Belgian pre-normative research project SuChar-BiLan on surface monitoring of bicycle lanes

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Abstract. Recently the need for more and better cycling infrastructure is soaring. The diversity of the means of transport other than ordinary bikes is increasing rapidly. Consequently, the users' expectations change. In their endeavor to deliver, road authorities managing cycle paths will benefit from new condition assessment and efficient asset management. In the two-year project "Surface Characteristics of Bicycle Lanes" (SuChar-BiLan), started on 1 November 2022, the Belgian Road Research Centre (BRRC) collects knowledge, information and practical experiences about measurement techniques and management allowing the assessment of the condition of bicycle infrastructure: evenness, skid resistance, texture and rolling resistance. The aim of the project is to help with developing European standards and with expanding the use of such techniques – to a better quality of the cycling experience. This contribution presents results of a literature review, mentions the development of surveys addressed to different stakeholders (users, road authorities, technology providers), describes how technology and service providers, and research organisations will be invited to demonstrate their solutions on bicycle lanes in Belgium, hints on future design by BRRC of laboratory test methods for skid and rolling resistance, and explains the importance of the expected outcomes and of the aimed development of European standards.

1 Introduction

A shift from car to bike kilometres has numerous advantages: it contributes to the urgent decarbonisation of road traffic, reduces our dependency on fossil fuels, cuts down on air and noise pollution, increases road safety - the chances of a cyclist killing or injuring another road user in an accident are negligible compared to a car driver - and last but not least, it contributes to a fitter and healthier population through exercise. The latter not only increases general well-being, but also has a positive economic impact through lower sickness expenditure and less absence through illness.

To get people to cycle more, a number of conditions must be met, and one of the most important of these is the availability of safe and comfortable cycle tracks. The surface characteristics of a cycle track (in addition to other characteristics such as lighting, adequate signing, safe crossings with cars, etc.) play an important role: good skid resistance, so cyclists can brake and turn without falling, is indispensable. Sufficient evenness is important for the

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comfort of the cyclist. Rolling resistance - the force a cyclist has to overcome to keep moving at the same speed - has been an underexposed aspect of cycle tracks up to now, but it is also important for the comfort of the cyclist and the range for the rider of an electric bicycle.

But there is more: a diversification of the users of cycle tracks has been noticeable in recent years. Electric bicycles are emerging, but so are other vehicles: users of electric scooters and monowheels invariably use the cycle track, especially outside built-up areas. The bicycles themselves are also more diverse: fast speed pedelecs are very popular for commuting; young parents transport their offspring on tricycles and carrier cycles, with or without electrical assistance. There are also more and more four-wheeled bicycles on the market intended for the elderly and the disabled.

The use of folding bicycles, whether electric or not, and folding e-scooters has an additional interesting potential: the promotion of intermodality. In our spatially fragmented country, not everyone lives within walking distance of a railway station or even a tram or bus stop. In such cases, the folding bicycles or e-scooters or the monowheel are useful for covering the last kilometres home quickly and comfortably.

It is therefore high time to prepare our cycle tracks for this new mobility and, in particular, to improve their surface characteristics.

Standards for measurement methods for surface characteristics exist and are drafted and regularly revised within the European group CEN/TC227/WG5, in which BRRC is also represented and plays an active role. Standards for measuring the surface characteristics of cycle tracks do not yet exist, and the methods for road surfaces for cars can sometimes be used, but certainly not always. In addition to adapted measurement methods for cycle tracks, there is also a need for the corresponding threshold values to be included in the standard tender specifications. It appears that no other CEN or ISO working group is competent for the development of measurement methods for the surface characteristics of cycle tracks and that the CEN/TC227/WG5 can be made competent by a simple decision of TC227. The time is therefore ripe for an initiative to start standardising the surface characteristics of cycle tracks, and that is what this project aims to do.

2 Project overview

The various parameters that are important for the safety, comfort and energy consumption of cyclists and other means of transport that use the cycle tracks are examined: the longitudinal and transverse evenness, the macro- and megatexture, the skid resistance and the rolling resistance. For each parameter it is determined what the state-of-the-art of the existing measurement methods is and which adaptations must and can be made to obtain an adapted version for cycle tracks (Task 1).

In this project, great importance is attached to the input of the stakeholders: the users of cycle tracks, the managers and the technology providers, and for that purpose three user groups were formed, with national and international representatives. Two times per year these user groups are informed and consulted to receive valuable feedback.

The flowchart of the project is shown in Fig. 1.

An important part of the project is the empirical research, which will consist of selecting a sample of sections of cycle tracks with different surface qualities, sampling these sections with the existing or newly determined methods and evaluating the different sections by a test panel that will drive over the sections with different vehicles and assign user scores. These scores are compared with the results of the measurements of the various parameters, from which threshold values will be derived (Task 2).

Although the various parameters will be studied separately, it is also planned to combine the results to come to a holistic recommendation on the standardisation of the surface characteristics of cycle paths (Task 3).

Finally, a great deal of importance is attached to dissemination and communication, especially consultation with the Belgian and European standardisation bodies (Task 4). As mentioned, there is BRRC representation in the relevant CEN/TC227/WG5 working group and there will be communicated about the project to this group from the start. Comments and recommendations from the CEN working group will be taken to heart by the consortium.

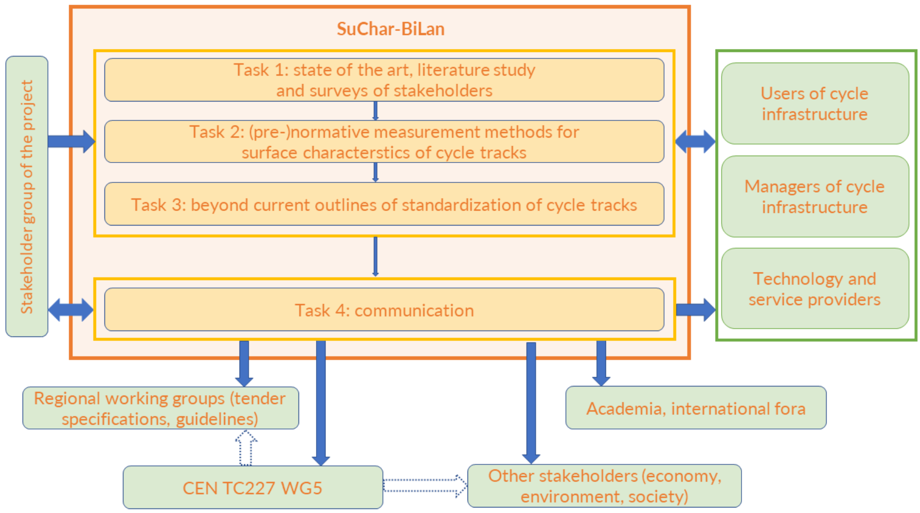

Fig. 1. Flowchart.

3 Literature study

3.1 Methods and devices for measuring surface characteristics of bicycle paths

By studying international literature a list of possible methods and devices for measuring surface characteristics of bicycle tracks (in use or under development) was made. Researchers in the field from Europe and beyond and Belgian road authorities who manage cycle paths were asked to review the list.

A basic method to measure macrotexture is the sand patch method [1] or the closely related volumetric patch test [2], yielding the “Mean Texture Depth” of a surface. The method is practical and does not require a sophisticated measurement device. More sophisticated (accurate and fast) methods for the measurement of the macro-and megatexture are according to an ISO standard series ISO 13473, Parts 1 – 6 [3], most measurement devices are based on the triangulation method, but other methods exist, such as the stereoscopic method. Measurement of the macro- and megatexture can be done along a straight or a curved line (2D) or can be 3D. For more information, the reader is referred to [4]. A variety of devices for measuring macro-and megatexture in 3D at walking speed are on the market, such as the Australian Walking profiler G3 [5], the American SSI/Smart Car system [6] and Robotex 3D [7], the Austrian 3D road texture scanner [8], the Portuguese 3D TexScan [9] and the Chinese PS portable measurement system for pavement surface macrotexture [10].

The British Pendulum Test (Skid Resistance Tester, SRT) [11] is worldwide one of the most widely used methods to assess wet skid resistance at low speed, but it is not the only method. A variety of methods exist, and a lot of them are listed and described in [12]. Measurement principles are one of the following three types: the pendulum type (loss of energy of the arm of a pendulum sliding over a given distance over the surface), measurement of the sliding force of a rubber patch on the surface or the measurement of the force needed to drag a braked rubber wheel over the surface. Examples of devices suitable for measuring the slip risk of a bicycle lane are: the Portable Friction Tester [13], the T2GO [14], GripTester MK2 and Microgriptester [15]. A special method actually designed for the slip risk of pedestrians is the "slope method" [16], which will in this project be used to assess the slip risk for cyclists (see further). Brake tests and turning tests with bicycles were found in several studies, more particular to test the influence of winter/icy conditions ([17], [18]).

Although there is no harmonized method yet to measure bicycle rolling resistance and no companies were found that offer rolling resistance measurements on cycle tracks, a lot of studies were conducted about rolling resistance testing. In several projects a bicycle was equipped with sensors to measure e.g. pedalling power versus speed, the power of the electric motor, road slope, pedalling cadence, GPS data, weather conditions, accelerations, … ([19], [20], [21], [6]). In a German project a four wheeled electrical bicycle (QuadRad) was used for this purpose [22]. An example of a simple method is the virtual elevation method or chung method, where a calculation is done based on measured power and speed [23]. Other research is based on coast-down testing indoor ([24], [25], [17]) and outdoor ([26], [27], [28]). Dynamometric methods make use of a bicycle that is towed on a flat ground at constant speed using a cable connected to a dynamometer ([29], [30]).

Several laboratory equipment are in use to determine bicycle rolling resistance. An example is a device where two bicycle wheels are clamped to each end of a weighted shaft with an eccentric mass placed at the centre. Rolling resistance is determined by releasing the wheelset from a static known starting position [22]. Also the drum method is used for this purpose, similar to the one in use for car tires [31].

A possibility could be to use a trailer method, as already in use for measuring rolling resistance of cars ([32], [33]). BRRC had developed such a trailer for conventional roads and will think of a new concept for bicycles in the frame of this project.

A lot of measurement devices were found to measure unevenness or roughness. Several devices were designed and implemented where a bicycle or other vehicle is equipped with an accelerometer measuring the response generated by the unevenness of the bicycle lane ([34], [35]). In Belgium, the Fietsersbond – a representative body of cyclists – started using an early version of their "comfort bike" in 2007. Today the comfort bike is equipped with an accelerometer on a third wheel towed by a bicycle and with a tablet for the registration of information on the infrastructure, and the Belgian Fietsersbond performs systematic measurements with it, commissioned by bicycle lane managers [36].

Several devices make use of laser profilometers to determine unevenness. In Belgium a laser profiler, installed in a trailer that is towed by a motorcycle, is used to measure evenness coefficients. The Flemish NRA and BRRC own such a "bicycle path profiler" ([36], [37]). In some cases lasers are mounted on a bicycle [38]. In other cases lasers are mounted on a small car or vehicle ([38], [6], [39]). Also walking profilers are in use ([34], [40]).

For transversal evenness developments are ongoing, mainly based on LiDAR systems.

3.2 Management systems for bicycle paths

A literature search was performed with the aim to obtain an overview of condition data collection effectively in use for the purpose of maintenance management of the existing bicycle lane network. A management system for bike paths in operation in Bogota is described in [41]. A system was developed for the network of a university campus ([42]). In Germany, the city of Nordhorn [43] and federal state Brandenburg [44] let their networks inspect with the aim of obtaining a list of priorities and an indication of the most appropriate maintenance measures. In a PhD thesis in Canada [45] an approach was designed and showcased, concentrating on on-street bicycle lanes and roads shared by cars and bicycles and extending the pavement management system to bicycle lanes and bicycle travel demand.

Other literature concentrates only on parts that are typically needed in a complete maintenance management system. Some propose the use of crowd sensing for maintenance management ([46], [47]). Some propose artificial intelligence for image processing with the objective of creating an inventory [48] or even a condition assessment [49] of bike paths. Some report on studies to determine indicators and thresholds ([50], [51]) for discriminating different condition levels of bicycle lanes. There is also some guidance for the choice of appropriate maintenance measures ([52], [53]).

In Belgium, the Flemish NRA uses a laser profiler for the determination of a condition index [54], resulting in a report on the current condition of their network every two years. Two provinces commission measurements with measuring devices using an accelerometer, combined with a visual audit or inspection. These are presented on a map, together with information about accidents.

4 Surveys

Three surveys were drafted. One was addressed to users in Belgium covering the full diversity of the means of transport currently used on cycling infrastructure. The survey probes for their potentially different expectations with respect to the surface characteristics of cycle lanes when driving city bikes, eBikes, scooters, steps, etc. 1189 users responded to this survey. Respondents are mainly driving following vehicles, in order of answers received: regular (city) bike, racing bike, mountainbike and folding bike. 50 to 70 respondents use cargo bike, longtailbike, bike with bicycle trailer or speed pedelec (bikes with electrical support up to a speed of 45 km/h). About 40 respondents are step users. Highest expectations are given to safety, comfort and evenness.

A second survey was sent to Belgian road authorities who manage cycle paths, asking about their inventory of the cycle assets, their priorities, their knowledge of accident data, and their management approach. 17 responses were received. Most attention is paid to safety, comfort and continuity.

A third survey was launched to technology and service providers in Europe. They were asked about their offerings and if they have examples of current practice. This includes the practical application of measurements with existing devices, existing quality procedures, and accompanying data processing procedures. Ten companies responded to the survey. A remarkable result is that 6 out of 10 is experiencing obstacles to bring the measurement equipment or services to the market. The lack of normative references, no specific reporting standards and different (accuracy) requirements in various countries are some of the obstacles mentioned.

The results are being analysed more in detail and are planned to be discussed further in another future publication.

5 Experiments

5.1 In situ

A field test is foreseen, aiming to link objective results of a variety of instruments measuring macro- and megatexture, evenness, “comfort index” and rolling resistance with the subjective assessment by a representative panel of cycle path users. This experiment does not include skid resistance, which cannot be assessed in this way and is studied in a laboratory experiment (see next paragraph). To this extent a selection was made of 23 sections of bicycle paths with varying surface characteristics, made of various materials and in various state of wear.

Fig. 2. Examples of sections to be used for the panel tests: a burlapped cement concrete bicycle path (upper left), a road with cobble stones often used by cyclists (upper right), a bicycle lane with a dense asphalt concrete (worn, lower left) and a bicycle lane in 20 cm x 20 cm cement concrete setts in fairly new state (lower right)

The 23 sections are chosen to be practically arranged in two closed loops, the first one in Overijse with a length of 10 km and 14 sections to be assessed and the second one in Herent with a length of 5 km and 9 sections. The idea is that the sections are assessed by 30 to 50 volunteers with a variety of vehicles. Volunteers are encouraged to do the assessment with more than one vehicle. Accurate descriptions of the sections/loops are made available to the participants. The participants will ride one or both loops and immediately after each section they are requested to stop and fill in a score on an evaluation form. A score is asked for three criteria: comfort, evenness and rolling resistance. The last parameter might be more tricky for vehicles which are electrically powered. The assessment involves assigning a score from 0 (very bad for this criterion) to 10 (excellent for this respect). Per participant the data will be normalized before the average scores per section are being calculated.

In the same period, measurements will be carried out on the same sections with a selection of devices measuring one or more of the following parameters:

- Surface texture (macro- and megatexture)
- Evenness ($EC_{0.5\,m}$, $EC_{2.5m}$…)
- Rolling resistance
- Comfort Index

As some of the participating devices need a minimum free width of 1,5 m and the majority of the selected sessions in the loops are narrower, some additional sections are selected on which these broader instruments will be deployed as well as the other participating measurement devices, in order to allow a comparison. Panel tests will not be done on those extra sections.

At the moment of the drafting of this paper the tests are still to be carried out (foreseen in May-June 2023), so no results are available yet.

5.2 In laboratory

As aforesaid, skid resistance is difficult to assess with a panel test for practical and ethical reasons, therefore a laboratory test has been designed. Skid resistance is a crucial parameter determining the safety and several methods are being used to assess it, among other the British pendulum test (SRT) equipped with rubber patch "57". Only in certain cases a threshold value for cycle paths is foreseen in the Belgian standard specifications, namely when the cycle path is coloured by means of a road marking product. It is worthwhile to find out if the used methods to measure skid resistance are representative and if yes what would be an appropriate threshold value. For this purpose, a laboratory experiment is designed to assess the skid resistance of a surface, inspired on the "slope test" for pedestrians, as described in CEN/TS 16165:2016. In this test, a secured test person is standing on a surface which is horizontal at the beginning of the test. The slope is gradually increased until the test person loses grip and slips. A similar test will be carried out in this project. A secured test bicycle provided with a load that simulates a 80 kg rider is put on a wetted test surface which can be tilted around an axis in a controlled way with a electromechanical system. The bicycle is a standard model with standard sized wheels provided with a common type of tyres under standard pressure. The test is carried out at 20°C. First, the bicycle is placed in the middle of the surface, parallel to the rotation axis. The electromechanical system then increases gradually the slope of the surface until the bike slips sideways. Then the measurement is stopped and the angle of the slope is noted, from which directly the maximum sideways slip resistance force can be calculated for the given tyres and surface. The experiment will be repeated with the bicycle perpendicular to the rotation axis and the wheels fully braked, yielding the maximum forward slip resistance force. SRT measurements will be done on the surface. The experiment will be repeated with several surface types (slippery to a high slip resistance) and several bicycle tyres. It will allow to assess the representativity of the SRT pendulum to assess the slip resistance of bicycle lanes and enable us to suggest a safe threshold.

6 Conclusions – Expected outcome and aimed development

Surveys will be analysed further in detail. Requirements of various bicycle infrastructure users (step, cargo bike, bike trailer, …) will be investigated. Expectations of users will be compared to actual priorities of road managers and measurement equipment and services available on the market.

A key requirement for a parameter used to assess the surface of a bicycle lane is its representativity. The panel tests carried out by a sample with a sufficient size of bicycle lane users on a representative sample of bicycle surfaces will yield a robust base for the representativity of the different test methods for evenness, comfort, rolling resistance and texture. As it would be difficult if not unethical to test slipperiness, a laboratory method is designed to assess the SRT pendulum as a test method for the risk on slipping/falling of cyclists on a given bicycle lane surface.

Furthermore, BRRC plans to design a concept of a test method for measuring rolling resistance and to realize some first trials.

Data collected and the experience gained by performing field tests will form a basis for comparisons and evaluations of the quality of the data and the techniques, for advice on their potential scope of use, and for recommendations for European standards. All this will contribute to the suggesting of indicators and thresholds useful for the asset management of cycle paths.

Input will be given to the European group CEN/TC227/WG5. More publications about results will follow.

The aim of the project is to help with developing European standards and with expanding the use of such techniques – to a better quality of the cycling experience.

Acknowledgments

The work presented in this paper results from the Belgian pre-normative research project "Surface Characteristics of Bicycle Lanes" (SuChar-BiLan, ref. CCN/NBN/PN22A54), partially financed by the Belgian national standards body (NBN) and the Belgian Federal Public Service (FPS) for Economy. The authors are thankful to all volunteers willing to fill in the surveys. Members of the stakeholder groups are acknowledged for their valuable input.

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