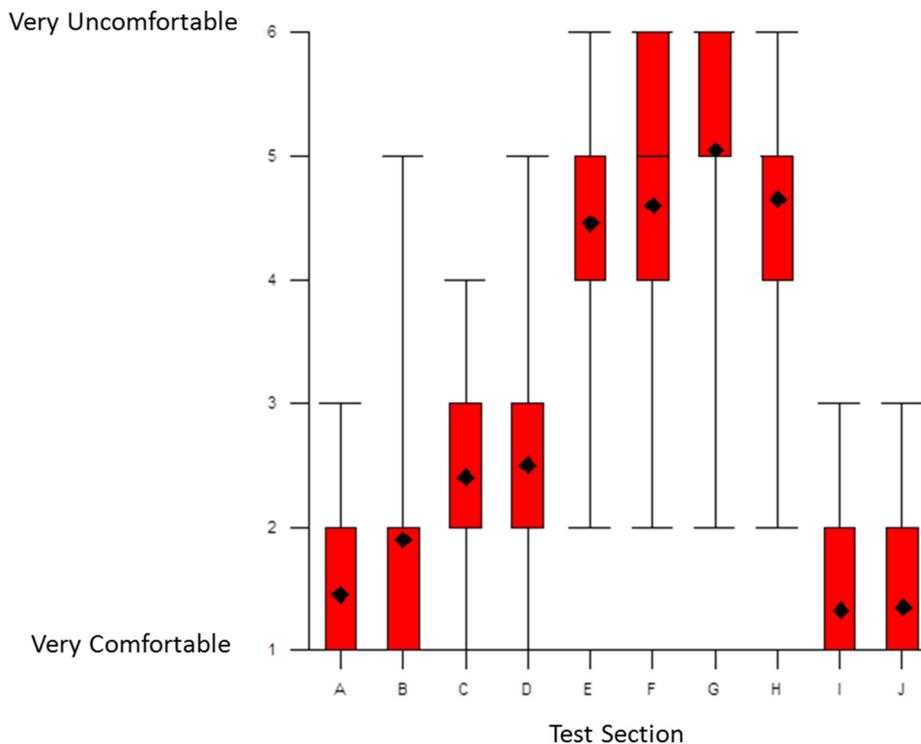


Figure 2. The cyclists' average assessment of the test sections in Malmö. Sections A and B were assessed a second time at the end of the loop, denoted "I" and "J" in the figure. The boxes are showing 25- and 75-percentiles of assessment values, mean values are marked with black dots and whiskers are showing minimum and maximum values.

The average assessment made by the cyclists corresponded well with the visual classification made prior to the test, when choosing test sections, with A and B being smooth and even and E to H having many deficiencies. In addition, the cyclists' relative assessment corresponded well with their absolute assessment.

Classifying the surface evenness measured

In order to describe surface evenness, a model was chosen in which a straight edge is drawn along the measured longitudinal profile of the cycle path and records the maximum difference in height. Analyses of straight edges of different lengths showed that 0.5 meter was the length that yielded the best correlation between measured value and the absolute assessment of the cyclists.

In order to set limits for classifying sections based on straight edge analysis of measured profile, the test where cyclists were asked to cycle over some bars of metal was used. That test showed that there appears to be a limit at the height of about 10 mm (amplitude) for an unevenness to be perceived as unpleasant. A metal bar of 5 mm thickness was not perceived at all when passing it with a bicycle, metal bars of 8 mm and 10 mm were perceived but not considered unpleasant to pass while a metal bar of 12 mm thickness was clearly unpleasant to pass, according to cyclists participating in the test.

Because it is not only occasional major bump that create a problem to cyclists, but also small bumps occurring frequently, it was decided that the classification should be based on both maximum and average values. Further, it was suggested that sections should be classified in three classes, "red", "yellow" or "green", where red implies that the section is functionally unacceptable. Based on the surface evenness measurements and cyclists' assessment, the classes were defined as follows:

- For the red class, 30 per cent or more of the maximum values measured with the straight edge should exceed 10 mm, or the average value over the section should be more than 8 mm.
- For the yellow class, between 10 and 30 per cent of the readings should exceed 10 mm or the average value should be more than 5 mm.
- Other sections are to be classified as green.

According to this classification, test sections A to D were classified as being "green", E to G as being "yellow" and H as being "red".

Practical experience

Narrow surfaces, a lot of loose material, poor sight in bends and near undergrowth, as well as more hold-ups in measurement than in measurements on motor roads, are some of the practical problems that were identified during the measurements.

Discussion and conclusion

Because of the limitations in the measuring method used, with a 0.5 meter straight edge unevenness with wavelengths varying from approximately 20 to 50 cm was measured. It is probable that unevenness of smaller wavelength also has great significance for the cyclists' riding quality, which implies that macro and mega textures should also be measured.

Measurements can in this way provide the basis for prioritising maintenance measures, but for complete information they should be complemented with visual inspections, preferably made from a bicycle. Since several factors, apart from vibrations in the cycle, have significance for the total impression of a cyclist, factors other than those which can be related to the road surface should also be considered. The measurement results should therefore be accompanied by photographs taken simultaneously with the measurement, preferably at 10 m intervals. The photographs should show intrusion by trees and undergrowth, damaged signs, and preferably parts of the surface. In selecting sections to be repaired, one must also consider production conditions and cyclists' safety, prioritise sections that are important links and have high cycle flows, and consider the kind of damage and possible budgetary restrictions, etc.

Based on the conclusions from this study, the Swedish Association of Local Authorities and Regions has formulated guiding principles for procurement of cycle path measurements.

Instead of measuring the longitudinal profile the acceleration response can be measured, which have been done in earlier studies (e.g. Vej & Park, Driftskontoret i Köpenhamn, 2004 and Nilimaa, 2009). Measuring the longitudinal profile is however easier and the results are not affected by the travelling speed, etc.

Smart systems and routines to collect cyclists own observations of deficiencies, is a cost effective way to identify the need for maintenance measures. At VTI application software to be used in a smartphone has been developed and tested during a condition assessment of a municipal pedestrian and cycle path network. Through the 3D acceleration recorded in the phone, the cyclability-app is logging the surface unevenness of the cycle path while cycling.

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Further readings

The evaluation study of a method for measuring the surface evenness of cycle paths was included in the research project "Service levels of cycleways". Several different studies have been conducted within that project including literature reviews, interviews with employees in Swedish municipalities, focus group studies with cyclists. They are all documented in separate reports - VTI report 558, 585, and 699, 726. The reports are all in Swedish (with an English summary) and can be found on VTI website: www.vti.se/publikationer

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