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Safe Cycling Network

Developing a system for assessing the safety of cycling infrastructure

R-2014-14E

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The Hague, 2014
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Report documentation

Number:	R-2014-14E
Title:	Safe Cycling Network
Subtitle:	Developing a system for assessing the safety of cycling infrastructure
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Project leader:	G.J. Wijlhuizen
Project number SWOV:	C09.15
Projectcode Contractor:	ALB/FT/svk/2014-034
Contractor:	Royal Dutch Touring Club ANWB
Keywords:	Cycling, cyclist, cycle track, road network, layout, network (transp), safety, evaluation (assessment), indicator, accident prevention, measurement, benchmarking, Netherland.
Contents of the project:	ANWB has taken the initiative to develop an expert system that helps road authorities assess the cycling infrastructure and, consequently, bicycle safety. This enables unsafe cycling infrastructure to be analysed and tackled. This report presents the scientific justification of the project.
Number of pages:	86 + 46
Published by:	SWOV, The Hague, 2014

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Summary

ANWB has initiated a project to improve the safety of the cycling infrastructure in the Netherlands – and, in the longer term, also in other countries: the *Safe Cycling Network* project. This project was inspired in part by the international European Road Assessment Programme (EuroRAP/iRAP). The objective is to develop a system of expertise, an expert system, to help road authorities assess the cycling infrastructure (and therefore bicycle safety). To this end it is especially important to proactively take a survey of unsafe cycling infrastructure and take measures. ANWB asked SWOV to provide the scientific justification of the project, which is embodied in this report.

Working method

The system came about as a result of a number of phases, the first of which comprised a desk study and consultation with bicycle safety experts (road authorities). This focused principally on the importance of risk-enhancing factors for cyclists. Based on this a set of indicators for lack of safety in the cycling infrastructure was selected. It was then determined how road authorities can use these indicators to assess the cycling infrastructure in practice. Pilot projects were launched in two municipalities (Harderwijk and Goes) to gain practical experience of the system. Additionally, a perception survey was carried out in which cyclists assessed the safety of bicycle facilities. These new practical insights improved the practicability of the expert system.

Result

The result of the project is a system that is described in *Appendix A.* To be able to apply the expert system, a working method involving two instruments was chosen. Firstly, a checklist (interface) was developed with indicators that impact on the safety of the cycling infrastructure. Secondly, a procedure was developed that allows road authorities to assess the cycling infrastructure on the basis of the interface and 360-degree panoramic images of the cycling infrastructure (supplied by CycloMedia).

Conclusions

In practice, the system proved useful for the systematic gathering of data on the safety of the cycling infrastructure and comparing this data. The system is also suitable for identifying locations that (based on indicators) are assessed as unsafe.

Furthermore, the expert system needs to be expanded or data need to be entered for the following topics:

- Insight into the relationship between a location that is assessed as unsafe and the risk of a cycling crash (validity of the system). In particular, there is a lack of essential data on:

- the volume of bicycle traffic (exposure);
- the location, facts and consequences of cycling crashes;
- weighting factors of indicators with which a final score can be determined for the safety of the cycling infrastructure;
- the degree of validity of the expert system: is there a correlation between the final score of locations and the risk of cycling crashes at those locations when making safety predictions (cycling crashes);
- formula in which the indicators and weighting factors are incorporated in a single final score for each road section (the output of the system).

- Knowledge about the extent to which different people encode the indicators of cycling infrastructure in the same manner (reliability).

- Applying the system outside the Netherlands to ensure that it is also valid for the local cycling infrastructure in other countries.

Recommendations

The following recommendations are made on the basis of the conclusions:

1. *Seek alliance with the EuroRAP method*
   This offers the following possibilities:

   - Interchange of knowledge for the purpose of further developing the system;
   - Application of the expert system outside the Netherlands and adapting it to the prevailing situation there;
   - Management of the system so that it is possible to compare research results (inside and outside the Netherlands).

2. *Decide the validity (relationship between the safety score and the* risk *of a cycling crash) of the system.*
   To determine the validity we recommend:

   - ensuring that regional and local government make more data available on dynamic factors, in particular the volume (exposure) of bicycle traffic;
   - ensuring that cycling crashes are properly registered (location, facts, consequences). for example, ANWB can encourage research into the application of mobile technology and services that allow cyclists to register crashes with a hotline;
   - testing the safety score empirically (determine the correlation between the safety score and the risk of a cycling crash).

3. *Establish whether the indicators have been coded reliably by finding out whether they are consistent if they have been set by different people.*

4. *Ensure that road authorities are involved in further developing the safety score of the system by carrying out pilots in practice, such as the pilots in Fryslân.*

Contents

Abbreviations

ANWB	Royal Dutch Touring Club ANWB
CBS	Statistics Netherlands (Centraal Bureau voor de Statistiek)
DHD	Dutch Hospital Data
EuroRAP	European Road Assessment Programme
FIA Foundation	Fédération Internationale de l'Automobile
IenM	Ministry of Infrastructure and Environment (Ministerie van Infrastructuur en Milieu)
iRAP	International Road Assessment Programme
LIS	Injury Information System (Letsel Informatie Systeem)
LMR	National Medical Register (Landelijke Medische Registratie)
OViN	Traffic Survey of the Netherlands (Onderzoek Verplaatsingen in Nederland)
SWOV	SWOV, Institute for Road Safety Research
VenW	Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat)

Foreword

The United Nations designated the period 2011-2020 as the Decade of Action for Road Safety. Based on its involvement in this programme, ANWB initiated the development of a project to improve road safety for cyclists: the *Safe Cycling Network*. The aim of this project is to develop an expert system to help road authorities assess the safety, or lack of it, of cycling infrastructure. To this end it is especially important to proactively take a survey of unsafe cycling infrastructure and take measures.

In other countries too, the bicycle is becoming an ever more popular mode of transport. Consequently, ANWB wants the cycling infrastructure in neighbouring countries to improve as well. The Netherlands is still regarded throughout the world as a 'benchmark country' in this respect. This is why the ANWB Safe Cycling Network project has received support from various international road safety organizations, such as the FIA Foundation and the International Road Assessment Programme (iRAP). In the Netherlands the provinces of Fryslân (Regional Road Safety Group) and Gelderland (Public Space and Accessibility | Mobility) are closely involved in the project, also financially. SWOV was asked to participate as a scientific partner in the Safe Cycling Network project.

Furthermore, there was close cooperation during the project with street-level image recording company CycloMedia, which made recordings of cycling infrastructure available. The municipalities of Harderwijk and Goes also cooperated in the project by facilitating practical applications of the proposed expert system. Finally, employees of the European Road Assessment Programme (EuroRAP) cooperated in the project in the form of comments and suggestions for the report.

The involvement of and collaboration between all these parties has been of huge importance in bringing about the Safe Cycling Network project.

1. Introduction

In this report we describe the results of the ANWB *Safe Cycling Network* project. The objective of this project is to develop an expert system to help road authorities take a survey of unsafe cycling infrastructure (and therefore cycling) and assessing it. ANWB asked SWOV to provide scientific justification for the project, which is embodied in this report.

In this introductory chapter we first describe the development of road safety (severe road traffic injuries, road fatalities) and the importance of paying attention to bicycle safety. We then outline a general framework for fostering road safety, concentrating on preventing cycling crashes. The importance of a proactive approach plays a major role in this, the aim being to optimize safety before crashes occur.

Using this framework as one of the starting points, we go into the reasons behind the Safe Cycling Network project in greater detail. We also discuss the relationship with the European Road Assessment Programme (EuroRAP), which is similar to this project. Finally in this chapter we discuss briefly the goals and motivation, forms of cooperation and phases of the project.

1.1. Background

1.1.1. *Changes in the number of road traffic casualties*

In the period 1999-2013 the number of road fatalities in the Netherlands declined. This is shown in *Figure 1.1*.

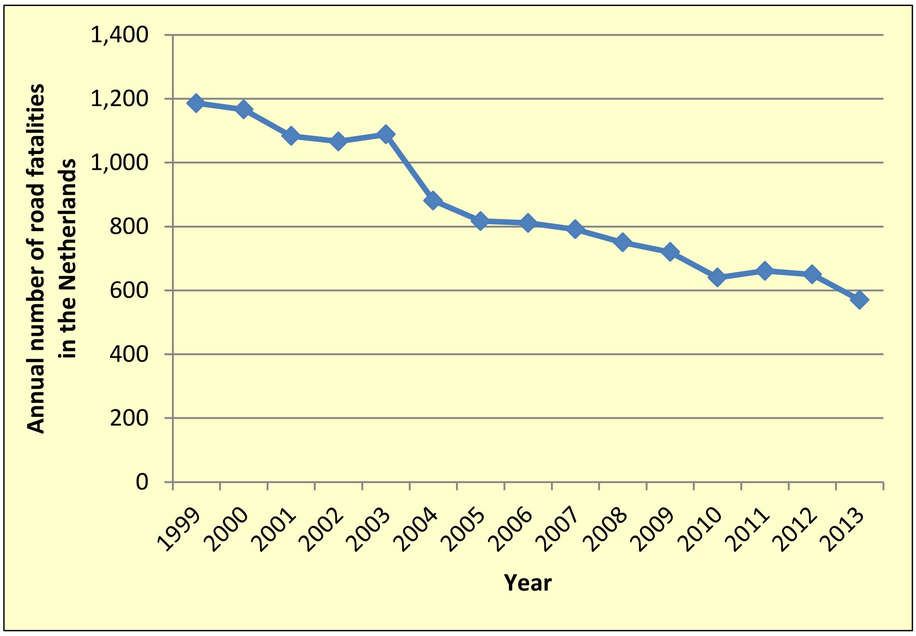


Figure 1.1. *Changes in the actual number of fatalities in the period 1999-2013. Sources: CBS and IenM.*

Proportionally, the decline of the number of road fatalities among car occupants is greater than that of the total (see *Figure 1.2*). Consequently, the share of vulnerable road users, including cyclists, among the road fatalities automatically increases. In 2013, the proportion of cyclists among all road fatalities was 32%, compared with 20% in 2000.

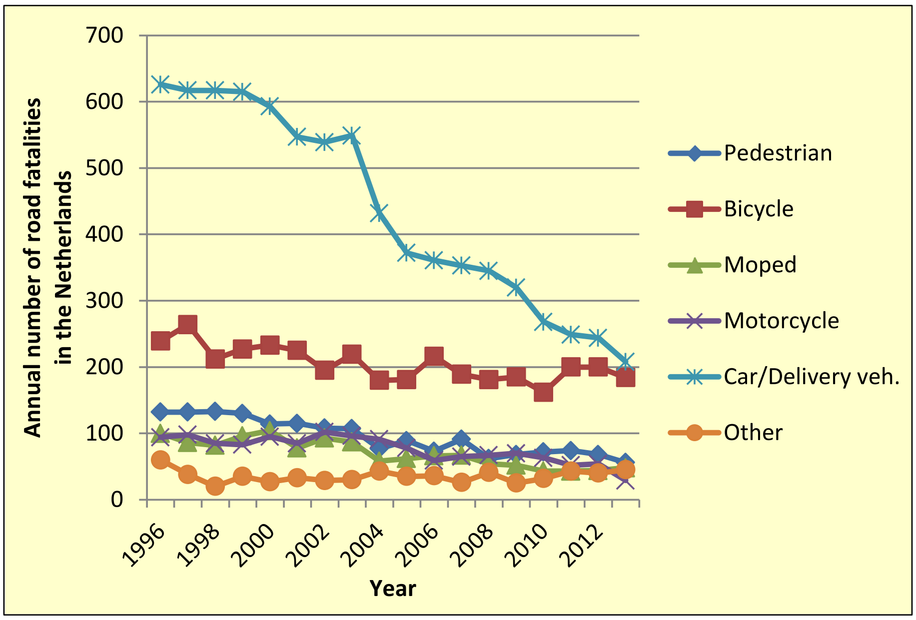


Figure 1.2. *Changes in the actual number of fatalities by transport mode. Sources: CBS and IenM.*

The number of serious road injuries declined slightly in the period from 1993 through 2006, but rose annually thereafter to 20,100 in 2011 (SWOV, 2013a). Because of a decline in the registrations in BRON (file of registered crashes in the Netherlands) a classification according to the casualty's age or transport mode was possible only until the end of 2009.

The change in the number of serious road injuries shows two different trends: a decline of the number of serious road injuries in motor vehicle crashes and a rise in the number of serious road injuries in non-motor vehicle crashes in the period 1999-2009 (see *Figure 1.3*). During the period 2000-2009, the total number of severely injured cyclists rose from 7,080 to 10,800. The statistics in *Figure 1.3* show that the increase is attributable almost wholly to cycling crashes in which no motor vehicle was involved (bicycle - bicycle, bicycle - pedestrian).

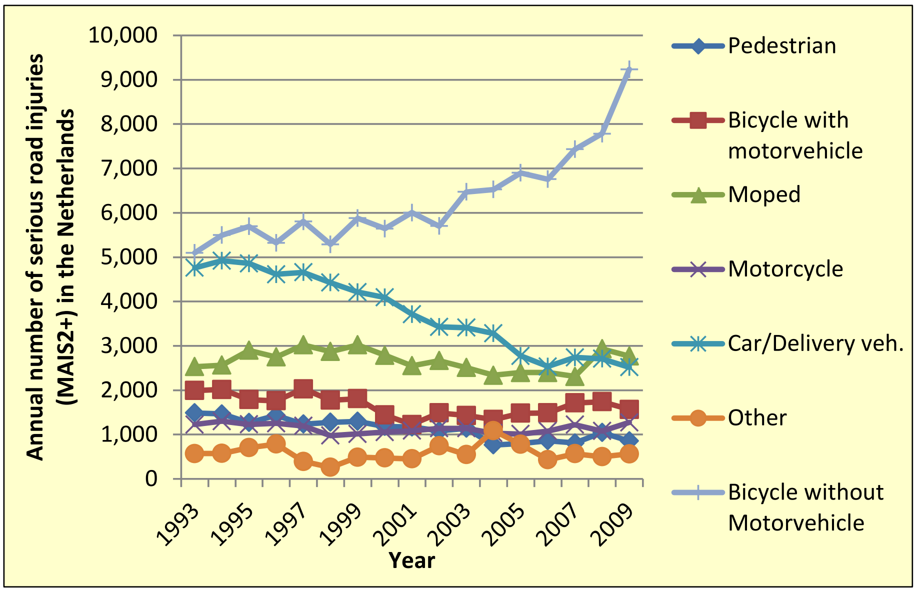


Figure 1.3. *Number of serious road injuries in the Netherlands by transport mode; cyclists are also differentiated according to the involvement of a motor vehicle. Sources: IenM and DHD.*

The *Strategic Plan for Road Safety 2008-2020* (VenW, 2008) gives a target of no more than 500 fatalities in 2020 – a reduction of 30% in comparison with 2009. The new target for the maximum number of serious road injuries is 10,600 for 2020 – a reduction of 40% in comparison with 2009 (VenW, 2010).

There are road safety targets at a European level too. The first target was set in 2001 (European Commission, 2001). The aim was that the number of road fatalities in the members states in 2010 would be half that of 2001. This target was achieved in only a small number of countries, including Sweden (-50%), the United Kingdom (-46%) and the Netherlands (-41%).

In 2011, SWOV made outlooks to see whether the targets for 2020 for the number of road fatalities and serious casualties could be achieved by carrying out the measures in the *Strategic Plan for Road Safety* (Wesemann & Weijermars, 2011). The researchers concluded that the target for the maximum number of road fatalities will be achieved only if mobility shows a modest growth and no cuts are made to road safety measures. They considered it unlikely that the target for the maximum number of severe road injuries would be achieved.

1.1.2. *Road safety policy based on knowledge of factors*

The negative development in the number of cycling casualties is now high on the policy agenda. This is why the Ministry of Infrastructure and the Environment (IenM) has drawn up the *Impulse for Road Safety Policy* (IenM, 2012). At the same time, knowledge is being developed in various ways with respect to preventing cycling crashes, for instance within the National Research Agenda Bicycle Safety (NOaF) and projects such as the *Forgiving Bicycle Path* of Remain Safely Mobile (*Blijf Veilig Mobiel* - BVM).

Bicycle safety is also an important policy topic in local government, which is generally responsible for managing the local cycling infrastructure. A recurring stumbling block here is that data on road crashes and casualties is insufficiently complete to be used as a basis for policy. In brief, there are three reasons for this:

- the success of the road safety policy (fewer black spots and fatalities, see *Figure 1.4*)
- the drop in the quality of crash registration
- the limited availability of correctly registered injury severity

This highlights the importance of a proactive approach: bicycle safety needs to be optimized *before* any crashes occur.

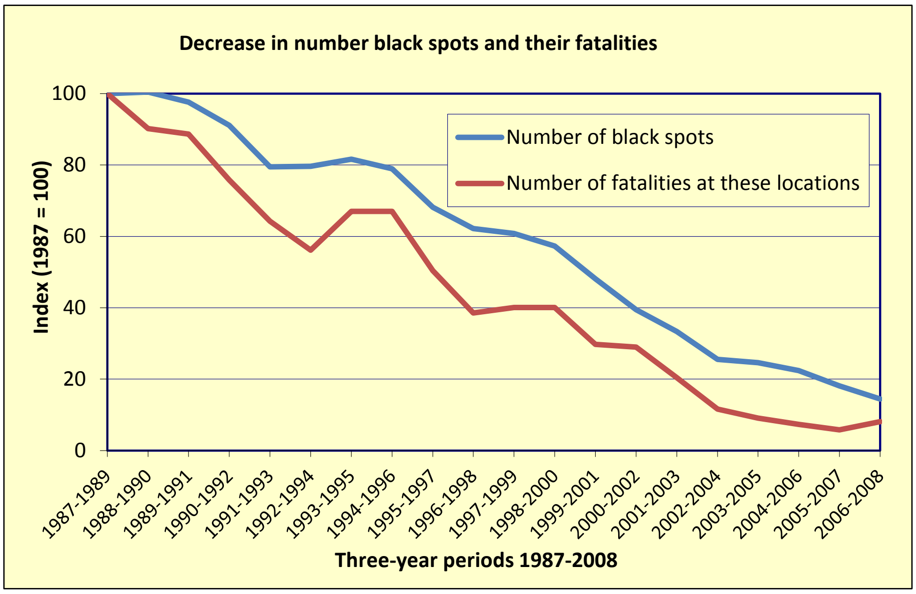


Figure 1.4. *Decrease in the number of black spots and road fatalities at those locations in the Netherlands (SWOV, 2010)*.

This development triggered a search for other factors from which to gauge the road safety situation, for example characteristics of particular roads or specific road user behaviour. What is the relationship between such possible factors and road safety, and to what extent do they affect bicycle safety? To study this, we first outline a conceptual road safety framework. We then go into the background of the factors that affect bicycle safety and the relationship with road safety.

The road safety pyramid

In the previous section we looked at the factors that can negatively affect road safety. The significance of each of the factors can be seen in the ‘road safety pyramid’ (see *Figure 1.5*). The five layers of this pyramid show the factors that are involved in road safety in a particular area (such as country, region or location). The pyramid can be regarded as causal: the context and situation in an area lead to crashes and casualties and ultimately to the social costs associated with them.

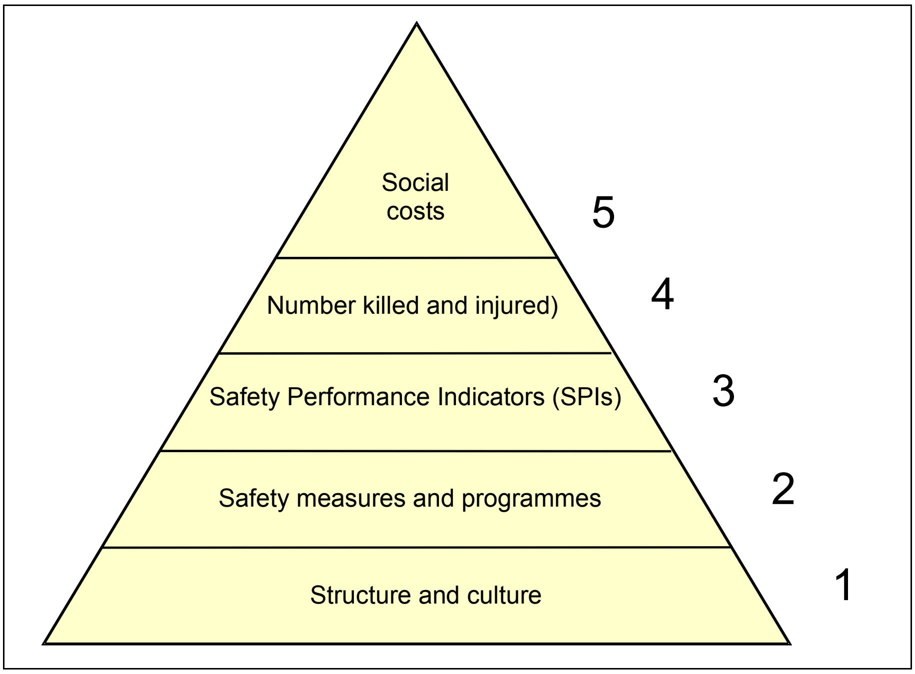


Figure 1.5. *Road safety pyramid (Koornstra et al., 2002; LTSA, 2000).*

The bottom layer of the pyramid (layer 1) represents the structure and culture of an area. These can be both static and dynamic factors. Typical factors from the bottom layer relate to geographic, demographic, socio-economic and climatological characteristics, as well as cultural, such as attitudes towards traffic-related topics (Wegman & Oppe, 2010).

Such structural and cultural characteristics form the context for policy measures (layer 2). This second layer concerns mainly the quality of the road safety policy and the road safety plans, and the conditions under which they are implemented. What are the available budgets? Was a thorough analysis carried out prior to the measures? Are well-founded measures being applied? Are the various actors cooperating to get the measures implemented in practice properly? (Bliss & Breen, 2009; ETSC, 2006)

The effect of policy measures can initially be observed from physical changes in the traffic system and the behaviour of road users. This is layer 3: the Safety Performance Indicators (SPIs). Roads have a specific quality and there are a specific number of people who drive too fast or under the influence of alcohol. SPIs are defined as factors that show a strong causal relationship to traffic safety. They are sometimes also described as indicators of risks present in the traffic system (ETSC, 2001; Hafen et al., 2005).

Ultimately, the traffic situation – influenced partly by the traffic volume – leads to more or fewer crashes and casualties: layer 4 of the pyramid. This is the layer at which targets are formulated and therefore also at which the developments in road safety are monitored.

Finally, the consequences of poor road safety are 'translated' into social costs (layer 5): material costs, medical costs and handling costs, along with the costs associated with loss of production and loss of quality of life (SWOV, 2012).

Therefore, every layer of the pyramid can provide an insight into the context and background of the road safety performance in a particular area. The system to be developed is intended for layer 3, with the aim of having an effect on other layers of the pyramid.

1.2. Reason for the study

The United Nations has designated the period 2011-2020 as the Decade of Action for Road Safety. Prompted by its close involvement in this programme, ANWB initiated the development of the *Safe Cycling Network* project. The aim of this project is to develop an expert system to help road authorities to assess the safety of cycling infrastructure and, eventually, tackle unsafe situations.

In other countries too, the bicycle is becoming an ever more popular mode of transport. Consequently, ANWB wants the cycling infrastructure in neighbouring countries to improve as well. Worldwide, the Netherlands is still regarded as a 'benchmark country' in this respect. This is why the ANWB Safe Cycling Network project has received support from various international road safety organizations, such as the FIA Foundation and the International Road Assessment Programme (iRAP).

iRAP/EuroRAP
The Safe Cycling Network project was inspired by the European branch of iRAP: EuroRAP, an initiative of ANWB and its European counterparts AA (United Kingdom) and ADAC (Germany). Through a points system using stars EuroRAP gives road authorities and road users an indication of the risk of a severe crash: a road with one star is rated unsafe, a road with five stars is rated safe. In 2012 and 2013, ANWB used this method to analyse the safety of provincial roads in the Netherlands (Hout, 2013). EuroRAP/iRAP showed that there is a need for a similar type of module for cyclists.

iRAP has already paid attention to bicycle safety by mapping the risks of a small number of characteristics of the cycling infrastructure (iRAP, 2013). These characteristics relate to the type of bicycle facilities (e.g. separated/ adjacent/ carriageway), the width of the paved surface for cyclists, the degree of separation from high-speed traffic, obstacle-free distance (very roughly), the type of junction and the volume of bicycle traffic.

The overall approach within iRAP is as follows:
- literature review of bicycle safety related to cycling infrastructure and selection of factors and indicators;
- estimate of impact of (combinations of) indicators on the risk, taking into account among other things the severity of the consequences;
- awarding a generic safety score (number of stars) to each road section.

Points to note with respect to the study:

- The current 'iRAP method' is barely applicable to bicycle safety. There are no characteristics involved that relate to factors such as the road surface quality, the verge and the role of obstacles on and alongside the bicycle facilities. The relevance of these characteristics for bicycle safety still has to be studied.
- Showing the degree of bicycle safety in a generic score does not make it clear to users (road authorities) which indicators have used for a specific location; this makes it hard to interpret the score. Attention is paid to this aspect in this study.

Fitting in with EuroRAP requires:

1. a set of indicators that are relevant to the safety of cycle paths;
2. a method of collecting data (fieldwork);
3. a method of recording the research work in images and being able to refer to the data;
4. a formula in which the data is processed;
5. an estimate of the coefficients (weighting factors) that are needed in the formula in order to arrive at a score;
6. validation; Answering the question: if we give locations a score of 'unsafe', does this mean that a lot of cycling crashes occur at those locations?

The requirements 1, 2 and 3 have been elaborated in this study.

The focus and overall approach of iRAP have been taken as the guiding principles for the project. The first step is to make a broad literature review of bicycle safety. Cycling infrastructure forms a significant part of this, because research has shown that it contributes to the safety of cyclists, in particular to the risk of cyclist-only crashes and possible injury (Reurings et al., 2012; Davidse et al., 2014).

1.3. Objective and motivation

The objective of this project is to develop an expert system that can assist road authorities[1] in proactively taking stock of and prioritizing locations that are unsafe for cyclists (rural and urban bicycle facilities).

In functional terms the expert system will consist of three parts: a knowledge database, an assessment model[2] and a user interface (see *Figure 1.6*). Ultimately, the expert system will also give road authorities potential solutions, making cycling safer through a safe/safer cycling infrastructure.

[1] The present project targets Dutch road authorities. If it proves useful, it may be expanded for international application.
[2] There are two assessment models: for the input (data collection) and for the output of the data (importance of measurement results for bicycle safety).

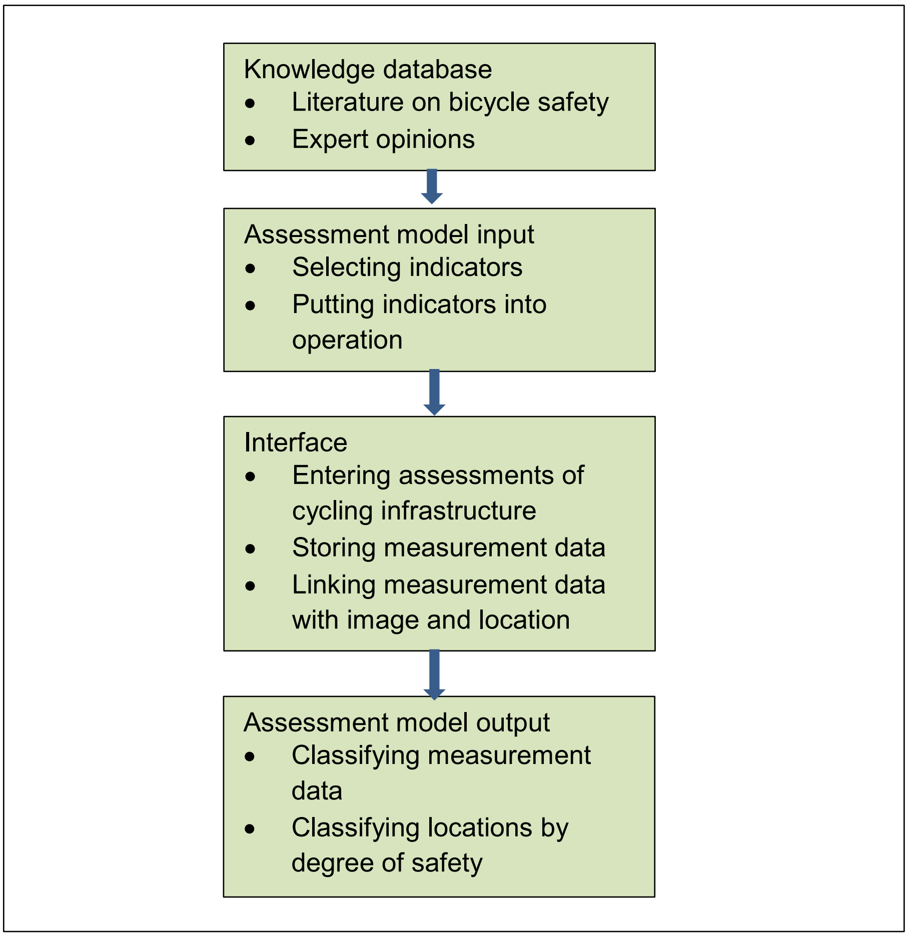


Figure 1.6. *The parts of the expert system.*

The expert system has been developed in six phases (see *Section 1.5.1*):

- Substantiating the choice of factors that are connected to the risk of cycling crashes, based on literature review and consultation with experts (phases 1,2).
- On the basis of these factors: selecting indicators and operationalizing them (phase 3).
- Developing an interface and a data collection process (phase 4).
- Implementing and evaluating applications of the system in collaboration with road authorities (phase 5) and users in a perception survey among cyclists (phase 6). The results of the final two phases form the input for adjustments in phases 3 and 4.

This makes it possible to gain experience of the use of indicators to analyse the safety of the cycling infrastructure at an early stage in the project. Road authorities can also familiarize themselves with the content and working method.

1.4. Cooperation and coordination

Various parties, working closely together, are involved in the development of the expert system. First of all, these are the road authorities, for whom the system is ultimately intended, and of course the experiences of road users are also very important.

Another objective is to collaborate with parties that are involved in developing the EuroRAP road authority instruments. The star rating system cyclist does not yet take cyclist safety into account adequately, especially with regard to assessing and prioritizing the cycling infrastructure. By building on the organization, knowledge and experience that are available both nationally and internationally, the project aims to make the likelihood of acceptance, appreciation and use of the expert system as great as possible.

Finally, as much knowledge as possible of other initiatives relating to bicycle safety is being used in developing the project. The provinces of Fryslân and Gelderland are involved and there are two pilot studies in the municipalities of Harderwijk and Goes.

1.5. Phases of the project

1.5.1. *Details of the phases*

The project to develop the expert system has six phases. The overall framework for the development process is a growth model. Parts of an initial draft version of the system have been applied in practice and reviewed in an iterative process and have been modified on the basis of new perceptions, both in terms of content (indicators), instruments (images) and procedures (instruction/ working method).

A summary of the method used, the intended result and the chapter in which they are described are given for each of the six phases In *Table 1.1*.

Part of project	Method	Chapter/ Result
Phase 1		*Chapter 2*
Initial inventory of risk-enhancing factors for cyclists.	Literature review.	Summary of factors that affect bicycle safety.
Phase 2		*Chapter 2*
Substantiating the importance of risk-enhancing factors for cyclists.	Literature review. Expert session (incl. road authorities) to build knowledge and support base.	Cycling infrastructure-related factors that affect bicycle safety.
Phase 3		*Chapter 3*
Creating the assessment model of the expert system.	Turning factors into indicators. Operationalizing indicators in observation categories. Expert opinion. Empirical testing (Phase 6).	Cycling infrastructure-related safety indicators with their categories. Instruction to determine degree of safety per indicator.
Phase 4		Chapter 3,4
Turning the model into an expert system	Linking indicators to data collection process and analysing results. Iterative process of practical application and modification (Phase 4, Phase 6).	Version of an expert system composed of an instrument for data collection, instructions and reporting method.
Phase 5		*Chapter 4*
User survey among road authorities (for the purpose of the user interface)	Applying pilot versions of the expert system in practice, in collaboration with road authorities.	Modifications to parts of the expert system on the basis of practical experience and input from experts and the road authorities concerned.
Phase 6		*Chapter 5*
Perception study among cyclists	Getting cyclists to ride the route and assess the safety of the cycling infrastructure on the basis of the indicators.	Summary of which indicators were considered important from the perspective of users, for the purpose of substantiating the importance of the indicators.

Table 1.1. *Summary of the six phases of the project with the method used, the intended result and the chapter in which they are described.*

1.5.2. *Executing the phases of the project*

1. *Initial analysis of factors that affect bicycle safety*
   The project started with a literature review, taking stock of factors relevant to bicycle safety. This involved studying the bicycle facilities at road section level as well as the network requirements based on Sustainable Safety (*Duurzaam Veilig*) (Weijermars et al., 2013). Aspects relating to the cycling network, such as types of bicycle facilities, were also included.

2. *Substantiating the importance of bicycle safety factors*
   The factors and measures resulting from the inventory were then fstudied in more detail , with attention for the role of the factors in relation to bicycle safety, in particular with respect to the cycling infrastructure. Study was made of what knowledge was available or gained in other recently completed or ongoing national and international cycling projects. The knowledge was gathered from three sources that were tested against each other:
   - Literature review;
   - Conceptual framework of Sustainable Safety (*Duurzaam Veilig*) for bicycles;
   - Expert session.

   This knowledge formed the basis for selecting infrastructural characteristics. Two aspects were important: the safety scores (e.g. on the basis of crashes, risks, SPIs, Sustainable Safety Indicator scores, expert opinions) and the possible solution approaches for road authorities. Within the project a procedure was developed to continually supplement the expert system with evidence-based information from completed research projects. This was done by using pilot versions of the expert system in practice, in collaboration with road authorities (Phase 6).

3. *Creating the assessment model of the expert system*
   Bicycle safety factors and the knowledge that is available about them were used to make the initial version of an assessment model for the intended expert system. The assessment model relates mainly to the input of the system, such as the choice of factors, turning them into indicators and operationalizing the indicators. The output side was considered to a lesser degree. The input side needed to be stable and assessed before the output (how to turn data into weighted results) could be assessed.

4. *Turning the model into an expert system*
   The information from the various phases (including the user survey) was included in the expert system. The design of this expert system was determined in close consultation with partners and users.

5. *User survey among road authorities (for the purpose of the user interface)*
   To test the user-friendliness of the instruments and the support base, a user survey was carried out among road authorities in two pilots with applications of the system. The results were used to improve the first version of the expert system. Actual data was obtained from road authorities in two other pilots. Knowledge was acquired about the data collection process and about the substantive aspects of measuring indicators in practice.

6. *Perception survey among cyclists (for the purpose of the knowledge database)*
   A perception study was carried out among cyclists themselves. The central question was what the effect of different infrastructural arrangements on the self-reported behaviour and the perception of cyclists. The study followed the form of the *ANWB road users' perception surveys*. The knowledge gained from this has been incorporated in the conclusions and recommendations for the expert system.

2. Factors affecting bicycle safety

In this chapter we discuss the first two phases of the project: an initial analysis of risk-enhancing factors for cyclists and substantiation of the importance of these factors. The working method comprised two steps:
1. Literature review;
2. Consulting bicycle safety experts (expert session).

2.1. Objective

To make an inventory of factors that are relevant to bicycle safety in general.

2.2. Method

Firstly a broad review was made of the literature on bicycle safety. That provided a picture of the factors affecting bicycle safety. Special attention was paid to publications relating to analysis of cycling crashes. The factors that were identified have been tested against the conceptual framework of the Sustainable Safety (*Duurzaam Veilig*) principles and conceptual requirements for the safety of cyclists (Weijermars et al., 2013). This was done to check whether these factors from literature sufficiently meet the 15 functional requirements for the safety of cyclists.

Then a selection was made of factors that are related to cycling infrastructure (concentrating on the objective of the project). This selection was then submitted to experts for review at a plenary session.

2.3. Factors that affect bicycle safety

The results presented in this section are based on the literature review. Firstly details are given of the aspects relating to cyclists in The Netherlands (*Section 2.3.1*) and to the bicycle as a ‘balance vehicle’ (*Section 2.3.2*). In the sections that follow the cycling infrastructure is discussed in terms of the analysis of cycling crashes. In *Section* 2.8 these aspects are tied in with the principles of Sustainable Safety regarding the safety of cyclists (Weijermars et al., 2013). Conclusions are drawn and recommendations are made on the basis of the insights gained from this.

2.3.1. *The cyclists*

Virtually all Dutch people have a bicycle and use it regularly. The total number of kilometres ridden per year (OViN 2010, 2011) is around 14.2 billion. *Figure 2.1* shows the kilometres cycled by age and gender (OVIN, 2010, 2011). Men cycle more kilometres than women. The number of kilometres cycled is relatively low among older people (75+).

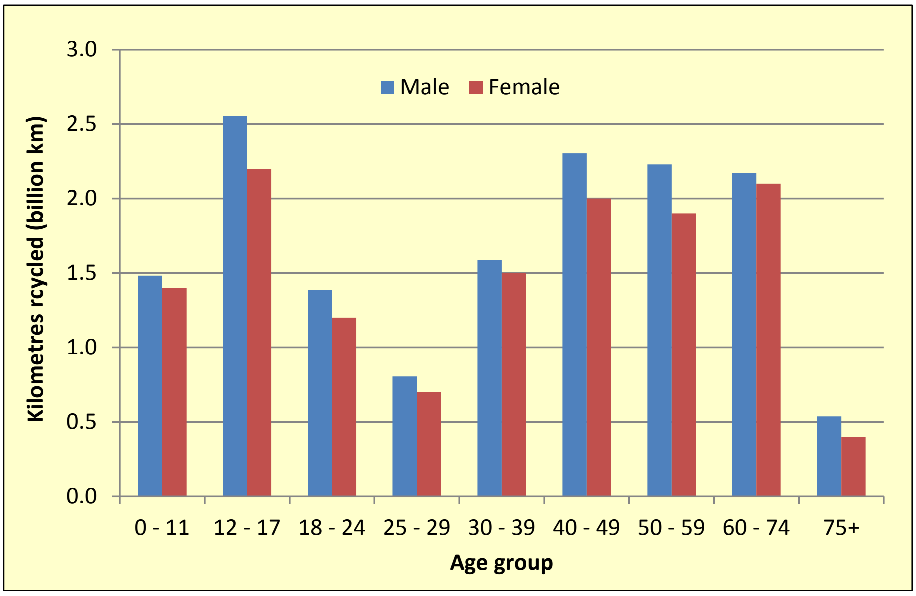


Figure 2.1. *Kilometres cycled in the years 2010 and 2011 according to age (Source: OVIN, 2010, 2011).*

Cyclists are vulnerable road users, just as pedestrians are. It is a known fact that the fatality rate for pedestrians increases as the collision speed with a car is higher, especially for elderly cyclists (*Figure 2.2*). Because of the vulnerability of cyclists, speed differences between the cyclist and other vehicles play a significant part in the injury severity in crashes.

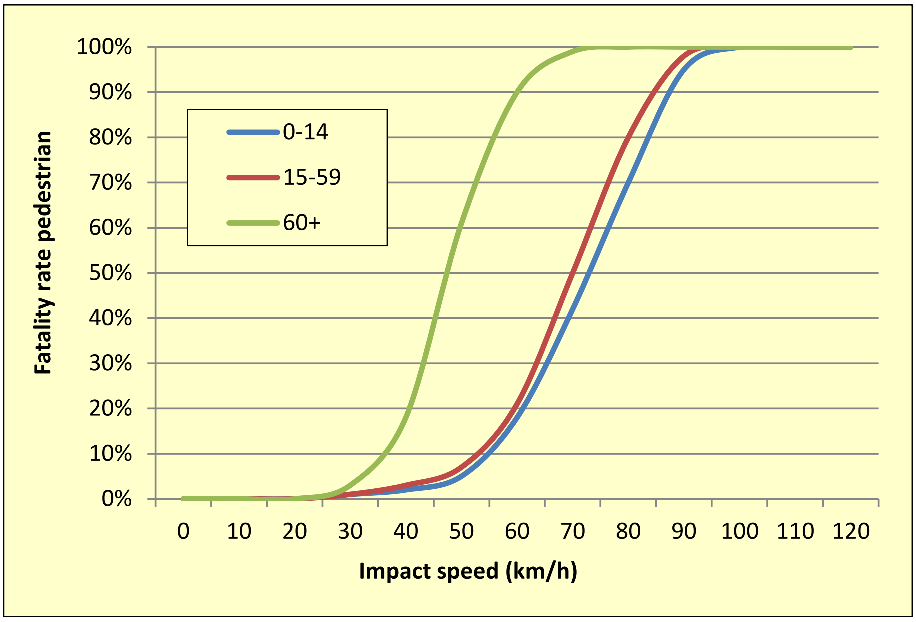


Figure 2.2. *Relationship between collision speed of car and fatality rate of pedestrian according to age. (Source: Rosén et al., 2011)*

2.3.2. *The bicycle as 'balance vehicle'*

The bicycle fleet in the Netherlands consists of an estimated 18 million bicycles (BOVAG-RAI, 2012), a figure that has remained virtually unchanged in recent years. In the last few years, however, an increase in the sales of electric bicycles can be observed(BOVAG-RAI, 2012). This is shown in *Figure 2.3*. E-bikes can easily reach speeds of 25-27 km/hour. Research has not shown that, assuming an average cruising speed, the e-bike has increased the speed difference between cyclists; both types of bicycle travel at about 18-19 km/h (Fietsberaad, 2013). This does not mean that if the e-bike is used increasingly by younger cyclists, they will not cycle faster.

In addition to the various types of bicycle, the light moped also uses the cycling infrastructure. Because of their width, light mopeds take up a lot of space and have a relatively high maximum speed of around 35 km/hour (Fietsersbond, 2012). Consequently, light mopeds contribute to speed differences on road sections used by cyclists. The number of light mopeds has increased in recent years; in the period 1 January 2007 – 31 December 2011 the number almost doubled from 292,000 to around 560,000 (BOVAG-RAI, 2012). Potentially this development contributes negatively towards the safety of cyclists. Even though light moped riders also use the cycling infrastructure, they have not been directly involved in the developmeny of the Safe Cycling Network; they do play a role, however, when it comes to the required width of the paved surface.

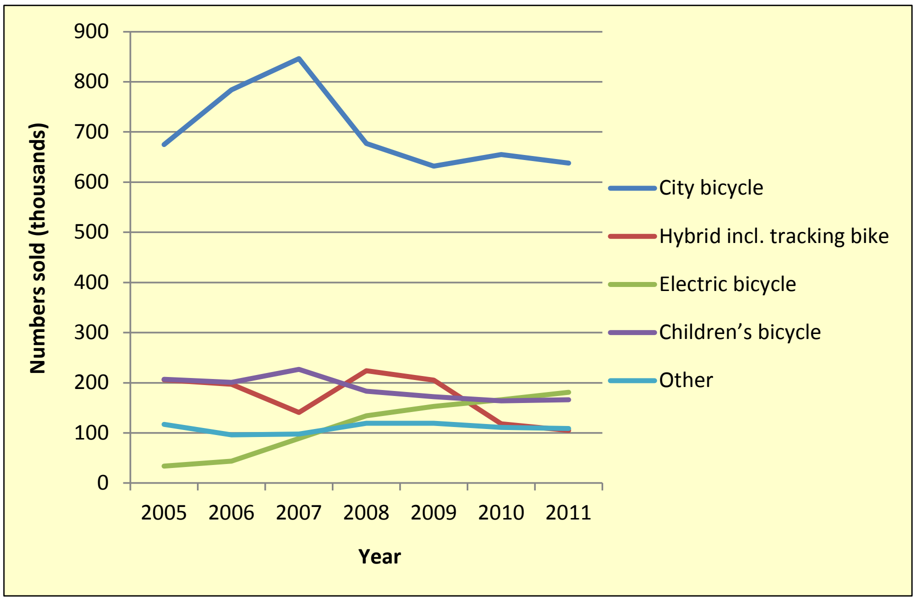


Figure 2.3. *Sales of bicycles 2005-2011 in thousands per year (source: BOVAG-RAI, 2012).*

Just like the scooter and the motorcycle, the bicycle is a 'balance vehicle'. At low speeds the vehicle becomes unbalanced relatively quickly (Moore et al., 2009), which makes mounting and dismounting risky. At high speeds the vehicle can slide in bends, for example if there is sand on the road. Furthermore, the vehicle becomes unstable if the front wheel or the handlebar hits an object such as a kerb or another bicycle, or if the rider brakes hard and a wheel jams, especially the front wheel (Beck, 2004).

The cyclist needs to have a number of vehicle control skills in order to be able to ride safely, such as:

- the ability to mount and dismount the bicycle and to start and stop it in balance (Schepers & Klein Wolt, 2012);
- proactive behaviour, such as changing speed or direction, to prevent the bicycle from having a collision and/or getting out of balance;
- quickly regaining balance when required.

In the following section we discuss two factors that affect bicycle safety. Two angles have been chosen:

1. characteristics of cycling crashes that emerge from crash studies;
2. the conceptual framework of Sustainable Safety principles and functional requirements.

2.4. Analysis of cycling crashes

2.4.1. *Core data*

In the Netherlands approximately 200 cyclists are killed every year, roughly a third of all road fatalities in the Netherlands (Wijlhuizen et al. 2012). More than half the serious road injuries are cyclists (58% in 2009). The number has risen sharply over time to almost 11,000 seriously injured cyclists in 2009 (Reurings et al., 2012). Especially among older people, the number of seriously injured cyclists has risen considerably in recent years. Partly for this reason the Ministry of Infrastructure and Environment (IenM) drew up the *Impulse for Road Safety Policy* (IenM, 2012). Among other things, it contains actions and measures that focus on older people and cyclists. In addition, the *Impulse for Road Safety Policy* pays attention to bicycle safety indicators. At the same time, several cycling crash studies are under way that in the long term could give greater understanding of the factors that play a role in bicycle safety.

A factor that is of essential importance in determining the risk of cycling crashes is the volume of the bicycle traffic, known as the exposure factor (Schepers et al., 2013; SWOV, 2013b). The volume of the bicycle traffic has an effect on the space for manoeuvring and overtaking without having a collision and losing balance. There is virtually no data on the volume of bicycle traffic on the public roads. It is nevertheless a factor that needs to be part of the expert system at the moment that risks are to be determined.

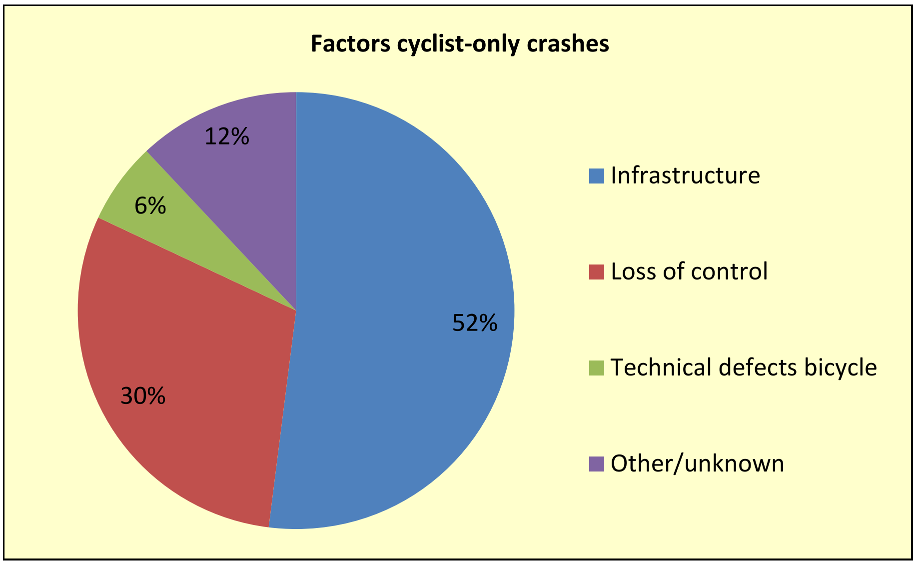
The majority of cycling crashes are cyclist-only crashes (around 75% of hospital admittances due to cycling crashes; Reurings et al., 2012). These are crashes in which a cyclist hits something or falls without having collided with another road user.

As cyclist-only crashes generally have a different cause than cycling crashes involving a collision with another road user, they are dealt with separately below.

2.4.2. *Cyclist-only crashes*

In the Netherlands no information is available National Medical Register (*Landelijke Medische Registratie* - LMR) about the location of cyclist-only crashes. To get some understanding of this, data from the Injury Information System (*Letsel Informatie Systeem* - LIS) has been used. Most cyclist-only crashes that are treated at hospital Accident and Emergency (A&E) departments (70%) take place within a built-up area; the percentage for 0-12 year-olds is as high as 86% (Ormel et al, 2009). Almost half (42%) occur while the cyclist was 'simply' cycling. An estimated 20% of cyclist-only crashes take place in the twilight or in the dark (Ormel et al, 2009).

On the basis a literature review Schepers & Klein Wolt (2012) made a classification of the principal factors that played a role in cyclist-only crashes. Subsequently, 669 cyclist-only crashes recorded in the Injury Information System (Crash and Emergency departments) were analysed and linked to these factors, with the possibility of linking several factors to a single crash. *Figure 2.4* shows the main classification of factors with the degree to which they play a role in cyclist-only crashes.



Afbeelding 2.4*. Main classification of factors with the degree to which they play a role in cyclist-only crashes in % (source: Schepers, 2012).*

Further details of the factors related to cyclist-only crashes are as follows (Schepers & Klein Wolt, 2012):

1. The infrastructure (52%[3])
   a. Preceded by dangerous cycling direction
      i. collision with objects that are part of the infrastructure, such as kerbs or bollards (12%[4]).
      ii. coming off the road and colliding with obstacles (21%).

[3] These percentages relate to the total N=669. The percentages add up to 100%; the major factor in the crash is pertient.
[4] This percentage relate to N=669; the percentages do not add up to the above-mentioned total because combinations of these factors may have arisen.

    b. Related to road surface quality
        i. sliding because of slippery surface (18%)
        ii. loss of control because of bumps or loose objects (7%)

2. The cyclist; loss of control (30%)
    a. At low speeds, e.g. when mounting or dismounting (16%). Physical disabilities play a role among older people (55+)

    b. Because of items carried that could touch the front wheel or other parts of the bicycle (8%)

    c. Cycling behaviour
        i. swerving suddenly (13%)
        ii. braking too hard (6%)
        iii. doing tricks with the bike (2%)

3. Technical defects (6%) For instance a loose/broken chain, problems with a wheel or fork, or a loose saddle.

4. Other or unknown (12%)

2.4.3. *Cycling crash involving a collision with a road user*

The road user who is involved in a collision with a cyclist may be a driver of a motor vehicle, a pedestrian or another cyclist. In comparison with cyclist-only crashes this type of crash causes the death of a relatively large number of cyclists, especially if a motor vehicle is involved (Reurings et al., 2012).

In the period 2005-2009 an average of 136 cyclists per year died in this type of crash and around 1.600 cyclists per year were seriously injured in a crash involving a motor vehicle (Reurings et al., 2012).

A comparatively large number of cyclists die as a result of a collision with a truck or bus (22% of cycling fatalities), whereas collisions involving a moped or light moped rarely have a fatal outcome (2% of cycling fatalities).

About 80% of the crashes in which cyclists are seriously injured involve passenger vehicles of vans and 10% involve a moped or light moped (Reurings et al., 2012).

Cycling crashes involving a collision are divided into:
1. *Crashes while crossing* (about 65% of cycling crashes, the majority of them collisions with a motor vehicle (Schepers & Voorham, 2010). There is a high risk of serious injury in these crashes).
2. *Crashes on road sections* (around 35% of cycling crashes, the majority of them collisions with moped/light moped riders and cyclists).

In the period 2005-2007 the majority (about 80%) of cyclists seriously injured in a collision with another road user were involved in a crash in an urban area (Reurings et al., 2012).

Crashes while crossing (65%)

Crashes while crossing can occur at a variety of locations. Basically there are two types of location, namely:

a) *Crossing a road section at a road crossing facility*
The road crossing is designated by markings or traffic lights. At a marked crossing the cyclist may or may not have priority.
b) *Crossing at a junction*
At junctions there are traffic flows that intersect because routes coincide. Various studies pay attention to risks for cyclists crossing at junctions.

Two factors play a role in crashes when crossing at junctions: infrastructure and behaviour.

<u>1. Infrastructure</u>
Limited evidence emerges from research with regard to the effect of infrastructure on the risk of a crash when crossing a road. Reurings et al. (2012) give the following indications:

a) One-way versus two-way cycle paths; at junctions, one-way cycle paths alongside distributor roads are safer then two-way cycle paths and cycle lanes. There are 50% more longitudinal crashes (crashes in which a cyclist is crossing a side road) on two-way cycle paths than on one-way cycle paths.
b) Approximately 35% more cycling crashes occur at four-legged junctions than at three-legged junction, but the benefit is wiped out when a four-legged junction has to be replaced by two three-legged junctions.
c) Junctions with a physical speed reduction facility for traffic from the side road are safer than junctions without physical speed reduction facility (also for cyclists).
d) At three-legged and four-legged junctions fewer crashes involving cyclists occur at road crossings if the junction is raised. In the case of junctions with solitary cycle paths there are indications that creating a road crossing on a speed hump leads to a larger number of crashes.
e) The use of left-turn lanes within urban areas leads to a rise in the number of crashes at road crossings involving cyclists.
f) There are fewer longitudinal crashes (on cycle paths alongside distributor roads) at crossings on side roads where no colour and marking have been used (Schepers & Voorham, 2010).
g) A restricted line of sight from an access road to a major road (defined at a distance of about 15 metres from the major road) increases the risk of a crash at a road crossing involving cyclists who are cycling to the left of the road, especially on two-way cycle paths.
h) Every year around eight cyclists die in ‘blind spot’ crashes.

Dijkstra (2013) indicates that cycling crashes at junctions can be divided into seven types. Firstly, a roundabout with a relatively slight risk: no relevant difference was found whether or not the cyclist has priority. However, a difference was found between three-legged and four-legged junctions: a four-legged junction has a higher risk.

Three types of such junctions can be distinguished:

- signalized junction
- priority junction
- junction without designated priorities

2. Behaviour

a. Virtually no research data is available on behavioural aspects associated with crashes when crossing a road, except that cyclists say that the other party was not paying attention (38%) or did something unexpected (21%) (Reurings et al., 2012). According to the cyclist, in 19% of the cycling crashes the other party committed an offence (e.g. by going through a red light).

Cycling crashes on road sections (35%)

The following factors play a role in cycling crashes on road sections involving a collision with another road user:

1) The cyclist; loss of control
   a. A collision between two cyclists is relatively often (22%) caused by a steering movement which results in a clash of handle bars or bicycles.
   b. Cyclists have a higher risk in the dark than in daylight (Reurings et al., 2012; Twisk & Reurings., 2013). The risk in the dark is particularly high in the early morning; this risk is roughly twice as high as the risk under other light conditions. For cyclists it is important to be able to see as well as to be seen (Kuiken & Stoop, 2012).

2) Speed differences

   Big speed differences between road users are a major risk factor in crashes with a severe outcome. Measurings show that light moped riders drive at an average of 34 km/h on compulsory cycle/moped paths, while cyclists travel at an average of 18-19 km/hour (Schepers & Voorham, 2010). Almost 40% of light moped riders travel at more than 35 km/h and 20% even travel at more than 40 km/hour.

3) Means and degree of segregation of road users

   In a report by the Dutch Cycling Embassy (19b, 2011) separating bicycle traffic from car traffic is regarded as an important way of improving bicycle safety. An increasing degree of segregation between bicycle traffic and motorized traffic is associated with significantly fewer cycling fatalities and serious injuries in crashes between cyclists and motor vehicles. Further research is needed in order to establish the exact reduction in casualties.

4) Width of bicycle facility

   Analysis of cycling crashes among the over-50s in the Dutch province of Zeeland (Davidse, et. al., 2014) indicates that insufficiently wide bicycle facilities or lanes played a role in 23%

(N=35) of the crashes. This related to situations where vehicles (cyclists) hit each other and/or where cyclists hit the verge and fell off their bike.

Research carried out by De Goede, Obdeijn and Van der Horst (2013) shows that dangerous situations on cycle paths (traffic conflicts) are caused partly by the bicycle facilities being too narrow. The survey calls for a minimum width of two metres in each direction in combination with a verge that can be driven on (forgiving) if swerving is necessary. Such a verge will also contribute to better use of the width of the bicycle facility.

2.4.4. *Conclusions*

In the preceding sections we discussed the results of a literature review of analyses of cycling crash data (including crashes involving other vehicles). Four factors for bicycle safety, with sub-factors, emerged.

1) Infrastructural factors in relation with cyclist-only crashes (slipping, loss of control, colliding with an object, coming off the road):
   a. quality of the surface of the cycling facility (rough, clean, even, no fixed obstacles);
   b. surface width of the cycling facility[5];
   c. verge quality or transition from, for instance, cycle path to verge/pavement (same level, obstacle-free area);
   d. public lighting (also bicycle lights);
   e. edge marking.

2) Infrastructural factors in relation with crashes at road crossings:
   a. the number of intersections that cyclists cross per kilometre cycled (if possible subdivided by characteristics that make a distinction between dangerous and less dangerous road intersections, including traffic volumes);
   b. visibility of potential collision opponents.

3) Factors in relation with crashes on road sections:
   a. speed differences between road users (in longitudinal direction);
   b. width of the bicycle facilities (room to overtake without hindrance);
   c. means and degree of separation of road users (e.g. separated cycle path (one-way or two-way), cycle lane, cycle street, distance from the road).

4) Volume of bicycle traffic (exposure) in relation with all types of cycling crashes.

In complement to the crash data as a reference framework for the choice of factors, in the following section we look at the conceptual framework of Sustainable Safety principles and conceptual requirements (Weijermars et al., 2013). This framework was chosen because it focuses specifically on factors that affect bicycle safety that apply in the Dutch situation.

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[5] Also relevant for collisions with other road users.

2.5. Sustainable Safety principles

The aim is to determine the extent to which the crash data and the Sustainable Safety principles are in accordance and what additions can be made in terms of Sustainable Safety.

The Sustainable Safety vision uses five principles. *Table 2.1* presents the application of the existing principles of the Sustainable Safety vision to cycling crashes not involving a motor vehicle (Weijermars et al., 2013). All principles except for the principle 'State awareness among cyclists' have been elaborated into functional requirements (CROW, 1997). State awareness will be discussed separately at the end of this section.

Principle	Application to cycling crashes not involving a motor vehicle
Functionality	Make a distinction between different types of bicycle facilities, depending on the traffic function (flow or exchange).
Homogeneity	Separate cyclists from each other as much as possible on the basis of speed and maybe also of size, mass and manoeuvrability.
Predictability	Make bicycle facilities recognizable to cyclists and adapt them to patterns of expectation with regard to matters such as road surface, road course and the behaviour of other road users.
Forgivingness	Make the infrastructure more forgiving for cyclists and bicycles.
State awareness	State awareness among cyclists. Specific topics could be alcohol and limitations of the elderly.

Table 2.1. *Application of the five Sustainable Safety principles to cycling crashes not involving motor vehicles (Weijermars et al., 2013).*

2.5.1. *Functional requirements for bicycle safety*

Weijermars et al. (2013) tested 15 functional requirements in terms of their relevance to bicycles. For each functional requirement the relevant factors discussed in the preceding section are shown in brackets.

1. Smallest possible part of the journey on relatively unsafe roads *[4]*
2. Make journeys as short as possible *[4]*
3. Ensure that the shortest and safest routes coincide *[4]*
4. *Avoid having to search [1d, e.]*
5. Make road categories recognizable
6. Limit and standardize the number of traffic solutions
7. *Avoid conflicts with oncoming traffic [1b]*
8. *Avoid conflicts with intersecting traffic and pedestrians crossing the road [2a]*
9. *Separate vehicle types [1b, 3a, b]*
10. *Reduce speed at potential conflict locations [3a]*
11. *Avoid obstacles on and alongside the carriageway and ensure that the verge is safe [1c]*
12. *Adapt infrastructure in residential areas to cyclists as much as possible [1d]*
13. *Ensure that the road surface is sufficiently rough but free from uneven patches that could create problems for traffic [1a]*

14. *Good passability and protection [1a, d]*
15. *Minimal traffic hindrance [1b, 3a]*

Functional requirements 5 and 6 are not part of the factors mentioned in *Section 2.4.4*. These functional requirements relate to the network level of the cycling infrastructure and that is an aspect that does not emerge as a major risk-enhancing factor in substantive crash analyses.

The following factors can be added, based on the aforementioned functional requirements:

16. Add limiting and standardizing the number of traffic solutions as a characteristic of crossing so as to clarify what road users can expect at a junction. Evidence for this is available in particular with regard to the priority rule at roundabouts (Dijkstra, 2004).
17. Good passability and protection. Alignment is important with respect to passability. Aspects of this are the number of and sharpness of bends and the presence of gradients.

However, there is insufficient evidence about the relationship between the recognizability of road categories (5) and the risk of cycling crashes to be able to recommend that this be added as an indicator.

2.5.2. *State awareness among cyclists*

Research into crashes involving cyclists has focused mainly on the consumption of alcohol (Li & Baker, 1994; Li et al., 2001; Li et al., 2000; Olkkonen & Honkanen, 1990). If the blood alcohol content is very high, the relative risk for cyclists is higher than for drivers. One of the differences between drunk drivers and drunk cyclists is that the latter are always casualties and generally end up falling off their bicycle, whereas drunk drivers can collide with somebody.

The prevalence of drunk cyclists is in the Netherlands is not known precisely. Indications can be found in the National Medical Register (LMR) as to whether seriously injured cyclists were under the influence of alcohol or drugs (Reurings, 2010). According to the LMR, in 1993 3% of the cyclists seriously injured in non-motor vehicle crashes had been drinking; this figure rose to 7% in 2008. The percentage is even higher on weekend nights and has risen over the years.

In 1993 24% of the cyclists aged 18-24 who were seriously injured in a non-motor vehicle crash on a weekend night had been drinking alcohol. This figure rose to 58% in 2008. Among 25-59 year-olds the consumption of alcohol on weekend nights is relatively high and still rising: 21% in 1993 and 44% in 2008. Alcohol not only increases the risk of crashes but also the severity of the outcome of the crashes (Nyberg, Björnstig & Bygren, 1996).

Alcohol consumption among cyclists plays less of a role in the cause of crashes between cyclists and motor vehicles than it does in cyclist-only crashes. Among cyclists seriously injured in motor vehicle crashes the number of cyclists who, according to the LMR, had been drinking alcohol was around 1%, but the trend is upward (Reurings, 2010). Cycling under the influence of alcohol is much more common among men than among women.

2.6. Conclusions and recommendations

The bicycle is a ‘balance vehicle’, which makes specific demands of the infrastructure and the cyclist in order to keep the risk of falling as low as possible.

Most cycling crashes resulting in serious injury occur urban areas and are generally cyclist-only crashes. A relatively large number of collisions between cyclists and motor vehicles occur while crossing a road, causing more fatalities among cyclists.

Crash research has brought to the fore various aspects of the cycling infrastructure that are important factors for the risk of a cycling crash. What these factors have in common is that they all relate to aspects that concern:

a. the condition of the infrastructure (*static*);
b. the use of the infrastructure (*dynamic*).

The qualification ‘s*tatic’* or *‘dynamic’* (see also the road safety pyramid in *Figure 1.5*) are given below for each factor. The relevance of this distinction is that the *static* factors can be monitored ‘from behind a desk’ if periodic (image) data is available. To monitor *dynamic* factors additional actual measurements are needed (such as determining traffic volume, speeds, alcohol consumption and use of bicycle lights).

The factors are:

1) Infrastructural factors in relation to cyclist-only crashes (slipping, loss of control, colliding with an object, coming off the road).
    a. Quality of the cycle path surface *(static):*
        i) rough (no steel, e.g. raised edges/covers, smooth longitudinal lines/marking at pedestrian crossings);
        ii) clean (e.g. no snow/ice, sand/stones, water, leaves, twigs, litter);
        iii) even (no bumps, potholes, sideways gradient);
        iv) no fixed/heavy obstacles (e.g. bollards, litter bins, parked vehicles).

    b. Width of the road surface for cyclists[6] *(static).*

    c. Verge quality or transition from, for example, cycle path to pavement (same level, obstacle-free area) *(static):*
        i) transition from cycle path surface to verge (level of height difference);
        ii) quality of the verge approximately 1 metre from cycle path surface (how level and/or paved it is);
        iii) edge marking.

[6] Also relevant to collisions with other road users

d. Lighting (also bicycle lights):
i) Is the cycle path lit at night *(static)?*
   ii) Do cyclists use front/rear lights *(dynamic)?*

2) Infrastructural factors in relation to crashes while crossing.
   a. The number of junctions or roundabouts that cyclists cross per kilometre cycled, subdivided wherever possible by characteristics that differentiate between dangerous and less dangerous junctions/ roundabouts, including traffic volumes *(static)*:
      i) three-legged versus four-legged junctions;
      ii) one-way versus two-way cycle path;
      iii) cyclists in blind spot of truck driver;
      iv) raised or level junction;
      v) good or limited line of sight from access road to through road.

   b. Speed differences between road users by measuring speeds of *(dynamic):*
      i) cyclists (distinction between electric, racing and city bikes);
      ii) light moped/scooter;
      iii) moped;
      iv) car, motorcycle.

3) Factors in relation with crashes on road sections:
   a. Speed differences between road users by measuring speeds of *(dynamic):*
      i) cyclists (distinction between electric, racing and city bikes);
      ii) light moped/scooter;
      iii) moped;
      iv) car, motorcycle.

   b. Means and degree (per kilometre of cycle route) of separation of road users *(static):*
      i) cyclists on carriageway without their own lane;
      ii) cycle lane (designated or non-designated);
      iii) separate cycle path (one-way or two-way), distance from the road section with motorized vehicles;
      iv) cycle street.

4) Factors in relation to the cycling network:
   a. Length of important cycle routes and degree of safety (expressed as a score based on the other factors) *(static)*:
      i) alignment: number and sharpness of bends and gradients;
      ii) length of important cycle routes (main cycle routes);
      iii) ‘total score’ for bicycle safety based on the remaining measured indicators.

5) Alcohol consumption among cyclists *(dynamic).*

6) Volume of traffic according to mode of transport and location *(dynamic)*. This is an important general indicator for determining risks and setting priorities when formulating policy (Schepers et al., 2013).

Recommendations
When developing the first version of the expert system it is advisable to begin with the *static* factors, because:

1. they relate to infrastructural characteristics – given the results of crash analyses they play an important role in cycling crashes;
2. existing visual material of the (cycling) infrastructure can be used;
3. it is a relatively new field of data collection (in comparison with, for example, speed and alcohol studies), of which little systematic scientific knowledge has been acquired

In addition, special attention must be paid to the *dynamic* indicator ‘volume of bicycle traffic’, as this is essential for determining risks.

When the method is further developed other dynamic factors can be elaborated. This expansion merits separate attention because other sources are used for collecting data on these types of factor (e.g. analysing speed difference, consumption of alcohol and using lights on bicycles).

Expert session
To underpin the importance of the static factors all the factors were presented to a group of bicycle safety experts. In the following section we go into the set-up and results of this expert session.

2.7. Selection of bicycle safety factors and road safety; consultation with experts

The expert session took place on 13 September in Utrecht. Twelve participants discussed 18 static factors that emerged from the literature review. Table 1 of *Appendix B* makes the link between these 18 factors and the factor raised in *Section 2.6*. These factors were regrouped to make them suitable for discussion in the expert session. The instructions given to the experts, the working method and the results are also included in *Appendix B*.

2.7.1. *Questions*

Two questions were in the forefront during the expert session:

1. What changes are needed in the ‘SWOV selection’ of static factors?
2. Can this selection be put in order of importance for assessing bicycle safety?

2.7.2. *Results and conclusions*

The view of the experts was that the 18 factors from the SWOV selection were recognizable, so none of the factors were removed. However, four factors were added:

- *Discontinuities.* Elements such as transitions between paved surface, cattle grids, rails and speed bumps for mopeds.
- *Plants*. Overhanging plants may make, or appear to make, the cycle path narrower and reduce visibility. Maintenance plans are important in tackling this.

- *Contrasts*. Using contrasts is important for older people in particular.
- *Visibility*. The longitudinal profile of the carriageway may make it easier for cyclists to be blinded by motorized traffic, especially in bends.

These additional factors can be incorporated in the original factors:
- *Discontinuities:* this indicator can be regarded as a special case of the ‘verge quality’ (1c-ii).
- *Contrasts:* this indicator, specifically targeting older people, can be assimilated in ‘edge marking’ (1c-iii).
- *Plants and visibility:* these factors can be combined in a general factor ‘restricted field of vision’.

The vast majority of the experts attached importance to six of the 22 factors (18 plus 4 additions). These factors got a minimum score of 6. All the experts considered the presence of bollards or traffic islands important and virtually all the experts (8) considered the ‘width of the paved surface’ and ‘quality of the paved surface’ important. A striking feature, however, is that the ‘location of the cycle path’ was mentioned by only one expert and ‘type of cycle path’, ‘longitudinal profile’ and ‘elevation profile’ by only two. A peculiarity of these factors is that they relate to characteristics of the cycling infrastructure that are less easy to influence than the other factors. They are the point of departure for further safety optimization by such means as removing bollards and altering the width and the verge, as suggested by one of the experts. These modifications reduce the risk of collisions with objects and preventing verge crashes among cyclists. This point of view is line with the literature, which shows that cyclist-only crashes represent a significant proportion – around 75% - of hospital admittances as a result of a cycling crash (Reurings et al., 2012).

In summary, we can conclude that factors with the highest score relate to prevention of cyclist-only crashes. These factors can be influenced relatively easily. Factors that are less easy to influence get a lower score (are less important).

Operationalization
This chapter discussed the first two phases of the project to develop an expert system for assessing the cycling infrastructure. Through a literature review we looked for factors affecting the safety of cyclists. These factors were then put to a team of bicycle safety experts.

The following phase is to build an assessment model of the proposed expert system. This means that the factors must be operationalized in a form that enables the cycling infrastructure to be assessed in practice: the indicators. In other words, translating the factors into indicators that show whether a situation is safe or unsafe. This is discussed in the following chapter.

3. Operationalizing the factors in the form of indicators

In the third phase of this project the factors from the previous chapter were operationalized in the form of indicators and linked to observation categories. Three steps were required: an internal SWOV expert meeting, consulting information sources and applying the instrument in two pilots.

SWOV expert meeting
At an internal SWOV meeting on 8 October 2013 the central issue was how to operationalise the factors in the form of indicators for an instrument that enables the cycling infrastructure to be assessed in practice. The first issue was which categories could be identified for each indicator. The second was the way in which an assessment could be placed in one specific category . An assessment could consist of, for example, an objective measurement (width of the cycle path in metres), but could also be an observation on the quality of the paved surface. In the latter case, a clear description needs to be given of the distinction between the various quality categories.

Design standards and classifications of bicycle facilities
Two sources were used to describe and make the distinction between the different indicators and categories as clear as possible:
- World Road Association[7]
- Bicycle Traffic Design Indicator (*Ontwerpwijzer fietsverkeer* - CROW, 2006)

Pilots
The operationalized indicators were tested in two pilot projects in the Dutch municipalities Harderwijk and Goes. These pilots are described in *Chapter 4*.

In the subsequent sections of this chapter we give details of the results of the three above-mentioned steps. In *Section 3.1* we detail the characteristics of the cycling infrastructure.

3.1. Characteristics of the cycling infrastructure to be assessed

Facilities
To display the legal status of bicycle facilities, the signs in *Figure 3.1* are used in public roads (). These signs also make it possible to distinguish between bicycle facilities when making an assessment.
- G11 mandatory cycle path, G12 end of mandatory cycle path
- G12a mandatory cycle/moped path, G12b end of mandatory cycle/moped path
- G13 non-mandatory cycle path (prohibited for mopeds and light mopeds with engine switched on), G14 end of non-mandatory cycle path

[7] http://www.piarc.org/en/Terminology-Dictionaries-Road-Transport-Roads

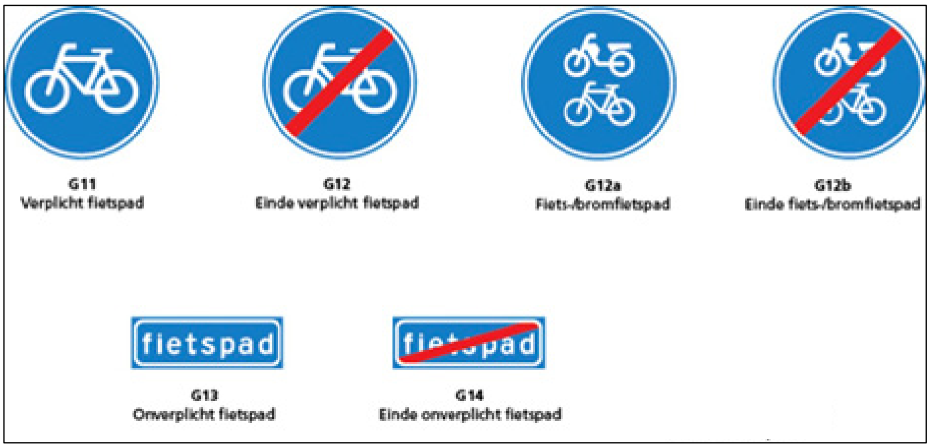

Figure 3.1. *Signs indicating the status of bicycle facilities (CROW,2006)*.

1. <u>Cycle/moped path</u>
   Purpose:
   To provide passage to cyclists and moped riders.
   Design:
   Sign G12a (mandatory cycle/moped path).
   Design speed 30 km/h within urban areas and 40 km/h in rural areas.
   Example:

2. Cycle path
   Purpose:
   To provide passage to cyclists.
   Design:
   Sign G11 (mandatory cycle path) or G13 (non-mandatory cycle path).
   Design speed 30 km/h for (main) cycle routes and 20 km/h for basic network.
   Example:

3. Cycle lane
   Purpose:
   To indicate and secure the position of the cyclist.
   Design:
   Sealed-surface cycle lane in red colour.
   A bicycle symbol is applied to the surface after every side road and possibly every 50 to 100 metres (within an urban area) or 500 to 750 metres (in rural areas).
   Broken or unbroken white lines; in the case of the latter, cars may drive on the cycle lane.
   Example:

4. Non-designated cycle lane
Purpose:
To indicate and enhance the safety of the position of the cyclist and to make the carriageway appear narrower.
Design:
Sealed-surface non-dedicated cycle lane not in red colour, bicycle symbol is not permitted.
Broken white lines, the non-dedicated cycle lane has no legal status and the position of the cyclist is therefore not protected.
Example:

5. Carriageway
Purpose:
To provide passage to cyclists and motorized traffic.
Design:
No lane classification; no separation of traffic types other than pedestrians from other traffic. Cyclists must use the right-hand side of the road whenever possible.
Example:

6. Cycle street
   Purpose:
   High-quality cycle carriageway, also used by motorized traffic. No legal status. The purpose is to reduce the dominant position of the car.
   Design:
   Preferably paved surface in red colour (to make the (main) cycle route recognizable).
   Priority rule at junctions (cycle street has priority), possibly physical speed reduction measure.
   No parking on the carriageway.
   Example:

7. Other:
   Other special forms that do not fit into the above categories, such as the fast cycle route, an example of which is given below.
   Example:

Location of cycle path

1. Separated/solitary cycle path
   Cycle path that either runs parallel to the neighbouring carriageway and is separated from it by a median, or follows an entirely different route.

2. Adjacent cycle path
   Cycle path that is separated from the neighbouring carriageway by a very narrow median, or runs at a raised level alongside the carriageway.

3. Not applicable
   In situations where no cycle path exists.

Direction of bicycle traffic

1. One-way traffic
2. Two-way traffic

Boundary of urban area

An urban area is a zone designated by local government where there are many buildings, making it possible for different rules to apply in urban areas. In the Netherlands there is generally a clear difference between residential areas, such as towns and villages, and the connecting roads outside them. An urban area usually corresponds with a residential area. Entry to and exit from a built-up area are designated by a traffic sign.

1. Urban area
2. Rural area

Volume per direction

In traffic engineering 'volume' means the number of vehicles per hour or per 24-hour period on a specific stretch of road. In this case it relates to the total volume of mopeds, light mopeds and bicycles in each direction.

Although volumes have an important realtionship with road safety, they are also a very dynamic factor. Data about volumes is therefore not included in this phase of the project, but merit attention at a future time.

Number of junctions according to type

A junction is an at-grade intersection of two roads. A junction allows (at-grade) interchange of traffic between several roads. There are eight different categories. The first seven are described by Davidse (2013). The eighth category ('crossing') is regarded here as a special form of junction.

1. Junction with no designated priorities (three-legged)
2. Junction with no designated priorities (four-legged)

   At a junction with no designated priorities the priority follows the general traffic rules, such as priority to the right.

   Examples

   Three-legged:

   Four-legged:

3. Priority junction (three-legged)
4. Priority junction (four-legged)
   At priority junctions the priority is indicated by traffic signs, road signs and/or road marking such as shark's teeth.
   Example:

5. Signalized junction (three-legged)
6. Signalized junction (four-legged)
   At junctions with a traffic control system the priority rules apply only when conflicts between traffic flows are not solved by the control system.
   Example:

7. Roundabout
   A round junction where traffic already on the roundabout has priority (provided that this is indicated by signs).
   Example:

8. Crossing
   Marked place where cyclists get the opportunity to cross the carriageway on road sections. The cyclist may or may not have priority over intersecting traffic.
   Example:

Exits
An exit for vehicles from a building or plot of land to the public road, and/or the entrance for vehicles from the public road. Examples are:
- the entry to a garage or carport;
- the driveway to a country house or country estate;
- the entrance to a meadow or wood;
- the entry to a car park;
- the entrance to an industrial estate.

Example:

Environment: use of bicycle facilities by others
This refers to an environment where the bicycle facilities are located in an area in which it is quite likely that the facilities will also be utilized by other road users. We can specify two categories where it is very likely that others will use the facilities: bicycle facilities traversing shopping areas and bicycle facilities traversing recreation areas. In these areas the risk of collisions is relatively high, as the speeds and objectives of other users of the bicycle facilities are different – shopping, running or rollerblading for example.

1. Use of bicycle facilities by others

Bicycle facilities that run through shopping areas or recreation areas, making it very likely that other users, such as walkers, runners or rollerbladers, will utilize them.
Examples:

2. Other

Speed limit on carriageway
The speed limit on the carriageway is significant in places where cyclists also make use of the carriageway or intersect with traffic on the carriageway. Relatively high speed differences to a large degree determine the severity of an injury that a cyclist may sustain in a collision with, for example, a car.

We make a distinction between the following road categories, with the prevailing maximum speed limits for each:

- *Through-roads:* roads that have a flow function, intended to facilitate conflict-free movement of motorized traffic to the greatest possible extent. Through-roads are characterized by a physical separation of carriageways and grade separated junctions. In the Netherlands cyclists are not permitted to cross a through-road.

- *Distributor roads:* roads whose function is both flow and interchange. Distributor roads are characterized by separation of fast and slow traffic (parallel cycle paths) and at-grade junctions. In rural areas the maximum speed for fast traffic is 80 km/h, within urban areas 50 km/h of 70 km/h.

- *Access roads:* roads in residential areas, whose function is to make properties accessible. Access roads do not have separate carriageways and fast and slow traffic may intermingle (possibly on the same carriageway), which requires a relatively low maximum speed. Through traffic should be kept out as much as possible. In rural areas the maximum speed for fast traffic on access roads is 60 km/hour, within urban areas 30 km/h.

3.2. General quality of the cycling infrastructure

Width of paved surface
Full width of the paved surface; for two-way traffic the total of the two directions. According to the Bicycle Traffic Design Indicator (*Ontwerpwijzer fietsverkeer* - CROW, 2006) a minimum width of 2 metres is required for all

types of cycle path, even at the lowest peak volume. As a continuous variable the width of the paved surface is measured in metres.

Sealed surface – Quality

The bicycle is a ‘balance vehicle’ that can become unbalanced by an uneven road surface, so the cyclist has to swerve in order not to fall. Consequently, when considering the quality of the paved surface attention is focused on the presence of any unevenness: cracks, holes and bumps. This also includes the area from the edge of the paved surface to the verge, which may have crumbled or cracked because, for example, the verge has subsided. The assessment also takes into account any additional facilities that could cause unevenness, such as drains, tram rails or cattle grids.

1. Adequate
   No cracks, holes and/or bumps identified.

2. Point of attention
   Some evidence of cracks, holes and/or bumps. No acute risk of losing balance if contact is made, but potentially uncomfortable.
   Example:

3. Problem area
   Substantial number of cracks, holes and/or bumps. Considerable risk of losing balance; avoid contact to prevent falling.
   Example:

Transition from paved surface to verge – Quality
A cyclist may come off the paved surface and lose balance because of the difference in height in the transition, so the cyclist has to swerve to restore balance or takes a fall. A level transition from the paved surface is important to allow returning to the paved surface without loss of balance.

The quality of the transition concerns the difference in height from the edge of the paved surface to the verge or other facility (footpath, carriageway). A transition could be a kerb, or it could be a verge that has subsided, so that there is a drop beside the edge of the cycle path. Big differences in height may be caused by a fence, a raised edge or plant growth directly adjacent to the cycle path, contact with which may potentially result in the cyclist losing his/her balance.

1. <u>Adequate</u>
   A level transition.

2. <u>Point of attention</u>
   Slight difference in height. No acute risk of losing balance, but potentially uncomfortable.

3. <u>Problem area</u>
   Substantial difference in height. Considerable risk of losing balance; avoid contact to prevent falling.

Verge – Quality
If a cyclist comes off the paved surface, there must be the possibility of making a correction and returning safely to the paved surface. In the case of a verge, vegetation may be involved or an adjacent pavement. The absence of a verge is considered to be a problem area. The side slope is also important (upwards, downwards), for example if the bicycle facilities run alongside a (low-lying) ditch.

1. <u>Adequate</u>
   Good to cycle on: level and free of obstacles within 1 metre.

2. <u>Point of attention</u>
   No acute risk of losing balance, but potentially uncomfortable.

3. <u>Problem area</u>
   Considerable risk of losing balance; avoid contact (also in the case of a hedge, bush, wall, fence or side slope in the verge). A special case are parking bays with or without a parked vehicles. Residential streets where vehicles may be parked could be a problem area too. In that case there is no verge to allow for swerving or correcting a loss of balance.

Markings
Lines on the paved surface. A distinction is made between
1. <u>centre line marking</u>
2. <u>edge marking</u>
3. <u>centre line and edge marking</u>
4. <u>no marking</u>

The three characteristics below further specify the type of paved surface, transition and verge whose quality is being assessed.

Paved surface – Type
1. asphalt
2. concrete
3. elements (e.g. tiles, bricks, cobblestones)
4. layer of gravel or chippings
5. other, namely:

Transition – Type
1. level
2. kerbstone – can be cycled across; levelled dropped kerbs (can be cycled onto without loss of balance)
3. kerbstone – cannot be cycled over; sharply sloping or rectangular kerb that causes loss of balance if sideways contact is made by bicycle
4. road surface with sharp edge (concrete/stelcon)
5. gully, for example to carry rainwater to drain
6. fence, high edge, vegetation
7. other, namely:

Verge – Type
1. grass
2. unbroken vegetation with plants, bushes, hedge
3. earth/sand/clay
4. gravel or chippings
5. paved surface (e.g. a pavement)
6. parking bay
7. ditch, canal
8. other, namely:

3.3. Obstacles

The guiding principle is that there are elements on the paved surface or in the immediate vicinity of the paved surface, contact with which could cause the cyclist to fall. This refers specifically to bollards in the cycle path that are generally intended to prevent cars from using the bicycle facilities. It could also refer to median islands, for example to separate cyclists from other traffic.

Bollard on path
A bollard is placed on the paved surface (middle or side).

1. Yes
2. No

Bollard – Visibility
If there is a bollard on paved surface, a distinction is made in terms of how noticeable it is: visually (with the help of street lighting) and/or through profiled road marking on the paved surface.

1. <u>Adequate</u>
   Clearly visible bollard (lit or contrasting with the background) with profiled road marking on the paved surface.
   Example:

2. <u>Point of attention</u>
   No profiled road marking but clearly visible.

3. <u>Problem area</u>
   No profiled road marking and not easily visible (e.g. unlit).
   Example:

4. <u>N.a.</u>

Median island – Present
This relates to a central island placed on the paved surface.

1. <u>Yes</u>
2. <u>No</u>

Median island – Visibility
If a median island is placed on the paved surface, a distinction is made in terms of how easily it can be noticed: visually and/or through profiled road marking on the paved surface.

1. Adequate
   Easily visible (lit or contrasting with the background) with profiled road marking on the paved surface.

2. Point of attention
   No profiled road marking but easily visible.

3. Problem area
   No profiled road marking and not easily visible.

4. N.a.

Obstacle – Distance
The distance of obstacles from the paved surface may form a hazard, for example upright obstacles in the verge (posts, trees etc.) with which cyclists could collide.

1. Abutting the paved surface
2. < 0.5 metre, but not abutting
3. 0.5 - 1 metre
4. 1-2 metre
5. 2 metres
6. N.a.

3.4. Road course and visibility during the hours of darkness

Sharp bends and differences in height (alignment) in a bicycle facility may affect the risk of cycling crashes. One of the factors is road visibility during the hours of darkness. Differences in height (descents) in combination with bends contribute to this risk, because speeds increase in a descent.

Bend – Degree

1. Gentle bend
   Can pedal faster in the bend without hitting the verge or getting onto the other half of the road).

2. Sharp bend
   Need to reduce speed and not use pedals to avoid hitting the verge or getting onto the other half of the road.

Bend – Visibility
Good view of the bend or of possible road users emerging from side road or exit, or oncoming vehicles in the bend.

1. No hindrance to line of sight

2. Line of sight slightly hindered
   Need to pay close attention, no change of speed needed.

3. Line of sight severely hindered
   Pay close attention, must brake to get adequate line of sight.

Difference in height

1. Level

2. Rise/fall
   Lower pedalling rate, need to use more power or cycle in lower gear when riding up a slope (for example on a bridge, in a tunnel, on a dyke, on a hill).

Narrowing

1. Little or none
   Virtually no change in direction needed, for example when the road narrows gradually.

2. Considerable
   Change direction by steering, especially if the narrowing is sudden, possibly because of an object. For example: cyclists alongside each other are forced to to cycle behind each other.
   Example:

Street lighting

1. Present
2. Not present

4. Pilot applications of the instrument and reporting the results

Local government bodies are generally responsible for managing the local cycling infrastructure. Consequently, in the fifth phase of the project a user survey was carried out among (municipal) road authorities . Experience was gained with the instruments that can be used to assess the cycling infrastructure. In addition, pilots involving the first version of the expert system were carried out in two municipalities. In Harderwijk the pilot tested the assessment process and the practicability of the expert system. The experience gained was used in a further pilot in the municipality of Goes.

This chapter gives more details of these pilot projects, beginning with a description of the method and procedure used.

4.1. Method and procedure

4.1.1. *The spatial level of the cycling infrastructure to be assessed*

The cycling infrastructure can be described at several spatial levels. These are explained briefly below. Subsequently an indication is given of the level at which bicycle safety is assessed.

1. *Network level*
   The network level involves the totality of the routes and the functions of those routes within a delineated geographical area (for example residential area, town, province or country). When assessing bicycle safety at this level characteristics of the network must be taken into consideration, such as the proportion (length in kilometres) of bicycle facilities for each type (e.g. cycle lane, cycle path, cyclists on the carriageway) and the number of junctions, roundabouts and bicycle crossings within such a delineated geographical area.

2. *Route level*
   There are many possible routes in a network of bicycle facilities. However, a small number of the possible routes are used by a lot of bicycle traffic: the main cycle routes. Assessment of the bicycle safety at this level may take account of, for example, important urban facilities (station, shopping centre, schools, sports grounds) that are accessible by bicycle from residential areas via a main cycle route. Characteristics of those routes can be assessed, such as the number of junctions, roundabouts and bicycle crossings on each route.

3. *Road section/junction level*
   At road section/junction level bicycle safety is assessed for each individual street. Scores are given for each fixed unit of length within the street level. In the two pilots (within a built-up area) an assessment was made every 25 metres. It is customary to use the available road and traffic characteristics (indicators) at road section/junction level to determine relationships with the crash level and/or the crash rate (Dijkstra, 2003).

Assessing the indicators at each of the spatial levels gives different pictures of the bicycle safety and potential measures. After all, assessing indicators at road section level (holes and obstacles on a road section) gives other points of departure for measures than merely monitoring the number of junctions per kilometre travelled that a cyclist has to cross when following a route.

When assessing the safety of the cycling infrastructure the first line of approach in this expert system is at road section/junction level. The main reason for this is that the expert system has been developed partly on the basis of data from research into cycling crashes and the facts and circumstances relating to them. This data generally provides evidence of the involvement of road section or junction characteristics in cycling crashes, and less evidence of the role of characteristics at network level.

Conclusion
The assessment of the safety of the cycling infrastructure is made at road section/junction level.

4.1.2. *The instruments of the expert system*

Two instruments were used to assess the cycling infrastructure:
1. a checklist with indicators;
2. 360-degree panoramic images of the cycling infrastructure.

Checklist with indicators
The checklist is an interface in the Microsoft® program Access, in which data can be entered or categories clicked. The data is then stored directly into a database. The checklist is composed of two parts:
- Data relating to aspects of the assessment process.
  The assessment process takes place by making observations at road sections and where roads intersect. The data recorded includes:
  - the street name;
  - the location of the street (coordinates, adjoining streets at the beginning and end;
  - the length of the street;
  - the starting point of the assessment;
  - a counter that differentiates subsequent assessments (ID).

- The indicators.
  The indicators mentioned in *Chapter 3* are given in *Appendix A* in the sequence ultimately shown in the interface (see also *Figure 4.3*). For

every indicator the various categories are shown in drop-down menus so that they can be selected by clicking on them.

360-degree panoramic images of the cycling infrastructure
When assessing the cycling infrastructure using a checklist we can choose from two working methods:
- go with the checklist to the streets to be assessed and assess the situation on site;
- make an assessment using visual material (360-degree panoramic images).

In this project the second method (360-degree panoramic images) was chosen for the following reasons:
1. There are a number of organisations that every year collect 360-degree panoramic images of the physical environment on which the cycling infrastructure is visible. The photos are usually taken from a passenger vehicle driving on the carriageway. In the case of separated carriageways the car generally drives in both directions. Sometimes the car also drives on a separated cycle path alongside the carriageway.
2. From a logistical viewpoint, the preference is for assessing images. The assessment is made at a location where not only the assessor is present but also other experts who can, if required, give advice on images that are ambiguous.
3. The assessment of the images is not dependent on weather conditions that make on-site observations difficult (rain, snow, twilight/darkness).
4. The use of existing images enables assessments to be linked to images of the location; the image concerned can be retrieved for each assessment.
5. The reliability of assessments can be tested, for example by getting the situation assessed by another assessor.
6. Around 90% of Dutch municipalities have 360-degree panoramic photos of the environment at their disposal that are taken annually. The photos are taken by CycloMedia.

Several questions about the usability of 360-degree panoramic images remained to be answered, namely:
1. Have photos been taken of the cycling infrastructure? CycloMedia takes the photos from a car that does not or cannot drive on the entire cycling infrastructure.
2. What is the quality of the images of the cycling infrastructure, given the indicators to be assessed?
3. How much time does it take to assess the cycling infrastructure using the images?

Figure 4.1 is an example of a 360-degree panoramic image. In the next section there is a discussion of the assessment procedure based on the CycloMedia application Globespotter, which gives access to such images.

Figure 4.1. *Photo of cycling infrastructure from the CycloMedia application Globespotter, which is used as the starting point for the assessment of the indicators.*

4.1.3. *The assessment procedure*

The assessment procedure consists of two parts. Firstly the main characteristics of the visual material used are described. Then details are given of how the indicators are assessed.

The visual material: the 360-degree panoramic images
The visual material can be viewed on the CycloMedia website, using an access code. *Figure 4.2* shows the screen visible to the assessor.

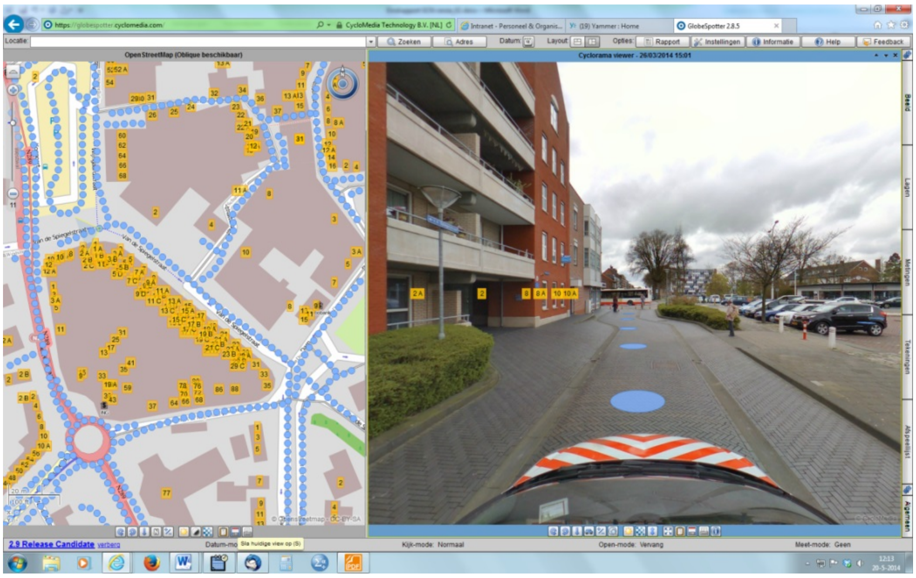

Figure 4.2. *The CycloMedia screen seen by the assessor when he makes the assessments.*

The left-hand side of the screen shows a map of the area where the assessment is taking place. The right-hand side shows a 360-degree panoramic image of the cycling infrastructure that is being assessed.

The link between both images is visible in the round blue dots that are projected both on the map and on the photo at an interval of five metres. Clicking on a blue dot on the map displays the corresponding photo on the right. When the blue dots on the photo are clicked the image switches to that point. The mainl functions of the programme are described in *Appendix C*.

The following features of the program are of importance for the assessment:

- Every blue dot has unique coordinates that define the observation point and link it to an image and a point on a map.
- From an observation point the image can be turned 360 degrees and be displayed from a vertical viewpoint; zooming in is possible as well.
- Images can be copied and saved, for example to illustrate or discuss particular situations.
- There are ways of taking measurements on the images so that for example the width of a cycle path can be determined.
- The length of a road section and/or street can be determined.

Assessment of the indicators
The following procedure is used in the assessment process.

1. The assessment is carried out by an employee who studies the visual material. The assessor gets instructions and training for this purpose (practising with images, assessing).

2. An input panel in the Access programme is used to save the results of the assessment in coded form (see *Figure 4.3*).

3. The location of the assessment is documented as follows:
   a. The street where the assessment takes place.
   b. A differentiation is made between road sections in the street (from junction to junction).
   c. An assessment is made of every 25-metre segment of each road section. In the images a continual assessment is made for all the indicators over a distance of five round blue dots.

4. After the location and the assessment of indicators of the first 25-metre segment have been recorded, for each successive segment the only changes to be recorded are those that differ from the previous segment. When the button for the next segment of the assessment is clicked in the input panel, a new panel is displayed in which the previous data is taken over. Only the changes now need to be entered into this panel.

5. The assessment takes place across the full width of the carriageway or cycle path (one-way or two-way), including the verge on either side. The width of a facility is determined by measurements obtained from the image.

6. If there are no bicycle facilities (including lanes) on a carriageway, the full width of the carriageway must be established.

7. If there is a cycle path on both sides of a carriageway, each path must be assessed separately.

8. If the cycling infrastructure is too poor or is invisible, it is recorded that it was not possible to make an assessment of the indicators in question.

9. If doubt arises over what assessment to give, a screen print is made of the segment and it is recorded which assessment is unclear. Consultation about this can take place later.

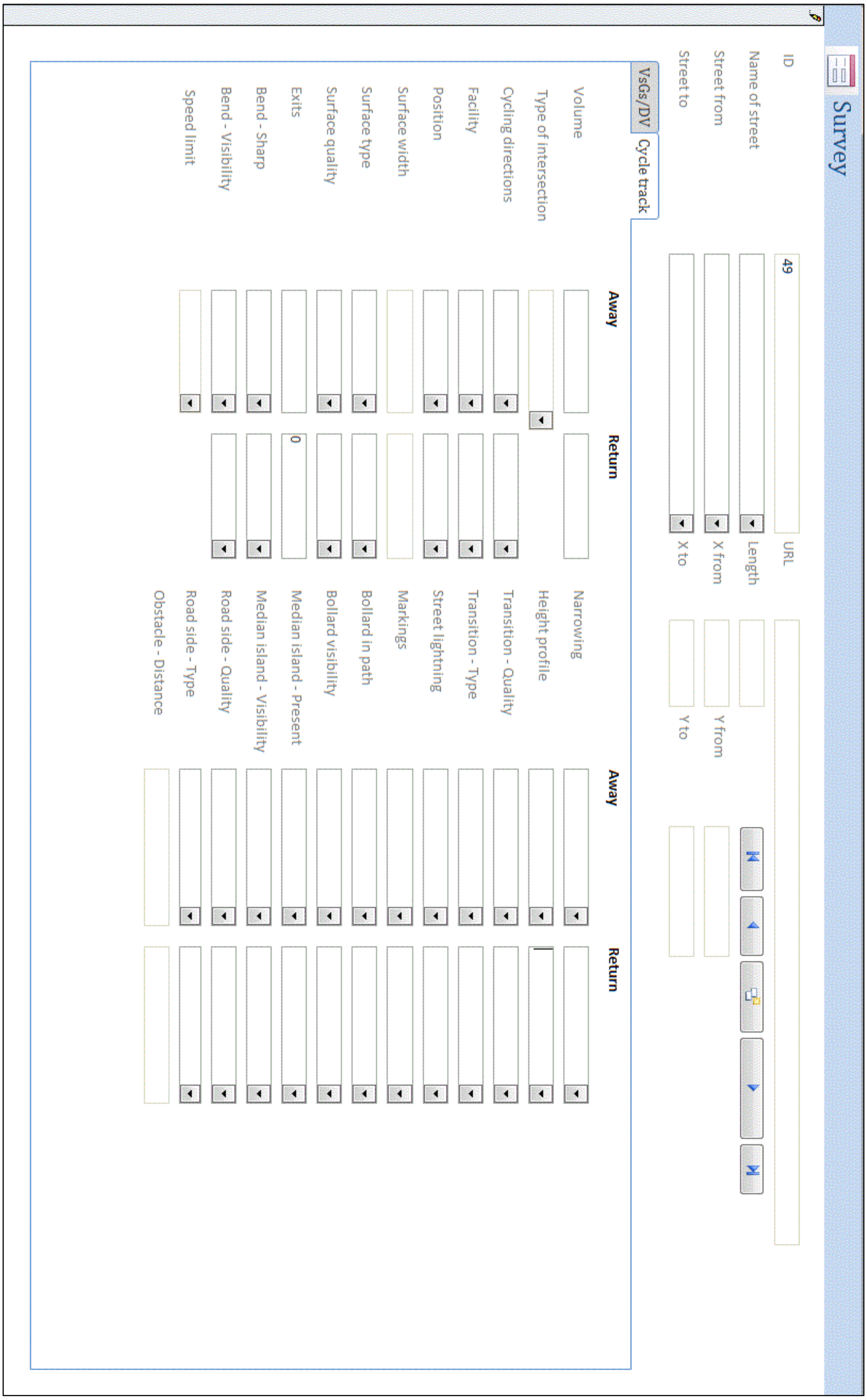

Figure 4.3. *Access input panel for assessments of cycling infrastructure.*

4.2. **Pilot 1: Harderwijk**

4.2.1. *Objective and questions*

In the preceding section we mentioned the two instruments used to assess the cycling infrastructure: a checklist with indicators, and 360-degree panoramic images. This section discusses the first pilot in which these instruments were applied; the pilot was carried out in the municipality of Harderwijk (province of Gelderland).

Objective:
To test the practicability of the instruments in the assessment process in an initial real-life application.

The questions were:

1. Is the visual material of the cycling infrastructure sufficient to be able to make an assessment?
2. Are the descriptions and definitions of the indicators unambiguous enough to be able to assess real-life situations?
3. How much time is needed to make the assessment?
4. Do measurements need to be made on the basis of the images or are estimates sufficient (e.g. to determine the width of a cycle path)?

4.2.2. *Procedure and selection of type of bicycle facilities*

The municipality of Harderwijk had the CycloMedia images at its disposal. The assessments of the cycling infrastructure were carried out by a temporary employee who was instructed and coached by SWOV. This employee assessed bicycle facilities at urban road sections with a 50 km/h speed limit (*Figure 4.4)*. These criteria were selected because no specific bicycle facilities (paths or lanes) are mandatory at 30km/hour road sections (CROW, 2006). The length of the bicycle facilities surveyed was 28 kilometres.

In this pilot the assessments were entered in Excel format. On the basis of this initial pilot the input panel for the second pilot in Goes was developed in Microsoft® Access.

When going through the images the assessor entered a selected street name in the CycloMedia program, thereby displaying the street in question. The observation started at one end of the street; the point concerned was entered in the input panel. From that point the street was surveyed and an assessment on the indicators was given for every 25-metre segment. On the initial observation the input consisted of the scores on all indicators, but subsequently only the changes from the previous assessment were entered.

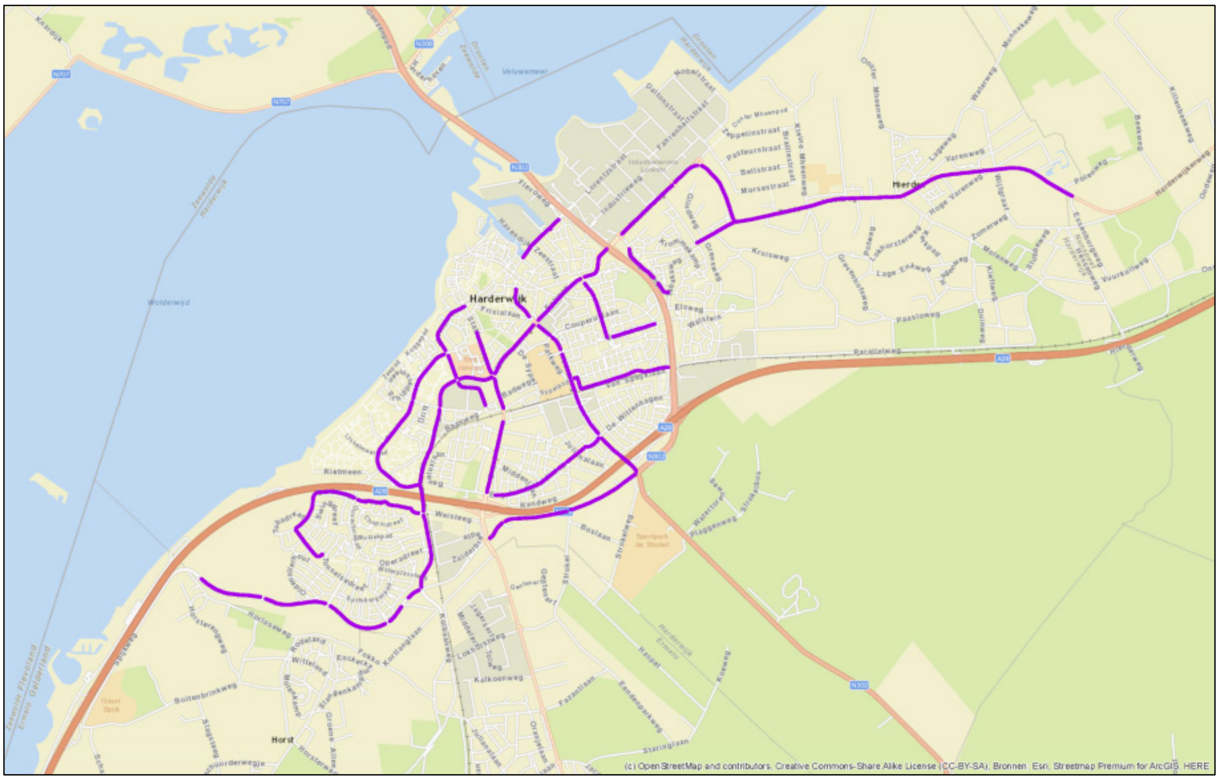

Figure 4.4. *Cycling infrastructure assessed (purple lines) in Harderwijk*.

4.2.3. *Results (mainly procedural; how was the working method?)*

The results of the assessment based on the four questions listed in *Section 4.2.1*. are discussed below.

1. *Is the visual material of the cycling infrastructure sufficient to be able to make an assessment?*

   At the start of the pilot it was not clear whether the visual material would give a sufficiently good picture of the cycling infrastructure to make an assessment possible. An unclear view could be the result of situations in which images of the bicycle facilities were made from the carriageway, and obstacles were in the way or bicycle tunnels were present of which no images were made.

   The assessor had the opportunity, if there was an insufficiently clear view of the cycling infrastructure, to record for each indicator that an assessment was not possible ('missing values'). To evaluate them, 51 assessments were selected at random. Each assessment involved 22 indicators; 51 x 22 indicators = 1,122 assessments in total. Of these assessments 12 were 'missing values'. That means that no score could be given for 1% of the indicators. As the assessment of the bicycle facilities involves meticulous segmentation – 25 metres – the availability of 99% of the scores is sufficient to get a distinctive picture of the safety of the cycling infrastructure for road sections or streets.

2. *Are the descriptions and definitions of the indicators sufficiently unambiguous to be able to assess real-life situations?*

   The instruction was that if the assessor had any doubts about the assessment, a screenshot was to be made of the situation in question so that consultation could take place over the solution. The following doubtful situations were reported.

Situatie:

In this situation the comment was made that it concerns a category of bicycle facilities that was not specified in the classification of the type of bicycle facilities. The sign indicates that it is a 'cycle street, cars are guests'. As this type of cycling infrastructure is recognizable via the signs it has now been included in the categories.

Situatie:

The issue here was whether the non-designated cycle lanes should be assessed separately for each direction. This is not the case: an assessment is made every 25 metres on both non-designated cycle lanes without differentiating whether a possible problem area or a point of attention is on the left-hand or right-hand side. Only in situations where there are adjacent or separated cycle paths on both sides of the carriageway are the two directions assessed separately.

Situatie:

The assessor submitted this situation to check whether or not the bend is sharp. This bend should not be assessed as sharp. The image shows a slight curve in the cycle path – a bend that a cyclist can take without reducing speed or stopping pedalling.

Situatie:

In this situation the question was whether the verge on the right-hand side was a problem area and how the transition from the paved surface to the verge should be assessed here. This is a transition where a cyclist has no opportunity to use the verge, so it should be regarded as a problem area. At the same time, the verge itself is a problem area as well because it is impassable for cyclists. Additionally, in this situation the obstacle distance comes into the category 0-1 metre.

3. *How much time is needed to make the assessment?*

A total of around 28 kilometres of bicycle facilities was assessed. This took 50 hours, meaning that in this first pilot 1.75 hours per kilometre were spent on the assessment.

4. *Do measurements need to be made on the basis of the images or are estimates sufficient (e.g. to determine the width of a cycle path)?*

In this pilot the width of a cycle path was determined on the basis of an estimate from the CycloMedia images and the width was subdivided into different classes (>2, 2-3, 3-4, 4>metres). The main problem in the assessment occurred when the width was on the boundaries of the categories and the assessor had to choose a category. As the CycloMedia program allows measurements to be taken from images, this is an alternative whose feasibility needs to be explored.

4.2.4. *Recommendations and modifications*

This first pilot in Harderwijk led to the following recommendations.

- The visual material used (CycloMedia images) turned out to be sufficiently practicable for the pilot, so it could also be used as the criterion for a subsequent application. Nevertheless, attention must still be paid in subsequent applications to the practicability of the image data.

- During the pilot a number of situations were identified that could not be assessed unequivocally on the basis of the instruction and the proposed categories. This requires a few modifications:
  - Include the cycle street as a category in the type of bicycle facilities.
  - Indicate in the instruction that a high obstacle directly abutting the paved surface, such as vegetation or a wall/fence, must be assessed as a problem area.
  - Extra attention should be given in the instruction to what facilities need to be assessed in individual or in two directions.

- In this pilot the time needed to assess one kilometre of bicycle facilities was 1.75 hours. The assessment could be made more efficiently if an input program were to be used in which the scores for each indicator are chosen by a mouse click and only the changes with respect to previous assessments need to be entered. Microsoft® Access allows this.

- In a subsequent application experience must be gained of measuring the width of the bicycle facilities rather than assessing them on the basis of images.

4.3. **Pilot 2 Goes**

4.3.1. *Objective and questions*

Based on the pilot in Harderwijk several modifications were made to the first version of the expert system for assessing the cycling infrastructure. The modified instruments of the system were then used in a second pilot: in the municipality of Goes (province of Zeeland).

Objective:
- To test the practicability of the modified instruments and procedures in the assessment process by means of a second real-life application.
- To develop a report format of substantive results for the user (the municipality of Goes).

The questions were:
1. What is the proportion of ‘missing values’ in the assessments because of an unclear view of cycling infrastructure in Goes?

2. Are the descriptions and definitions of the indicators unambiguous enough to assess real-life situations?
3. How much time is needed to make the assessment?
4. What form of report satisfies the wishes of the municipality of Goes?

4.3.2. *Procedure and selection of type of bicycle facilities*

In Goes approximately 40 kilometres of urban bicycle facilities were assessed. *Figure 4.5* depicts the main cycle routes in question. Of the 40 kilometres 53% were cycle paths, 20% carriageways, 11% non-dedicated cycle lanes, 7% cycle lanes, 6% cycle/moped paths and 3% other.

The assessments of the cycling infrastructure were carried out by a temporary employee who was instructed and coached by SWOV.

The main differences from the pilot in Harderwijk were:

- Data was entered via an input panel in Access.
- The width of the bicycle facilities was measured from the screen, using a CycloMedia application, instead of making a ‘visual estimate’.
- The instruction was altered in some places, e.g. for the assessment of verges.

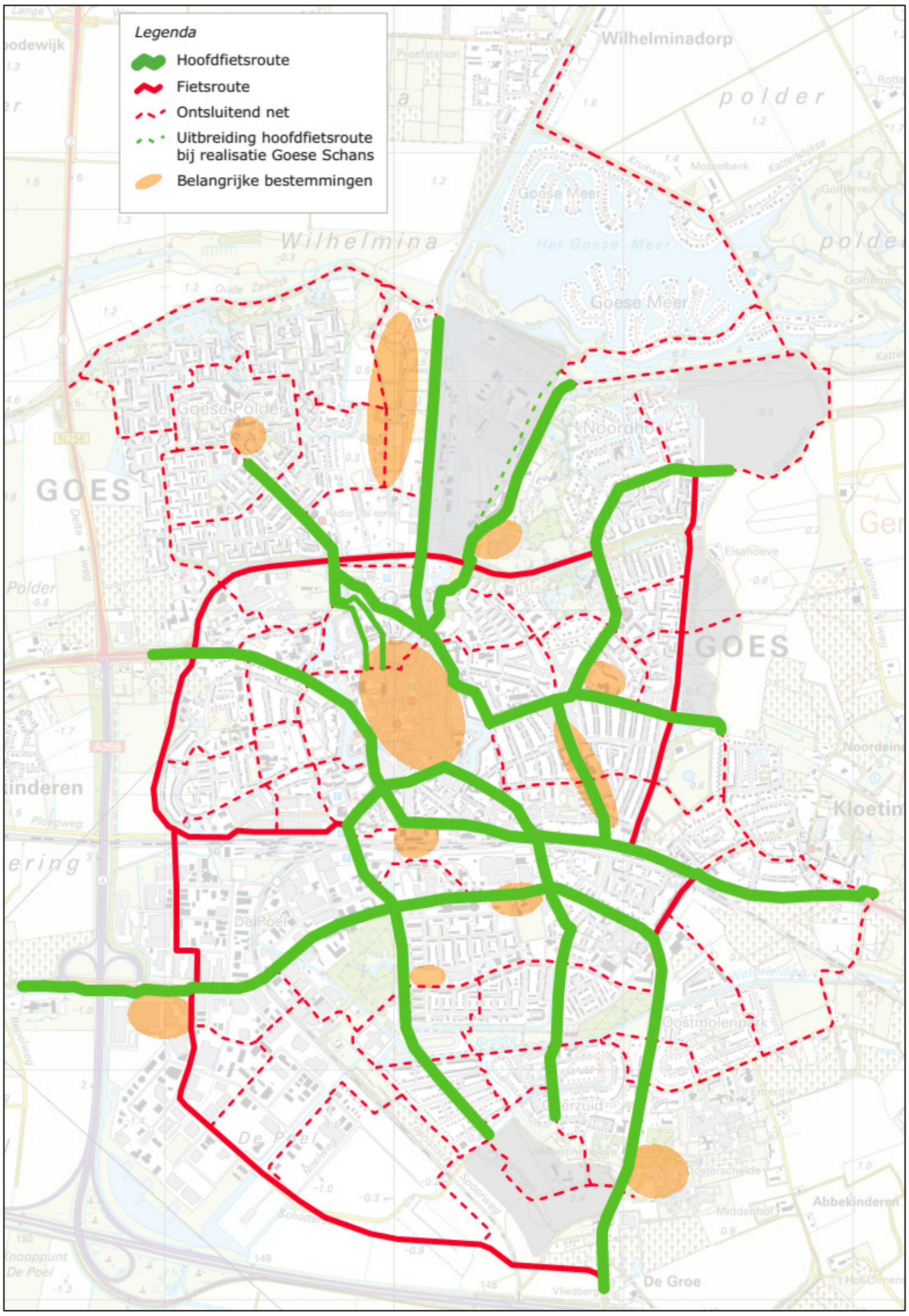

Figure 4.5. *Principal urban bicycle facilities in Goes; the main cycle routes were assessed in this pilot.*

4.3.3. *Results (substantive and procedural)*

The results of the assessment are presented below, based on the four questions listed in *Section 4.3.1*. The results of the pilot were obtained from two sources:

- the input assessment data
- discussions with the assessor during and after the project

1. *What is the proportion of 'missing values' in the assessments because of an unclear view of the cycling infrastructure in Goes?*

   For Goes an analysis was made on the basis of all the assessments, a total of 1,574 25-metre segments of bicycle facilities with 22 indicators per segment. The total was 22 x 1574 = 34,628 scores. Of these 701 (2%) were 'missing' (could not be determined on the basis of the images). The vast majority (N=679, i.e. 97%) of those that could not be determined (N=701) related to the quality of the verge. For example, where there is a pavement alongside the bicycle facilities the score 'cannot be determined' was given, because the pavement was not regarded as a verge. More concrete instructions about what does and does not constitute a verge can help reduce the number of missing values.

2. *Are the descriptions and definitions of the indicators sufficiently unambiguous to assess real-life situations?*

   The assessment of the verge was already an issue in the previous question. Another question that emerged during the discussions was how to deal with car parking spaces alongside bicycle facilities. After all, the cars are obstacles that can be dangerous for cyclists when parking and driving away and when car doors are opened. Parking spaces therefore contribute to lack of safety of the bicycle facilities, so parking spaces must be included as an indicator in an amended version of the list of indicators.

   During the discussion of the results the following possible additions were suggested:
   - Is there evidence that justifies making a distinction between types of junction according to the degree of road safety? The different types of junction were mentioned in *Chapter 3* (see also Davidse, 2013).
   - The obstacle distance is not sufficiently meticulous when measured in categories. Many objects are located at a distance of 1 metre and others virtually abut the paved surface. These are not differentiated when the obstacle distance is assessed in categories (see also *Chapter 3*).
   - With regard to measuring the width of the paved surface there is a loss of information when the outcome is classified in categories and the measured value is not entered (see also *Chapter 3*).
   - A proposal was made to add an indicator of whether there is a risk of the cycling infrastructure being used by others (pedestrians, joggers). The risk of use by others has so far been estimated as high for shopping and recreation areas (see also *Chapter 3*).
   - Finally, it was observed that the speed limit for high-speed traffic on the carriageway is an important factor in situations where the cyclist rides on the carriageway (see also *Chapter 3*).

3. *How much time is needed to make the assessment?*

   A total of 40 kilometres of bicycle facilities was assessed in about 75 hours, so 1 hour 50 minutes per kilometre were spent on the assessment.

4. *What form of report satisfies the wishes of the municipality of Goes?*

   This question focuses on the form of the report and not on the content. As long as the instrument itself is still being developed it is not advisable to present the substantive results of the assessments as an illustration of the safety of the cycling infrastructure in the municipality of Goes. In practice, a draft report was put forward to the municipality. Based on this the municipality indicated the parts where changes/additions are needed. These considerations and an example of the reporting method are given in the next section.

4.4. Reporting results

4.4.1. *Considering the characteristics of the cycling infrastructure from the viewpoint of road safety*

Before discussing the reporting of the results, a summary of the considerations will be given. The consideration process has not ended, but is at an interim stage. When the instrument is developed further, indicators may be removed or added on the basis of new insights and analyses of new results.

We have made the following steps in the consideration process:
1. On the basis of literature about facts and circumstances relating to cycling crashes a number of factors were selected that are deemed to be relevant to the safety of cycling infrastructure (see *Chapter 2*).
2. The factors were put forward to experts, who made several additions to them (see *Chapter 2*).
3. Factors were operationalized in the form of indicators that can be used to differentiate between safe and unsafe situations. To this end the indicators were provided with assessment instructions.

The three steps outlined above relate to the considerations that need to be made when collecting data during observations of 360-degree panoramic images of cycling infrastructure. Once the data has been collected, frequency distributions per indicator can be made from the results, for reporting purposes. However, these do not give a very consistent picture of the safety aspect. Consequently, indicators have been clustered and a score can be calculated on that basis. For each cluster scores are compiled based on the assessment of the indicators in question. We give further details of this in the next section.

4.4.2. *Clustering of indicators to calculate scores*

It was decided on the basis of the observations not just to make a total score for the safety of the cycling infrastructure as is done in EuroRAP, where the assessment is expressed by the number of stars awarded, but to start with several scores based on clusters of related indicators. This was because the outcomes per cluster can be interpreted more accurately than a general score that represents the outcome on all indicators.

Not all the indicators were clustered in this phase; some of them were used to make separate assessments, namely:

- type of cycling infrastructure;
- one-way or two-way cycle paths.

Consequently, our report makes a distinction between substantive clusters; we present the scores for different types of cycling infrastructure, subdivided into one-way and two-way traffic. The four clusters are listed below.

1. Overall quality of the cycling infrastructure

Comprising:

1. Width of bicycle facility (0-2 metres or 0-3 metres = 1[8])
2. Quality of transition (point of attention/problem area = 1)
3. Quality of paved surface (point of attention/problem area = 1)
4. Quality of verge (point of attention/problem area = 1)
5. Road marking (no marking = 1)

A quality score is compiled for each 25-metre segment. If in assessing a 25-metre segment a situation is encountered where the width of the cycle path is 0-2 metres, and the quality of the transition and the verge is a point of attention or problem area and there is no road marking, a score of 4 is awarded. No distinction is made between point of attention and problem area; the problem areas are scored separately.

The higher score in the assessment of the quality of the cycling infrastructure is awarded when there are a greater number of indicators of lack of safety:

- score of 0: no safety problem
- score of 5: maximum lack of safety

2. General obstacles

Comprising:

1. Bollard in paved surface (yes = 1)
2. Visibility of bollard (point of attention/problem area = 1)
3. Median island in paved surface (yes = 1)
4. Visibility of median island (point of attention/problem area = 1)
5. Obstacle distance in verge (0-1 metre = 1)

The score is made up in the same way as for the quality of the cycling infrastructure: for each 25-metre segment observed.

3. General elevation/longitudinal profile

Comprising:

1. Bends (sharp = 1)
2. Bend – Visibility (somewhat/severely obscured = 1)

[8] A score of 1 indicates a hazard; the higher the score, the greater the danger. For each 25-meter segment observed the maximum possible score is 5.

3. Elevation profile (rise/fall = 1)
4. Narrowing (considerable = 1)
5. Streetlamp (no = 1)

The score is made up in the same way as for the quality of the cycling infrastructure: for each 25-metre segment observed.

4. **Number of problem areas**
A separate score has been introduced based on the number of problem areas per 25 metre-segment. Problem areas relate to extremely unsafe situations in the cycling infrastructure, meaning that a cyclist has to avoid contact with an object in order to prevent an crash.
Comprising:
1. Bend – Visibility (problem area (3) =1)[9]
2. Transition – Quality (problem area (3) =1)
3. Verge quality (problem area (3) =1)
4. Sealed surface quality (problem area (3) =1)
5. Bollard in path (problem area (2) =1)
6. Median island (problem area (2) =1)

The score is made up in the same way as for the quality of the cycling infrastructure: for each 25-metre segment observed.

4.4.3. *Reporting the scores*

For each 25-metre segment a score is determined for the quality, the obstacles and the elevation/longitudinal profile. *Table 4.1* gives an example with fictitious values to illustrate the reporting method. This example relates to the frequency distribution of the scores for the quality of the cycling infrastructure on one-way cycle/moped paths.

Quality of cycle/moped paths; one-way traffic				
Quality score Number of indicators of lack of safety per 25-metre segment		**Frequency**	**Percentage**	**Cumulative percentage**
	0	40	8.0	8.0
	1	90	18.0	26.0
	2	300	60.0	86.0
	3	60	12.0	98.0
	4	10	2.0	100.0
	5	0	0.0	100.0
	Total	500	100.0	

Table 4.1. *Frequency distribution of the quality scores for one-way cycle/moped paths with fictitious values.*

The table above shows the frequency with which one or more of the given situations (point of attention/problem area) occurred in an assessment of a

[9] A score of (3) or (2) indicates a problem area for each of the six assessments.

25-metre segment. In the above example, none of the five situations were found in 40 assessments (safest). In 10 assessments, points of attention/problem areas were found simultaneously on four of the five indicators. From the perspective of the road authority the location of these 10 assessments is of overriding importance because a combination of four risks has been identified there.

The (cumulative) distribution of the quality scores provides the basis for comparing the safety of one-way cycle/moped paths - between municipalities for example. This can be done in a similar way for other types of bicycle facilities.

4.4.4. *From score per cluster to the observation location*

Starting from the example in *Table 4.1* the municipality of Goes wanted to be able to determine the locations that are considered the least safe and to see the images of them. Therefore, for every road section assessed the precise location was recorded on file in a code that gives immediate access in CycloMedia to the images of the road section in question. This way it is possible to add, for example, for the locations with the ten poorest assessments of quality the other scores (obstacles, longitudinal/elevation profile and number of problem areas), along with the images of the road sections in question in CycloMedia. In this way a link can be made between the somewhat more abstract scores and the concrete images on which they are based.

4.4.5. *Recommendations and modifications*

The visual material used in Goes resulted in 2% missing values, mainly because it was often impossible to determine the verge quality. The number of missing values can be reduced by making it clear in the instruction that a pavement must be regarded as a type of verge.

This second pilot led to the following recommendations about data collection:

- Distinguish between the types of junction according to the degree of road safety (see *Chapter 3*).
- A measurement of the both the object distance and the width of the paved surface should be taken and the value recorded on file, replacing the distance categories used previously. In the analysis any desired classification for the width of the infrastructure can be chosen; the basis for this is the Bicycle Traffic Design Indicator (*Ontwerpwijzer fietsverkeer* - CROW, 2006).
- Add an indicator for the possibility of the cycling infrastructure being used by others in shopping and recreation areas (see *Chapter 3*).
- Include a speed limit for high-speed traffic on the carriageway (see *Chapter 3*).

In Goes the time spent assessing one kilometre of cycling infrastructure was similar to that in Harderwijk. The assessor in Goes was different from the assessor in Harderwijk. In Goes 1 hour 50 minutes were needed per kilometre, despite the more efficient data entry (via Access). Measuring the width of the paved surface instead of making a visual estimate may have contributed to the extra time spent. If time needs to be saved in the data collection process, it will be necessary to reconsider the number of indicators, for example, the meticulous segmentation of the assessments (every 25 metres) could be revised. For example, the segmentation on cycle paths in rural areas could be different from that in urban areas.

New pilots
Pilot projects play an important role in the development of the expert system for assessing cycling infrastructure. Therefore the data collection method is to be revised and trialled in two further pilots:

1. The assessment of the main cycling infrastructure within a built-up area in Leeuwarden. In this pilot project several assessors will award a score to the each of the images. This will make it possible to check the consistency of the assessments.
2. The assessment of the route of the Eleven Cities Cycling Tour in the province of Fryslân. This route is about 200 kilometres long and travels through eleven towns and villages as well as on rural cycling infrastructure. On 9 June 2014 15,000 cyclists rode this tour, during which incidents (traffic crashes) were registered. In this project a link will be made between registered cycling crashes and the characteristics of road sections as assessed using the instrument in GIS. In the longer term this approach can provide information about which characteristics of the cycling infrastructure contribute to the risk of registered cycling crashes: the validation of the expert system.

5. Perception survey

5.1. Introduction

This Safe Cycling Network project was launched to develop an expert system that enables road authorities to assess the cycling infrastructure (and therefore bicycle safety). In the preceding chapter we saw how the initial draft versions of this system were applied in two pilot projects in Harderwijk and Goes. Alongside these pilots a perception survey was carried out among the principal target group: the cyclists themselves. The set-up and main results of this survey are discussed in this chapter.

5.1.1. *Objective and question*

Objective:
To study the degree to which cyclists actually perceive the indicators set out in the preceding chapters as unsafe characteristics of the cycling infrastructure.

Question:
What indicators (safety characteristics of the cycling infrastructure) are assessed by cyclists as unsafe?

5.2. Design

5.2.1. *Method*

For the perception survey among cyclists, four cycle routes in the province of Gelderland were marked out. The participants were given a list of points of attention with 18 indicators (safety characteristics of the cycling infrastructure), on which they could enter the characteristics they encountered on the route that they assessed as unsafe. An example of the instruction and list of points of attention can be found in *Appendix D*.

This is a good working method and provides descriptive data. Because of the short time available only the number of assessments has so far been calculated and those assessments have been categorised. This initial classification justifies a general examination of quality, but not a quantitative analysis.

5.2.2. *Cycle routes*

The four cycle routes marked out varied in distance from 20 to 25 kilometres. Each route was divided into separate segments of around 2 to 3 kilometres. The participants were asked to assess each of the segments. Each route was a clockwise circuit, so potentially hazardous crossings to the left were avoided as much as possible. *Figure 5.1* shows the ‘Doetinchem route’ as an example. The other routes can be seen in *Appendix E.*

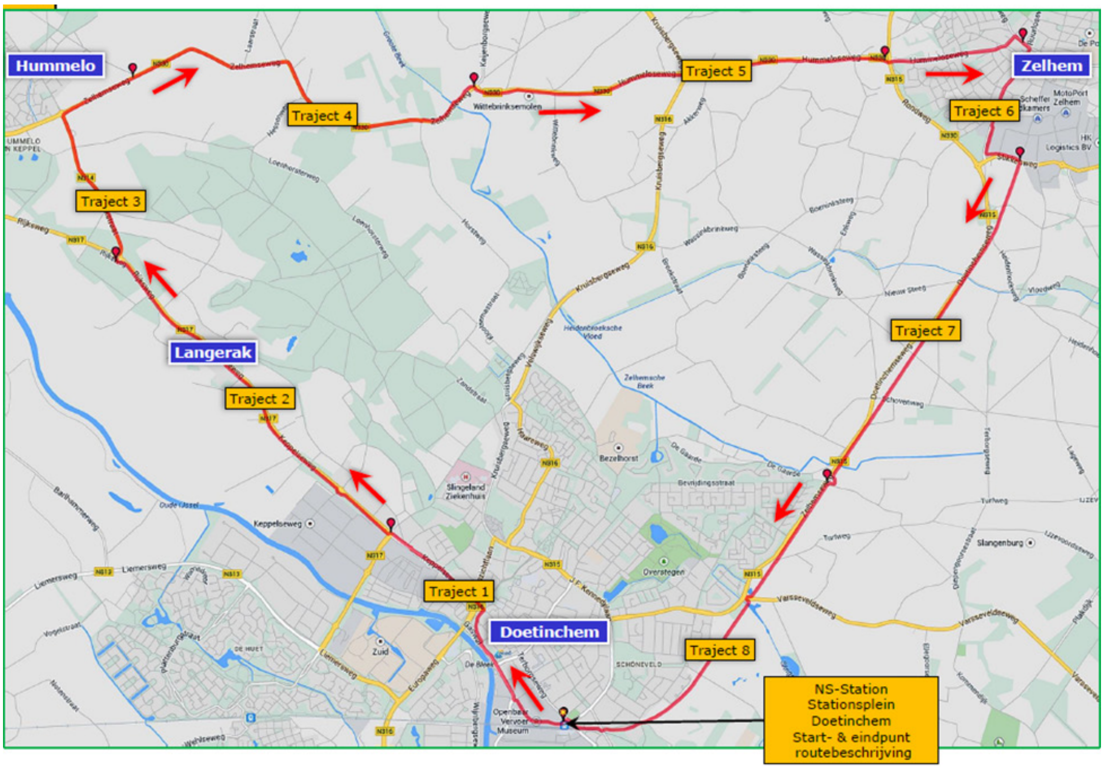

Figure 5.1. *Doetinchem cycle route; one of the four cycle routes ridden by participants in the perception survey*.

5.2.3. *Participants*

There were 200 registrations to take part in the perception survey, most of them ANWB members. The participants were recruited in various ways, namely:

- among the regular ANWB volunteers, the 'consuls', who also inspected the routes beforehand;
- among subscribers to the ANWB Volunteers' Newsletter;
- through an advertisement in a regional magazine;
- via the ANWB Twitter account;
- among volunteers from Gelderland in the ANWB database.

5.3. **Results**

5.3.1. *Characteristics of the participants*

Registrations for the survey totalled 200, of whom 170 actually took part (60% men, 40% women). Approximately 110 participants cycled in pairs and gave one assessment per pair; the remaining participants cycled on their own.

Some of the participants cycled more than one route, and a total of 141 assessments were submitted. The age distribution is shown in *Figure 5.2* (N=105; the age of 10 participants is not known). The average age of the participants was 60.

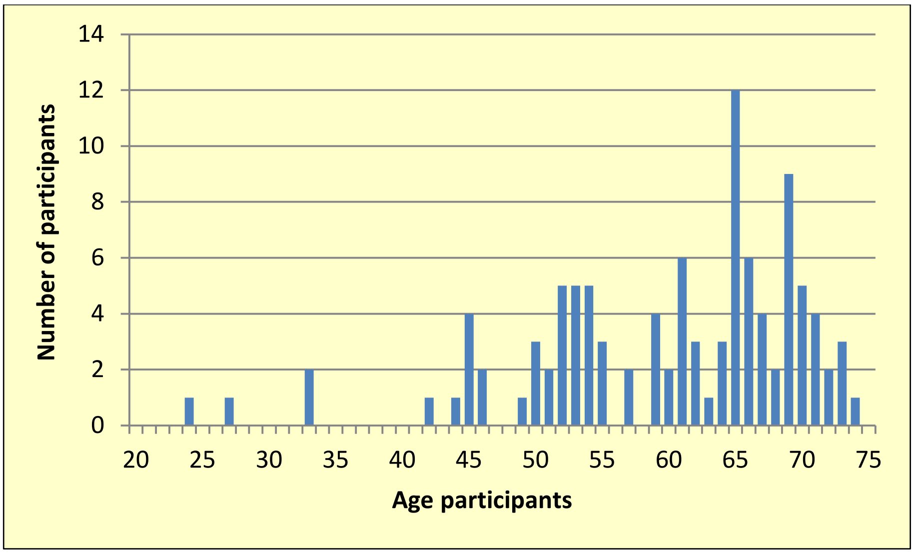

Figure 5.2. *Age distribution of the participants in the perception survey (N=105).*

The participants used their own bicycles to cycle the routes. Most of them stated what type of bike they were riding. The main types of bicycle were:

− city bike:	41%
− electric bike:	44%
− touring/racing/trekking bike:	14%
− mountain bike:	3%

5.3.2. *Assessment of safety cycling infrastructure (indicators)*

The participants were able to give their assessment of the safety of the characteristics of the cycling infrastructure. *Figure 5.3* gives a picture of how frequently indicators were assessed as unsafe across all the routes.

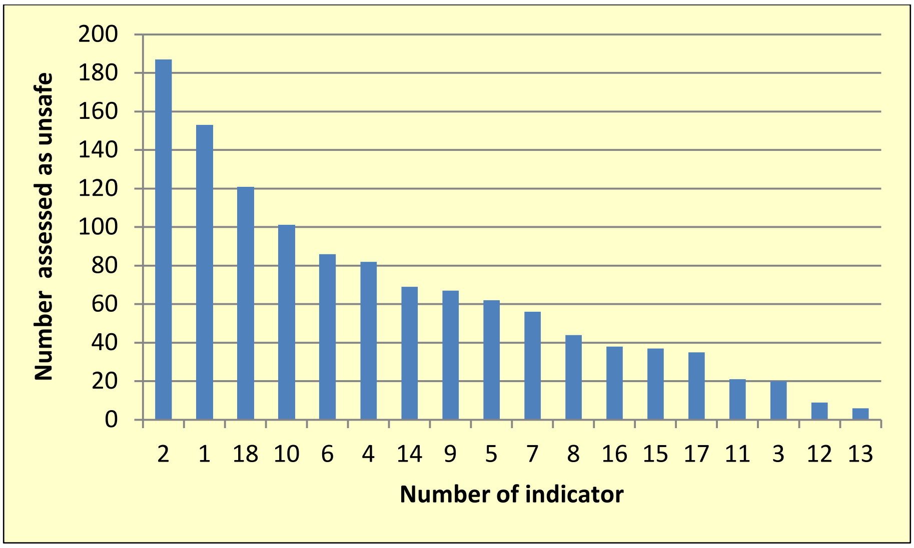

Figure 5.3. *Number of times that a characteristic of the cycling infrastructure (indicator) was assessed as unsafe across all the routes combined.*

The text box below lists the indicators, given in descending order of frequency.

Indicators; arranged in order of the number of times assessed as unsafe

2.	Poor road surface (e.g. cracks, holes, loose paving, gravel or chippings)
1.	Road, cycle path or cycle lane too narrow
18.	Other, namely: …
10.	Dangerous junction/fork
6.	Obstacle on or alongside the road (e.g. fence, hedge, bollard, lamppost, tree, parked car)
4.	Poor road marking (e.g. none or hard to see)
14.	Inadequate signposts (e.g. none or hard to see)
9.	Hindered by other traffic
5.	Road surface uneven (e.g. speed bumps, tram/train tracks, manhole covers)
7.	Hazardous verge or road edge (e.g. kerb, downward slope, gully)
8.	Hazardous/inconvenient bollard on the road
16.	Risk of slipping (e.g. sand, clay, grit, oil on the road)
15.	Road works
17.	No lighting/inadequate lighting
11.	Dangerous bend
3.	Pools on the road (e.g. inadequate drainage, blocked drain)
12.	Dangerous incline
13.	Hazardous exit

The two most frequently mentioned indicators (2 and 1) relate to the quality of the cycling infrastructure. This is probably because both the quality and the width of the road surface form a standard part of the cycling infrastructure, while obstacles are present at only a small number of places. This is also the case for junctions, which are frequently mentioned as unsafe.

Indicators relating to the longitudinal/elevation profile are mentioned relatively infrequently as unsafe (17, 11, 12 and 13). However, it is not known how many inclines and exits, for example, were found on the routes. It is striking that the indicator ‘dangerous bend’ is one of the four least frequently mentioned indicators. This may be because junctions generally involve sharp bends and this may have been taken into account in the assessment of the junction.

As an illustration, we set out below the four most frequently mentioned indicators, with a brief summary of the participants’ findings.

- *Indicator 2: poor road surface*

The most frequently mentioned comment is that there are holes and cracks in the road surface. Participants also mentioned subsided paving stones on a number of occasions. Uneven manhole covers and ramps on the cycle path are also mentioned.

- *Indicator 1: road, cycle path or cycle lane too narrow*

Under this indicator participants mentioned in particular excessively narrow cycle lanes on a carriageway.

- *Indicator 18: other*

This category covers all the other situations participants found unsafe, namely:

− busy spots, for example many pedestrians/tourists;
− situations where the layout is poor;
− low-hanging branches;
− no priority for bicycles on roundabouts;
− clumsy priority situation between cyclists;
− road layout: getting into lane
− differing asphalt colours on cycle path.

- *Indicator 10: dangerous junction/fork*

  The following situations are mentioned under this indicator:
  − dangerous crossing/poorly laid out junctions;
  − unclear priority situation;
  − unclear side roads;
  − traffic lights: green simultaneously for cyclists going straight ahead and cars turning;
  − crossings with two-way car traffic;
  − no priority on roundabouts;
  − change of side of road for cyclists (not clearly signposted);
  − no separate crossing point for cyclists.

5.3.3. *Assessments according to characteristics of cyclists*

Age and gender
No major differences were found between the assessments made by men and by women and the age of the participants. As far as age is concerned, two indicators were mentioned in particular by people over 65: dangerous inclines and pools on the road. However, overall these were mentioned relatively infrequently. Inclines might conceivably be regarded as unsafe because of balance problems, for example if the speed drops on an incline or when mounting or dismounting on an incline.

Type of bicycle
The most commonly used types of bicycle were the city bike and the electric city bike. Fewer people used a touring or racing bike, electric folding bike, mountain bike or trekking bike. No major differences were found between the assessments involving these types of bicycle.

Cycling alone or in pairs
The majority of participants rode the route in the company of someone else. Each pair filled in a single form. In the assessment of the first six indicators there were a few differences between the assessment by pairs and that by solo cyclists. *Table 6.1* shows the top six.

Top six indicators mentioned as unsafe		
No:	**Solo cyclist**	**Two cyclists**
1	Dangerous junction/fork (10)	Poor road surface (2)
2	Inadequate signposting (14)	Road, cycle path, lane too narrow (1)
3	Road, cycle path, lane too narrow (1)	Obstacles on or alongside the road (6)
4	Poor road surface (2)	Anders (18)
5	Obstacles on or alongside the road (6)	Road surface uneven (5)
6	Road works (15)	Dangerous junction/fork (10)

Table 5.1. *Top six indicators mentioned as unsafe by solo cyclists and by cyclists riding in pairs.*

A striking point is that solo cyclists frequently found junctions (indicator 10) and the absence of signposting (indicator 14) dangerous. In the case of signposting the reason might be that those concerned were looking at which road to take and paying less attention to other traffic.

The indicator 'poor road surface' (2) was assessed less frequently as unsafe by cyclists riding on their own. This might be because it is easier for them to swerve to avoid worn patches on the road surface.

5.4. Conclusions from the perception survey

The following conclusions may be drawn from the perception survey:

1. Indicators that have been included in the expert system are mostly those assessed as unsafe by the cyclists. It is not clear, however, how frequently different unsafe characteristics occurred in the routes (on the

basis of another method of observation, for example). Partly for this reason the results are of a descriptive nature.

2. Specific indicators such as ‘poor road surface’, ‘width of the cycling infrastructure’ and ‘dangerous junctions’ are those that are most frequently assessed as unsafe.
3. Indicators relating to the longitudinal/elevation profile (lighting, incline, profile) are assessed relatively infrequently as unsafe. An incline is assessed as dangerous mainly by older people.
4. In general there are no differences between the assessments made by men and by women, or according to age group or the type of cycle ridden.
5. There are a few differences in the assessments made by solo cyclists and those riding in pairs. For instance, the indicator ‘poor road surface’ (2) is assessed less frequently as unsafe by cyclists riding on the own; This might be because it is easier for them to swerve to avoid worn patches on the road surface.
6. The results justify the addition of more specific attention for the characteristics of junctions.
7. The perception survey does not provide any reason to develop variants of the expert system for specific target groups (gender, age, type of bicycle).

Recommendation:
Use the developed expert system on the routes of the perception survey. This would make it clear whether the opinions of participants in the perception survey and the assessments under the expert system are comparable.

6. Conclusions and recommendations

This report describes the ANWB Safe Cycling Network project, which was inspired by the method developed by EuroRAP to assess the safety of road infrastructure. The objective of this project is to develop an expert system that enables road authorities to assess the cycling infrastructure and therefore bicycle safety (see *Appendix A*). A set of 25 indicators, linked to specific categories, has been developed for this purpose.

To be able to apply the expert system, a working method involving two instruments was chosen:, a checklist of indicators and the assessment of the cycling infrastructure on the basis of 360-degree panoramic images. This working method was then applied in two pilot projects in the municipalities of Harderwijk and Goes. Furthermore, a perception survey was carried out to see how cyclists experience these indicators in practice.

In this final chapter we present the conclusions and recommendations based on the experience acquired in developing the expert system.

6.1. Conclusions

1. *The factors that affect the safety of the cycling infrastructure have been identified.* The static factors (related to cycling infrastructure), such as the width of paved surfaces, verge quality and obstacles on the paved surface have been operationalized.

2. *The dynamic factors have not yet been fully studied and operationalized. Literature shows that the traffic volume (exposure), in combination with other factors, has an influence on the risk of a crash. Consequently, this is also an important factor .*

3. *The expert system makes it possible to:*
   - systematically collect and compare data on the safety of the cycling infrastructure
   - identify (and view images of) locations where the safety level of the road layout is indicated by one or more of the indicators.

4. *With the expert system it is not yet possible to arrive at a single safety score for each road section on the basis of the indicators. This is because there is currently insufficient knowledge of:*
   - the influence of bicycle traffic volume (exposure) on the risk of crashes;
   - a formula that incorporates the indicators and consideration factors to form a single final score *for each road section* (the output of the system).

5. *The system must be validated. It is not known whether locations that the system has assessed as unsafe actually represent a relatively big risk of a cycling crash. A lot of essential data is missing, namely about:*

- the bicycle traffic volume (exposure);
- the location, facts and consequences of cycling crashes.

That knowledge is necessary for investigating whether crashes occur relatively frequently in places that the expert system has assessed as unsafe.

6. *There is insufficient knowledge of the degree to which different people code the indicators of the cycling infrastructure in a similar manner.* That knowledge is needed in order to be able to improve the reliability of the indicators.

7. *The system has been developed for application in the Netherlands. In other countries there might be additional indicators that affect the safety of the cycling infrastructure.*

6.2. Recommendations

Based partly on the conclusions, the following recommendations are made:

1. *Try to align to the EuroRAP method.*
   This offers the following possibilities:
   - Interchange of knowledge for the purpose of further developing the system. The main aspect that needs to be developed is the weighting of indicators in relation to each other. This should lead to a single safety score per road section, making integral prioritization possible. It must then be clear what indicators have contributed to each score.
   - Application of the expert system outside the Netherlands and adapting it to the prevailing situation there.
   - Management of the system so that it is possible to compare research results (inside and outside the Netherlands).

2. *Decide the validity (relationship between the safety score and the* risk *of a cycling crash) of the system.*
   To determine the validity we recommend:
   - Ensuring that regional and local government make more data available on dynamic factors, in particular the volume (exposure) of bicycle traffic.
   - Ensuring that cycling crashes are properly registered (location, facts, consequences). For example, ANWB can encourage research into the application of mobile technology and services that allow cyclists to register crashes with a hotline.
   - Testing the safety score empirically (determine the correlation between the safety score and the risk of a cycling crash). This survey should show whether locations considered to be unsafe according to the expert system are actually locations where a relatively large number of crashes occur. This was initiated in the pilot 'Eleven Cities Cycling Tour' in the province of Fryslân.

3. *Establish whether the indicators have been coded reliably by finding out whether they are consistent when they have been set by different people.*
4. *Ensure that road authorities are involved in further developing the safety score of the system by carrying out pilots in practice, such as the pilots in Fryslân.*

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Appendix A Safe Cycling Network: Observation and scoring safety of cycling infrastructure

The Safe Cycling Network system offers a systematic method of observing the safety of the cycling infrastructure per 25 metres of road length. A number of indicators were chosen for the evaluation; these are shown in an Access interface (*Figure 4.3*), and each of them is described in the section 'Indicators and their operationalization'. The table below lists the 25 indicators; the category for each indicator is explained in more detail. In the report on the results of the study, a number of indicators were grouped in clusters. The table also shows the 4 clusters into which the indicators were grouped:

1. General quality of the cycling infrastructure;
2. General obstacles;
3. General longitudinal/height profile;
4. Number of obstacles (cyclist must avoid contact in order to prevent a crash).

Indicator	Description	Cluster
Intensity	Number of vehicles an hour in morning rush hour traffic	
Sort of intersection	Differentiate types of intersections	
Driving direction	One or two-way cycle traffic on cycling facility	
Facilities	Differentiate cycling facilities, such as cycle path, cycle lane, suggested cycle lane	
Location	Solitary or not, inside or outside built-up area, large or small chance of other use	
Width of hard surface	Full width of hardened surface of cycling facility	1
Type of hard surface	Differentiate the various forms of hard surfaces	
Quality of hard surface	Cracks, holes, or bumps in hard surface	1/4
Exits	Presence or absence of exit from company, house, parking area, etc.	
Sharp curve	Presence or absence of sharp curve	3
Visibility in curve	Limited view of side or length of cycling facility	3/4
Speed limit	Speed limit on the carriageway (km/hour)	
Narrowing	Sudden change in width of cycling facility	3
Height profile	Incline on cycling facility	3
Quality of transition	Transition from facility to verge: cracks, holes, difference in height	1/4
Type of transition	Further details of transition	
Street lighting	Present or absent	3
Road markings	Presence or absence of side markings, central markings	1
Pole in path	Pole placed in hard surface	2/4
Visibility of pole	Visibility of pole/presence or absence of markings	2
Presence of median island	Median island in hard surface	2/4
Visibility of median island	Visibility of median island	2
Quality of verge	Extent to which cyclist can keep balance in verge	1/4
Type of verge	Differentiate sorts of verges	
Distance obstacle	Distance from obstacle to hard surface	2

The evaluations were done using Cyclomedia images (*Figure A.2*)..

The following section contains instructions for using and evaluating the collected data.

The result of the evaluation is to determine the extent of safety per 25 metres of road length based on the number of indicators that point to unsafe situations. An example of this is described in the section 'Output of Access data'.

The following is needed to carry out the evaluation:

- Cyclomedia images of the cycling infrastructure
- Access interface with indicators

The documents included below are:

- Instructions to the evaluator;
- Access input window of indicators;
- The Cyclomedia screen with images being evaluated;
- Indicators and their operationalization;
- Output of Access database.

Instructie aan de beoordelaar

Observaties worden uitgevoerd op de volgende wijze:

1. Er wordt gebruik gemaakt van een invoerscherm in Access (zie *Afbeelding A.1*).

2. Daarnaast wordt gebruik gemaakt van CycloMedia beelden (*Afbeelding A.2*) die zijn gemaakt van de rijbaan en waarop ook de fietsinfrastructuur zichtbaar is. Als de fietsinfra te slecht of niet zichtbaar is zodat geen oordelen kunnen worden gegeven, dan dit aangeven. Bij elke indicator is dit een mogelijke score. In *Bijlage C* is de gebruikershandleiding van CycloMedia toegevoegd.

3. Observaties worden per straat per wegvak uitgevoerd (van kruispunt naar kruispunt). Het wegvak is opgedeeld in een aantal segmenten van elk 25 meter (5 stippen die elk 5 meter uit elkaar staan) die worden beoordeeld. Na elke kruising opnieuw beginnen met het beoordelen van een segment van 25 meter. Dit markeren door de URL na dat kruispunt in het invoerscherm te kopiëren.

4. Bij het begin van elke straat wordt de naam van de straat genoteerd waar gestart wordt (naam Van) tot het eind van de straat (naam Tot).

5. Er wordt voor het eerste segment van 25 meter een score gegeven voor elk item.

6. Bij elk volgende segment van 25 meter worden uitsluitend de veranderingen aangegeven ten opzichte van het voorgaande segment. Wanneer bij het invoerscherm rechtsboven de middelste knop rechtsonder wordt aangeklikt komt er een nieuw scherm waarin de vorige gegevens zijn overgenomen.

7. Bij een tweerichtingen fietspad wordt de totale (2 richtingen) breedte geschat. Daarbij wordt er één beoordeling (Heen) gemaakt gebaseerd op aspecten die voor (één van de) beide rijrichtingen van belang zijn.

   Als er aan beide zijden van een rijweg een aanliggend/ vrijliggend fietspad is, dan moeten beide aanliggende/vrijliggende paden apart worden beoordeeld (Heen en Terug).

   Als er op een rijweg geen vrijliggende fietsvoorziening is (ook geen belijning), dan moet de volledige breedte van de rijweg worden beoordeeld; analoog aan het tweerichtingenfietspad.

Bij een aantal items zijn de categorieën Voldoende, Aandachtspunt , Knelpunt gegeven. Als er op het te beoordelen weggedeelte van 25 meter voor een indicator tenminste 1 knelpunt is, dan knelpunt aangeven (geen aandachtspunt). Bij ten minste 1 aandachtspunt: aandachtpunt aangeven. Deze scoringswijze geldt voor alle items die deze categorieën onderscheiden.

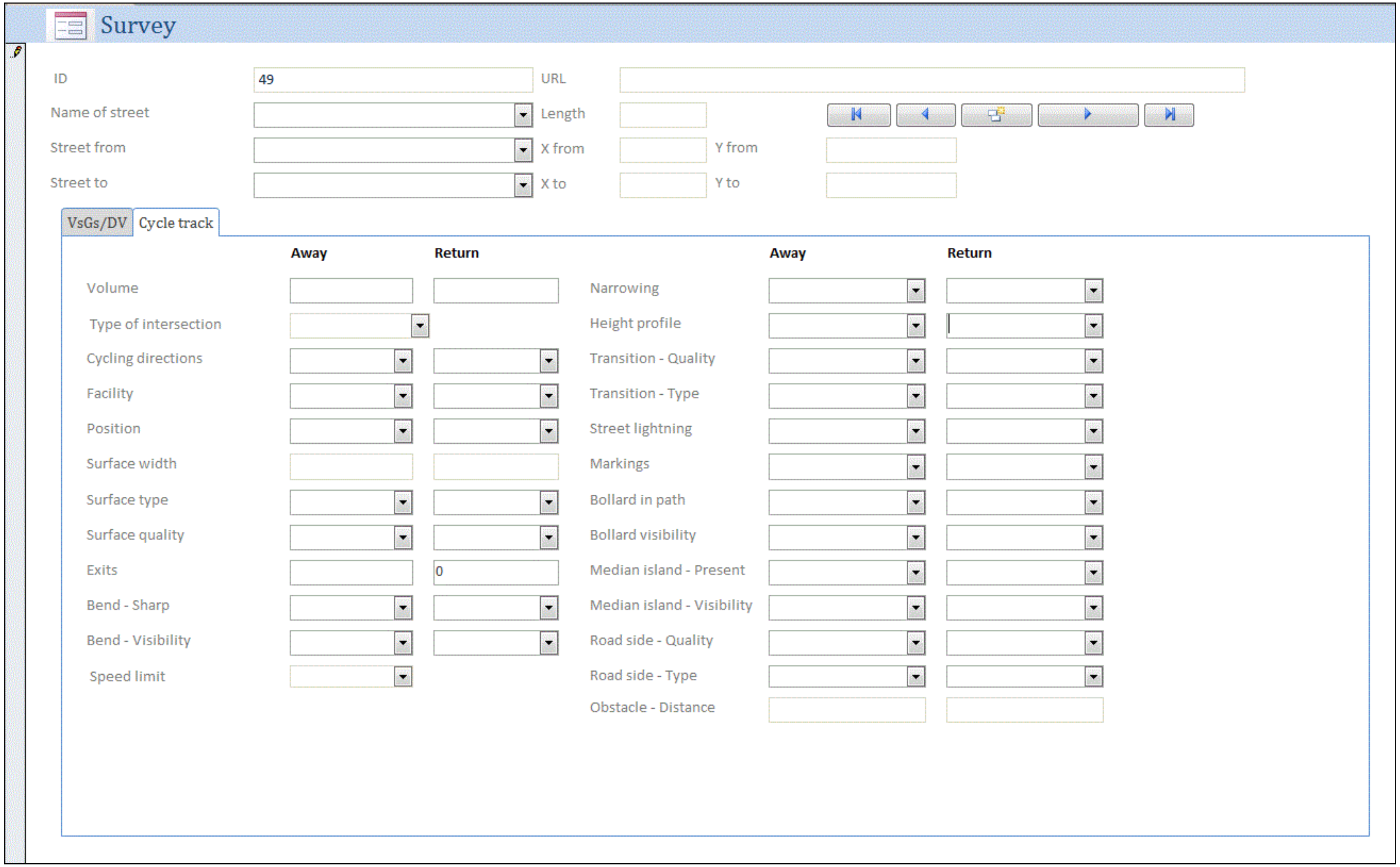


Figure A.1. *Access input screen with the indicators for Safe Cycling Network assessments of the cycling infrastructure*

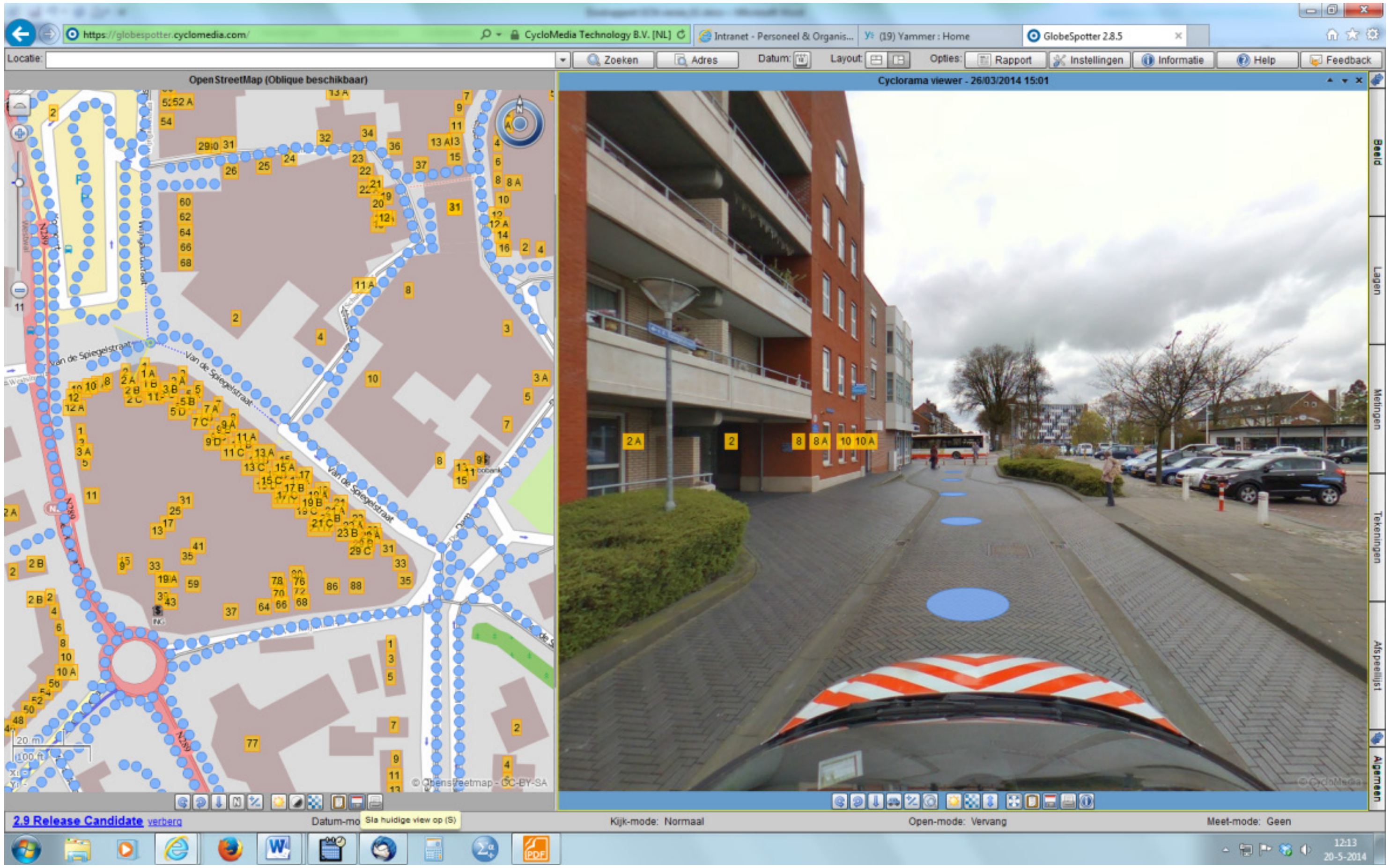


Figure A.2. *The Cyclomedia screen that the evaluator sees when making the evaluation.*

Indicators and their operationalization

The input window (Figure 1) displays the following (input) fields of the indicators with related categories.
From top to bottom and from left to right:
The following fields are used to determine the location of the evaluation:

Id
This is the counter that continues to run with each successive evaluation of 25 metres. Cannot/Must not be adjusted.

URL
Copy from Cyclomedia window for input of new street/cycle path and for each new road surface (after intersection or roundabout).

Name of street
Name of the street/cycle path to be evaluated.

Name of street from

For a new street, indicate the starting point for the street/cycle path (what street does it connect to?).

Name of street to
For a new street/cycle path indicate where it ends.

Lengte [Length]
Length of the street in metres.

X from, Y from; X to, Y to
Cyclomedia coordinates from the beginning and end of the street.

Away, Return

Observation in the direction being observed (van-tot/from-to) ‘Heen’. This is the basic direction of observing cycling facilities. Observations in the other direction ‘Terug’ are done only in situations where there is a separate/adjacent cycle path on the other side of the road.
The indicators are:

Volume
Number of vehicles (including bicycles) per hour during the morning rush hour (7-9 am). This information must be provided by the municipality. Preferably give the exact number; if not possible, an estimate.

Intersection type (intersection/roundabout/cycle crossing)
Indicate the type of intersection per street, including the intersection at the beginning and end of the street in question. Differentiate the following types:

1. Junction without priorities (3-legged/4-legged);
2. Right-of-way junction (3-legged/4-legged);
3. Traffic lights (3-legged/4-legged);
4. Roundabout;
5. Crossing; Also applies if the cycling facility is >10 metres from intersection.

Cycling direction

1. One-way path
2. Two-way path

Facility

1.	Moped/cycle path	Cycle path shown by G12a sign (changed Traffic Regulations 1990) and available to cyclists and mopeds (used in situations in which mopeds are not allowed on the carriageway for fast traffic)
2.	Cycle path	CROW, Nomenclature of road and traffic (2001): road, traffic lane or carriageway for cyclists, light mopeds and mopeds.
3.	Cycle lane	Lane with image of bicycle painted on road surface
4.	Suggested cycle lane	Lane without image of bicycle suggested for cyclists
5.	Carriageway	No road markings for cyclists
6.	Other:	*Enter text here*

Location / Surroundings
Explanation:
Separate cycle path: cycle path that either runs parallel to the adjacent carriageway and is separated from it by a verge or one that follows its own trajectory;
Cycle path: cycle path that is separated from the adjacent carriageway by a very narrow verge or one that lies higher than the carriageway.

1. Solitary or separate, *Inside the built-up area* Separate from carriageway, separated by physical facility (e.g. difference in level, greenery). Also cycle path through a park and not along a carriageway.
2. Solitary or separate, *Outside the built-up area*
3. Not Solitary or separate, *Inside the built-up area*
4. Not Solitary or separate, *Outside the built-up area*
5. Not applicable/unknown

Surroundings is used to differentiate other uses of cycle infrastructure

1. Recreation area, park, woods Large chance of other uses
2. Shops/schools Large chance of other uses
3. Other, namely:

Surface Width (measured in centimetres)]

Surfac Type [Hard surface – Type]

1. Asphalt
2. Cement
3. Elements (e.g. tiles, bricks, stones)
4. Layer of pebbles/stones
5. Other, namely: *Enter text here*

Surface Quality: splits (S), holes (G), bumps (H)]

1. Sufficient

   Almost no S,G,H. This applies to surface on which people cycle. Pay attention to:

   - Drains and other facilities that can cause bumps
   - The edge of the cycle path. This may be crumbled or otherwise damaged

2. Point of attention

   Small amount of S,G,H; no acute danger of losing balance; uncomfortable

3. Problem

   Large amount of S,G,H; large chance of losing balance; avoid contact

Exits

Present or not	Per 25 metres of street, cycle path. These are exits from companies, houses, parking areas, etc. (NB: This does not include the exit of an intersection).

Curve – sharp

1. No curve or curve is slight	Can continue to cycle in the curve without going onto the other half of path
2. Sharp curve	Need to reduce speed in curve, stop peddling, large chance of cycling onto the other half
	Count number of curves per 25 metres

Curve – visibility

Explanation:

View from path of: side road, exit, course of path, oncoming traffic

1. Visibility not obstructed
2. Visibility somewhat obstructed (cyclist can continue to cycle but needs to pay attention)
3. Serious obstruction (focus on path, need to brake or slow down for enough visibility)

Speed limit of carriageway (km/h)

1. 30
2. 50
3. 60
4. 70
5. 80
6. 100
7. 110
8. 120
9. 130

Narrowing

1.	None or slight	Hardly any change in course needed, for example in the case of a gradual narrowing
2.	Considerable	Requires active steering, especially if narrowing occurs suddenly (e.g. obstacle). For example, cyclists next to one another have to cycle behind one another

Height profile

1.	Flat	
2.	Incline/Decline	Less peddling, more strength or cycling in lower gear when going up an incline

Transition – quality

1.	Sufficient (flat)	The difference in height between the cycle path and the verge is important. A verge can, for example, be worn down so there is a ditch right next to the path. Or the asphalt can be higher than the verge. Sometimes there is no clear transition, as in the case of bushes or a hedge right next to the path. You can consider this an obstacle and/or an aspect of the quality of the verge.
2.	Point of attention	Slight difference in height profile; S,G,H; no acute danger of losing balance; uncomfortable
3.	Problem	Large difference in height profile; S,G,H, large chance of losing balance; avoid contact

Transition – type

1.	Flat	
2.	Kerb – can be cycled over	Very flat, inclined kerb (can be cycled over without affecting balance
3.	Kerb – cannot be cycled over	Very inclined or vertical kerb that affects balance if cycled over
4.	Sharp edge of road surface (cement/slabs)	
5.	Gulley	For example, from rainwater runoff
6.	Fence, wall	
7.	Other, namely:	For example, greenery

Street lighting

1. Present
2. Not present

Road markings

1. Centre line marking
2. Side line marking
3. Centre and side line marking
4. No marking

Bollard in path

1. Yes
2. No

Bollard – Visible

1.	Sufficient	Well visible (lit or contrasts with background) with profiled road markings
2.	Point of attention	No profiled road markings but is visible
3.	Problem	No profiled road markings, not visible
4.	Not applicable	

Median island – present

1. Yes
2. No

Median island – visible

1.	Sufficient	Well visible (lit or contrasts with background) with profiled road markings
2.	Point of attention	No profiled road markings but is visible
3.	Problem	No profiled road markings, not visible
4.	Not applicable	

Verge – Quality **Good definition of verge; is an adjacent pedestrian path a verge?**

1.	Sufficient	Good for cycling; flat and no obstacles within 1 m
2.	Point of attention	No acute danger of losing balance, but uncomfortable
3.	Problem	Large chance of losing balance; avoid contact (also with greenery on verge such as hedge, bush or wall, fence, slope etc.) Special cases are parking spaces with or without parked vehicles. Also residential streets with possible parked vehicles. Then there is no margin (verge) to change course or make a correction for the sake of balance.

Verge – Type **Add features of verge**

1. Grass
2. Continual greenery consisting of plants, bushes, hedges
3. Earth/sand/clay
4. Pebbles/gravel
5. Hard surface
6. Parking space
7. Other, namely:

Obstacle – Distance

Explanation:

This concerns obstacles that cyclists can hit (poles, trees, etc.) as well as other dangers such as a side slope of a quay or ditch/canal.

1. Adjacent to hard surface
2. <0.5 metres
3. 0.5-1 metres
4. 1-2 metres
5. >2 metres
6. Not applicable

Output of Access database

We have decided not to make one total score for the safety of the cycling infrastructure but rather to begin with a number of scores based on the contents of related indicators (clusters). We chose to clearly indicate the scores with respect to their related content indicators. The form in which the output will be shown is still under development and has to be discussed with other users (such as road managers).

In this phase, not all indicators have been included in the clusters; a number can be used to make separate categories, such as:

- Type of cycling infrastructure.
- One-or two-directional cycle path.
- Speed limit

The following four clusters have been created based on contents:

1. General quality of the cycling infrastructure

Consisting of:

1. Width cycling facility (0-2 metres of 0-3 metres =1[10])
2. Quality transition (point of attention/problem=1)
3. Quality of hard surface (point of attention/problem=1)
4. Quality of verge (point of attention/problem=1)
5. Road markings (no markings =1)

The quality score is composed of evaluations per 25 metres. If in one 25-metre evaluation a situation is found in which the width of the cycle path is 0-2 metres, the quality of the transition and the verge is a point of attention or a problem and there are no road markings, a score of 4 is awarded. No distinction is made between points of attention and problems; the problems constitute a separate score.

The evaluation indicates that the quality of the cycling infrastructure becomes less safe as the number of indicators of unsafe situations increases:

- Score of 0: no safety problems

[10] A score of 1 indicates a danger; the higher the score, the greater the danger. Per each 25-metre observation, this score can be a maximum of 5.

- Score of 5: maximum number of unsafe indicators

2. General obstacles

Consist of:

1. Pole in hard surface (yes=1)
2. Visibility of pole (point of attention/problem=1)
3. Median island in hard surface (yes=1)
4. Visibility of median island (point of attention/problem=1)
5. Distance to obstacle in verge (0-1 metres=1)

The scores are formed as explained above for the quality of the cycling infrastructure; an evaluation per 25 metres.

3. General longitudinal/height profile

Consists of:

1. Curves (sharp=1)
2. Visibility in curve (somewhat/seriously impeded=1)
3. Height profile (ascending/descending=1)
4. Narrowing (considerable=1)
5. Street lamp (no=1)

The scores are formed as explained above for the quality of the cycling infrastructure; an evaluation per 25 metres.

4. Number of problems

A separate score is made based on the number of problems scored for each 25 metres. The problems are the most serious unsafe situations in the cycling infrastructure that a cyclist must avoid to prevent an accident.

Consists of:

1. Visibility in curve (problem (3)=1)[11]
2. Quality of transition (problem (3)=1)
3. Quality of verge (problem (3)=1)
4. Quality of hard surface (problem (3)=1)
5. Pole in path (problem (2)=1)
6. Median island (problem (2)=1)

The scores are formed as explained above for the quality of the cycling infrastructure; an evaluation per 25 metres.

[11] A score of (3) or (2) is the 'problem' score for each of these 6 evaluation categories

Example of a report

For each 25-metre evaluation, a score is given based on the quality, the obstacles and the longitudinal/height profile.

Table 1 below shows an example consisting of fictitious numbers to illustrate how a report is made. This example illustrates the frequency spread of the quality scores of the cycling infrastructure for moped/cycling paths with one-way traffic.

Quality moped/cycle paths; one-way traffic				
Quality score Number of unsafe indicators per 25 m		**Frequency**	**Percentage**	**Cumulative Percentage**
	0	40	8,0	8,0
	1	90	18,0	26,0
	2	300	60,0	86,0
	3	60	12,0	98,0
	4	10	2,0	100,0
	5	0	0,0	100,0
	Total	500	100,0	

Table 1 *Frequency spread of the quality scores for scooter/cycle paths with one-way traffic (fictitious numbers)*

The above table shows the frequency with which 0, 1 or more of the five situations above (point of attention/problem) was found in 1 evaluation of 25 metres. In this example: in none of the 40 evaluations were the five situations found (thus, safest). In 10 evaluations four points of attention/problems were found for the total of five indicators. From the perspective of the road manager, the locations of these 10 evaluations are the most important because a combination of four risks was found there.

For every evaluated stretch of road, a location has been included in the database in a code that gives direct access to photos of the stretch of road in question in Cyclomedia. Using this information, the road manager can see photos of concrete details of the locations with the most risks and can take the necessary measures.

Appendix B Expert session 13 September 2013

The following is a list of the 12 participants in the meeting of experts held in Utrecht on 13 September 2013 to select the cycling safety factors.

Name	**Organization**
Hillie Talens	CROW
Paul Schepers	WVL
Sipke van der Meulen	Provincie Fryslân – ROF
Lippe van der laan	Provincie Fryslân – ROF
Frank Twiss	ANWB
Frans de Kok	ANWB
Peter Morsink	DHV
Arnoud Hoogstraat	DHV
Minke Pronker	Provincie Gelderland
Atze Dijkstra	SWOV
Jan Hendrik van Petegem	SWOV
Gert Jan Wijlhuizen	SWOV

Work was done as follows:

The point of departure was the list of factors shown in *Table B.1*. This list was composed from the literature study as described in the previous section. The central issue are the *Static* factors focusing on the cycling infrastructure.

	Cycle path	Coupling with factors from section 2.6
1	Type of cycle path (extent to which cyclists are separated from other traffic participants)	3b
2	Location (separate, adjacent, intersections, crossings)	2a
3	Cycling direction	3b
4	Intensity of cycling traffic	6
	Alignment	
5	Longitudinal profile (number of curves)	4
6	Height profile (inclines)	4
7	Curves (sharpness of curves)	4
	Hard surface of cycle path	
8	Width of hard surface	1b
9	Quality of hard surface (cracks, holes, irregularities, etc.)	1a
10	Temporary hard surface (e.g. for road works)	1a
11	Slipperiness (snow, sand, etc.)	1a
12	Lighting (street lighting)	1d
13	Markings (road markings)	1c
14	Drain covers	1a
	Obstacles	
15	Poles and median islands	1a
	Shoulder	
16	Transition from hard surface to verge (kerb, gutter)	1c
17	Quality of verge (hard, not hard, holes, etc.)	1c
18	Obstacles in verge	1a

Table B.1. *Static factors safety of cycling infrastructure at beginning of the Expert session and coupling with factors in Section 2.6.*

The list of factors was examined in two rounds.

Round 1
In the first round the experts discussed the need to make changes to the list. Which factors could be dropped and which should be added. The result of this round is a possibly altered list of factors on which there is a consensus. The participants studied the desired changes to the list of factors in three subgroups and the results were then discussed by all participants.

Round 2
In round 2 the participants indicated which factors on the adjusted list they considered to be most important. Scores could range from 0 (no one thought the indicator was important) to 9 (all 9 non-SWOV participants). *Table B.2.* shows the importance score of each indicator. The participants could give a positive assessment to a maximum of 10 factors.

	Cycle path	Importance of indicator
1	Type of cycle path	2
2	Location	1
3	Cycling direction	6
4	Intensity of cycling traffic	5
	Alignment	
5	Longitudinal profile	2
6	Height profile	2
7	Curves	5
	Hard surface of cycle path	
8	Width of hard surface	8
9	Quality of hard surface (cracks, holes, irregularities, etc.)	8
10	Temporary hard surface (e.g. for road works)	4
11	Slipperiness (snow, sand, etc.)	5
12	Lighting (street lighting)	2
13	Markings (road markings)	6
14	Drain covers	3
	Obstacles	
15	Poles and median islands	9
	Verge	
16	Transition from hard surface to verge	6
17	Quality of verge	5
18	Obstacles in verge	4
	Additions by experts	
19	Discontinuities (9)	3
20	Greenery (visibility obstructed)	2
21	Contrasts (13)	1
22	View of road (visibility obstructed)	1

Table B.2. *Total of factors after consultation of experts showing a score of the importance of each indicator for traffic safety (0-9 in order of increasing importance).*

Appendix C Cyclomedia Quick Start Guide

The following pages (109-117) contain the Cyclomedia Quick Start Guide.

GlobeSpotter Quick Start Guide

Version: 131203

T +31 418 556100 | **E**: info@cyclomedia.com

Index

Welcome to the world of GlobeSpotter. We will briefly show you all its features in this Quick Start Guide.

More information

More information in Dutch about the functions of GlobeSpotter can be found on https://globespotter.cyclomedia.com/v28/viewer/manual/index.html?lang=nl.

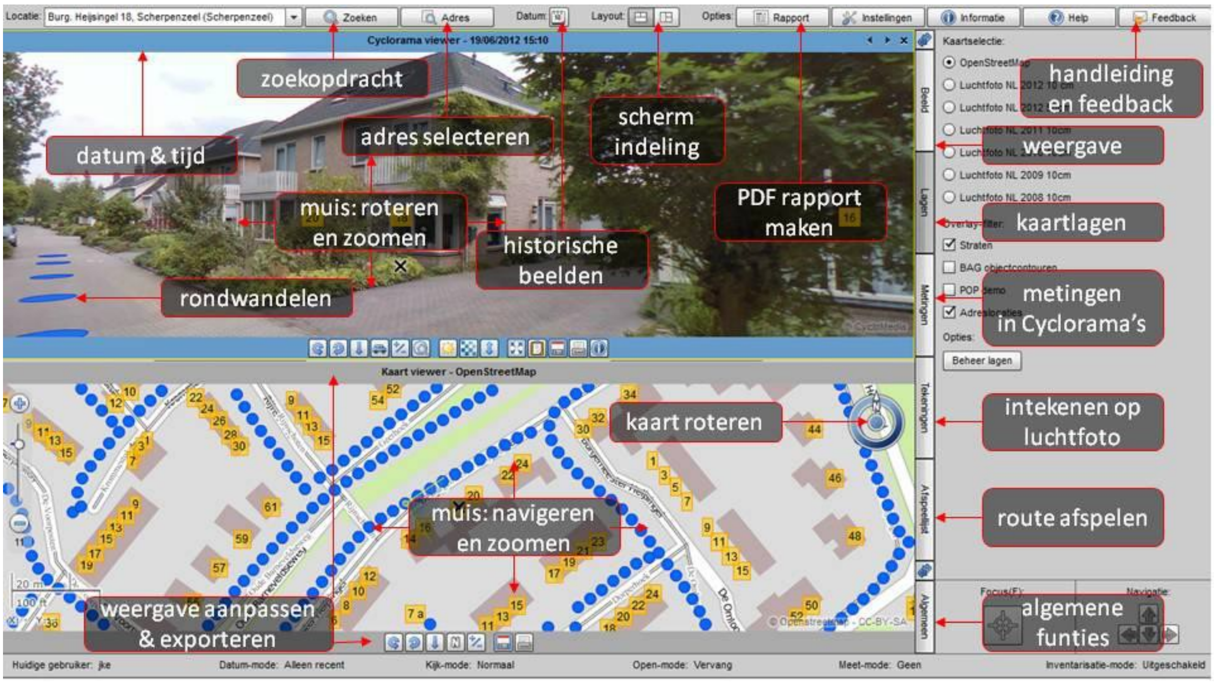
Need support?

Please feel free to contact CycloMedia if you have any questions or need support.

T +31 418 556100 **| E**: info@cyclomedia.com.

Introduction

The GlobeSpotter application provides access to 360-degree photos throughout the Netherlands. The file is updated once yearly. Historical photos are also available. In addition, materials may have been retrieved locally, e.g. images shot from the water or from a helicopter or detailed images of the street or facades. Furthermore, annually updated aerial photos throughout the Netherlands with a 10 cm resolution are available.



Searching and navigating

You can zoom into the map, enter a search command or select an address from the list. The search function is based on the National Facility for the Basic Registration of Addresses and Buildings (BAG).

Standard map layers

Annually updated aerial photos throughout the Netherlands with a 10 cm resolution are available. An OpenStreetMap is provided for orientation purposes. The streets can also be shown on top of the aerial picture. The BAG layer provides access to the outlines of buildings from the BAG.

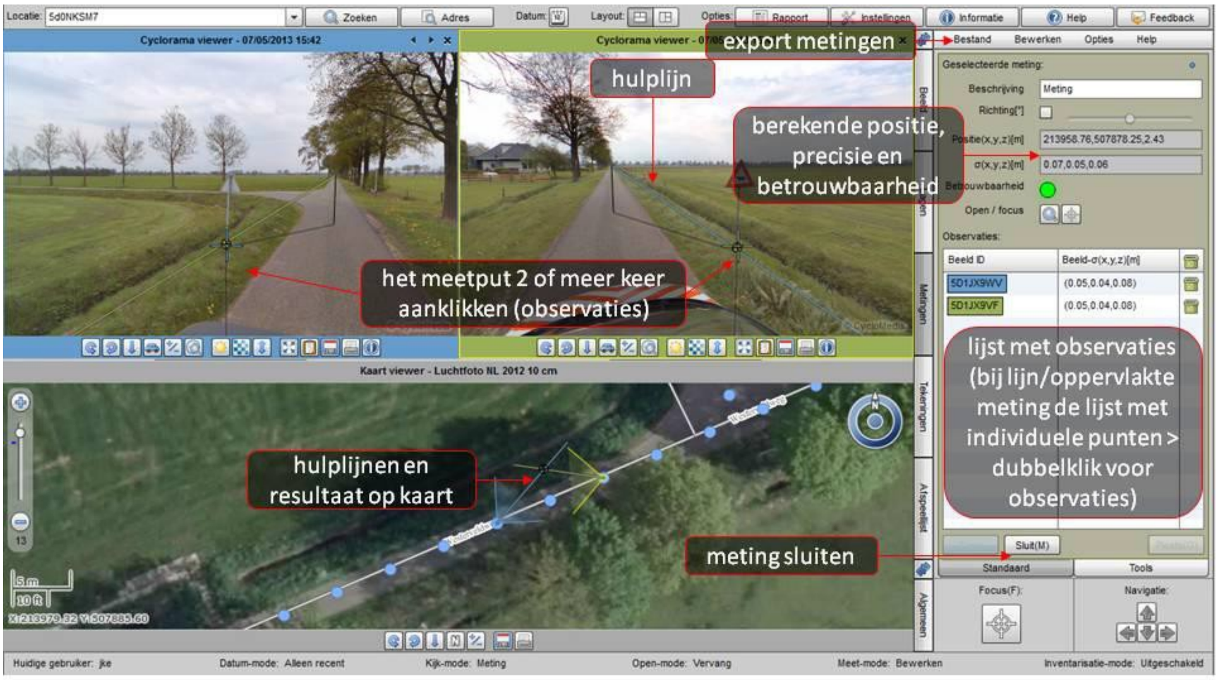
Viewing oblique images

Images from NederlandObliek can be shown in the map window from all four main directions.

Making measurements

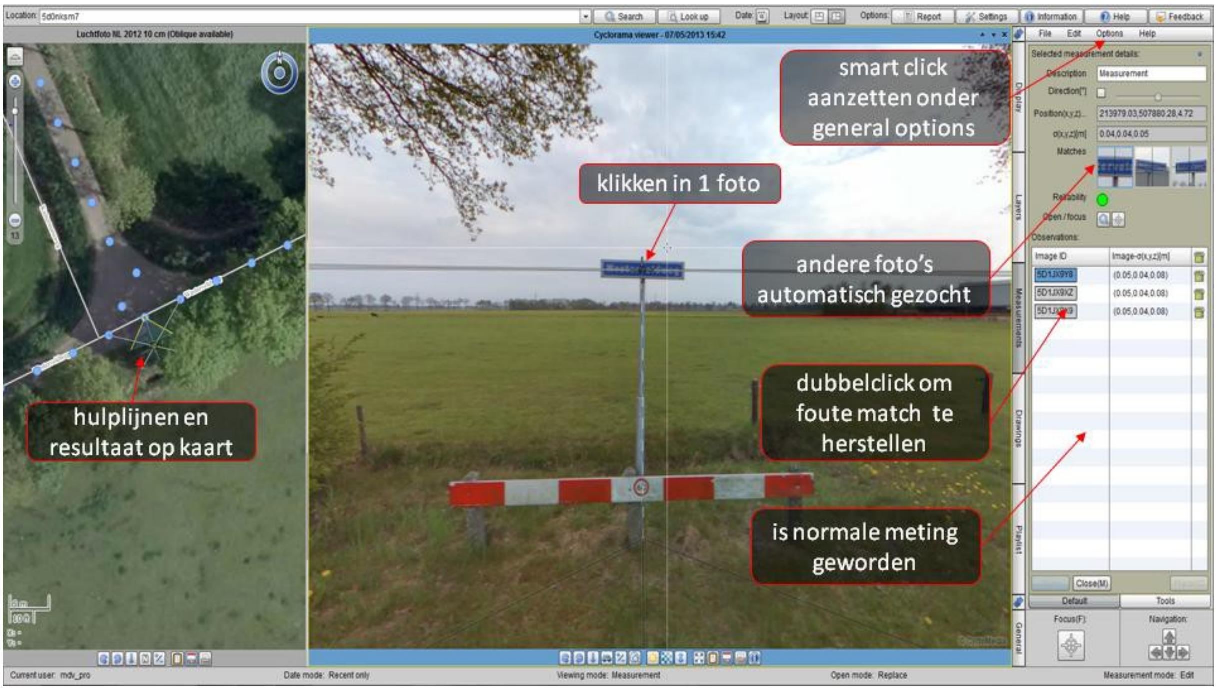
Positions and dimensions of visible objects can be measured. This allows you to measure e.g. lampposts or the height of houses.

Measurements are based on triangulation: you need two or more images. Zooming in and using more images will improve accuracy and reliability.



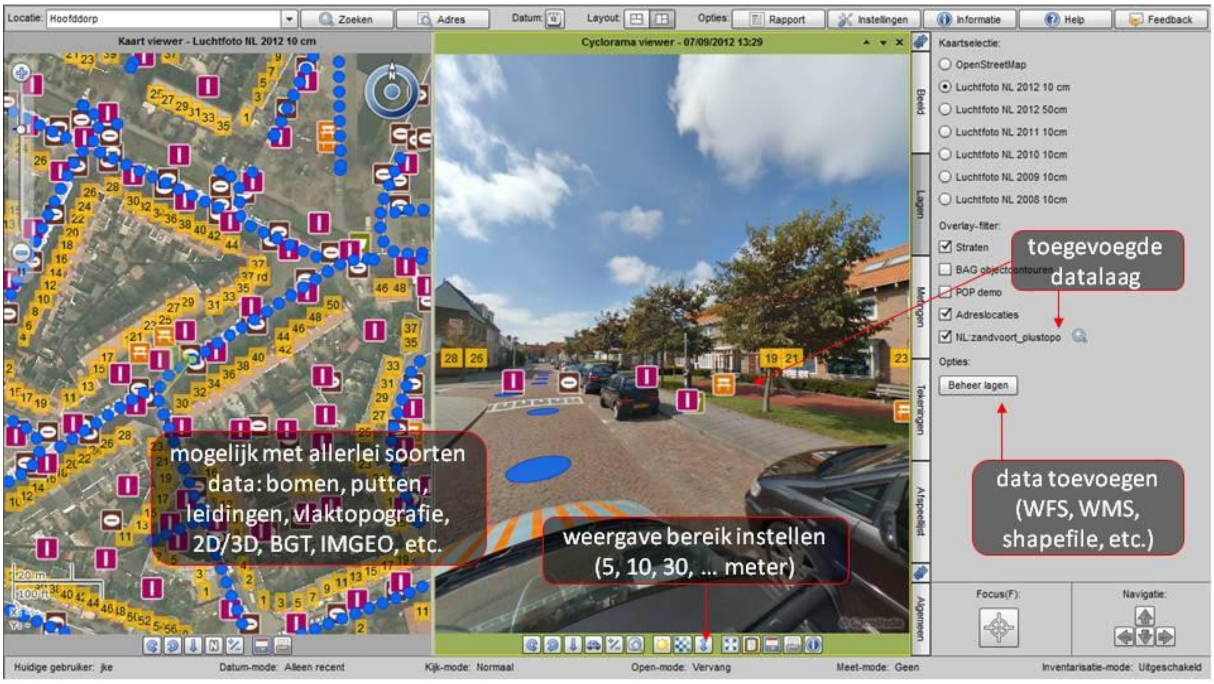
You can export the data to a file using the menu at the top of the measurements.

This action can be performed more simply using the “Smart Click” function. The second and, potentially, third pictures, are automatically found.



Adding your own data layers

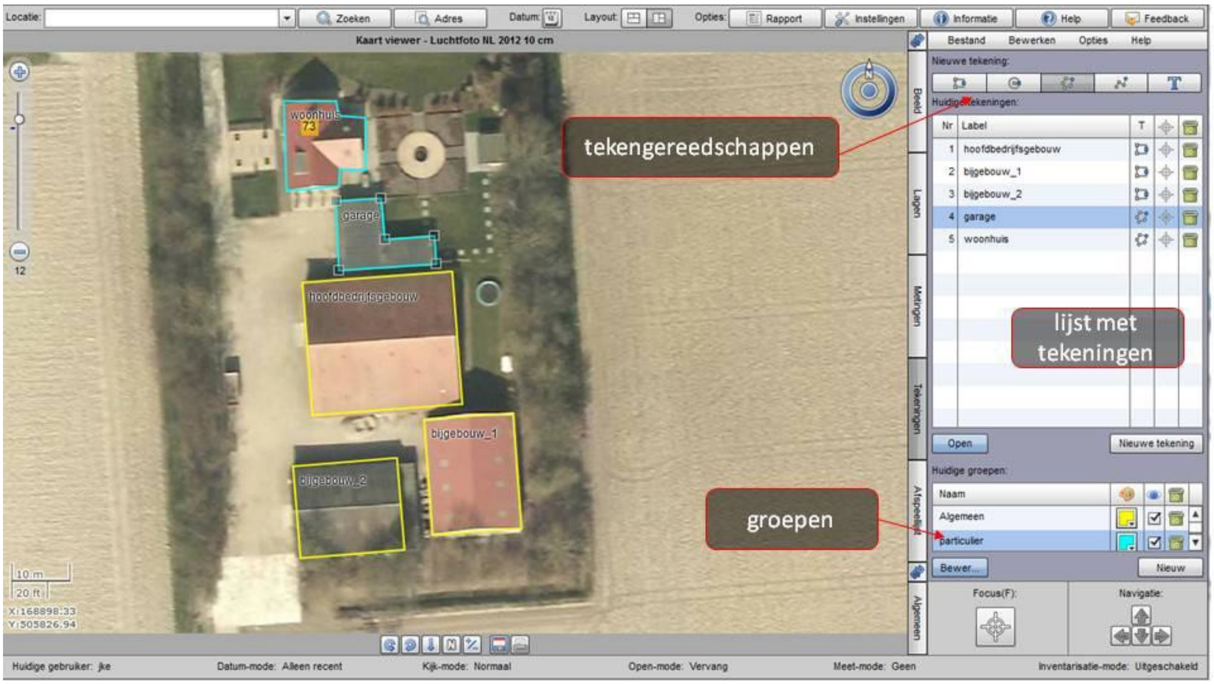
You can present your own data on top of the photo images.



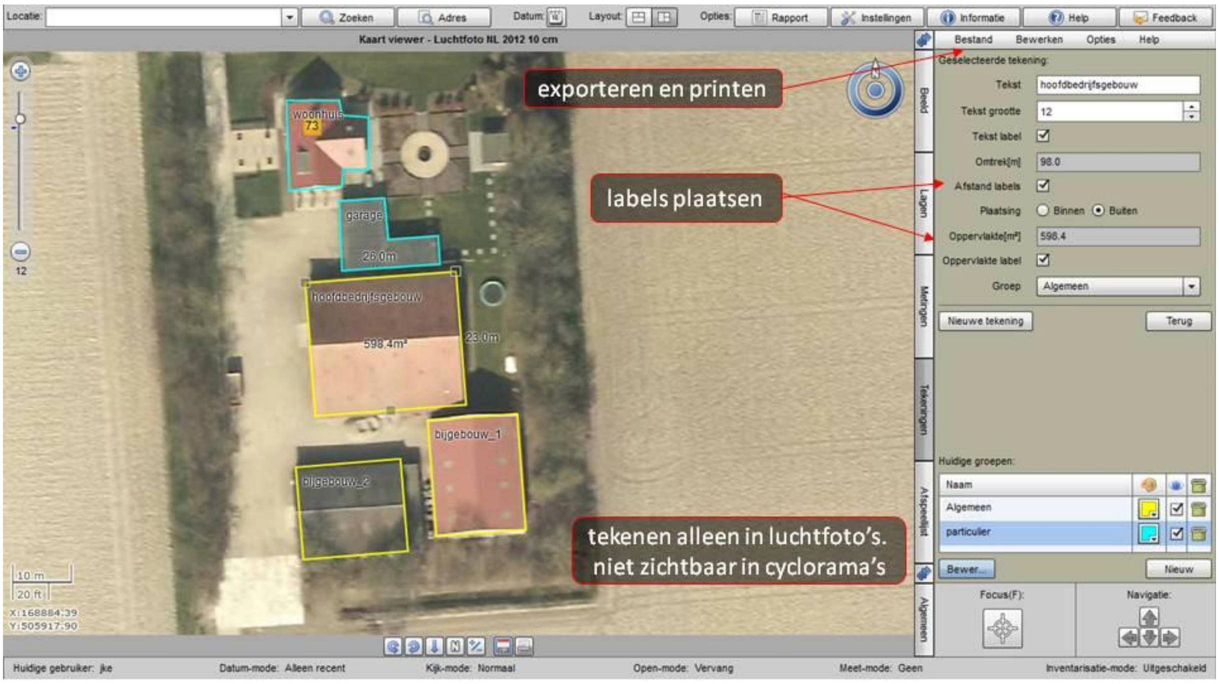
This allows you to make data visible in a very simple manner, so that you can verify a file's quality, accuracy or completeness.

Drawings

Various tools may be used to draw in aerial pictures. Drawings may be grouped. Drawings are only visible in the aerial photo, not in the Cyclorama.

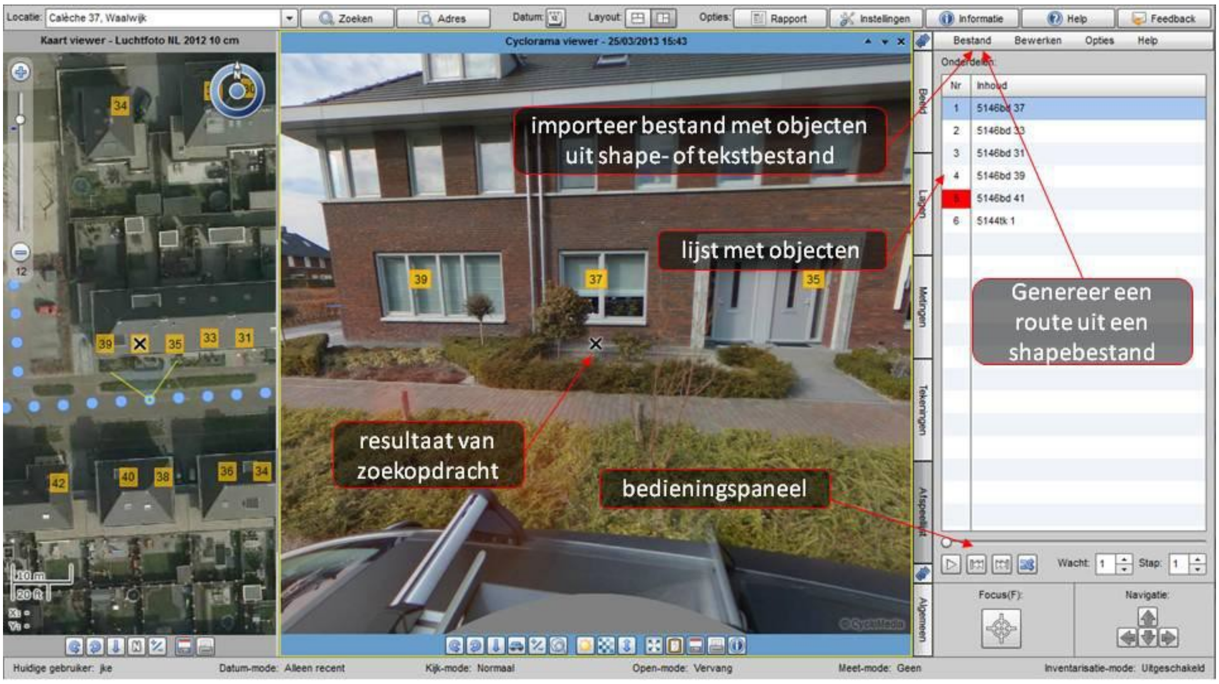


Distances, surfaces and additional text labels may be shown. The drawings may subsequently be printed and/or exported to a shape file.



Playlist

Using the playlist, a list of locations can be played, e.g. to verify whether a collection is complete or up to date. Examples include trees, drain holes and lampposts. Importing is possible using a shape file or a text file listing coordinates or addresses.



Shortcut keys

Map viewer	
Rotate left	Q
Rotate right	W
Rotate 180 degrees	E
Undo rotation	R
Toggle zoom levels	1,2,3
Save current view	S
Print current view	P
Close active Cyclorama viewer	Z
Close inactive Cyclorama viewer	X
Close all Cyclorama viewers	C

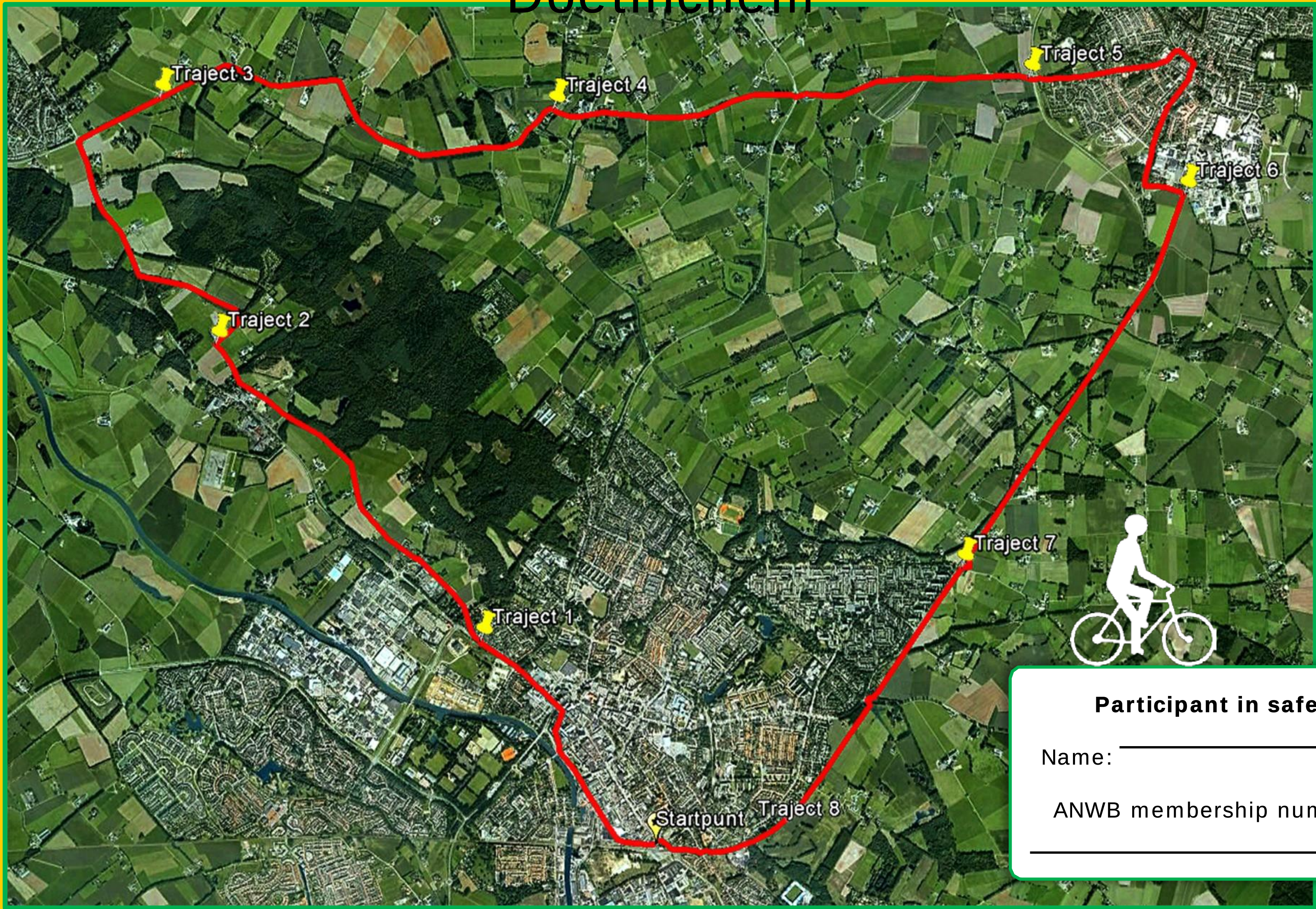
Cyclorama viewer	
Copy link to clipboard	L
Save current view	S
Print current view	P
Show location in map	V
Toggle zoom levels	1,2,3
Rotate left	Q
Rotate right	W
Rotate 180 degrees	E
Undo rotation	R
Image information	I(i)
Change brightness of selected Cycloramas	< >
Change transparency of selected Cycloramas	; '
Change character spacing in selected Cycloramas	[ ]
Change brightness of all Cycloramas	Ctrl + <
Change transparency of all Cycloramas	Ctrl + ; '
Change character spacing in all Cycloramas	Ctrl + [ ]
Detailed images	B
Open new Cyclorama viewer	Shift +
Open multiple Cyclorama viewers	Ctrl +
Measurements	
New measurement	N
Close measurement	M
Place measurement point (only available in “focus mode”)	G
Focus mode	F
Drawings	
Close drawing	D
Playlist	
Play/pause playlist	H
Previous point	J
Next point	K

Appendix D Perception survey: Instructions municipality of Doetinchem

The following pages (119 – 130) contain the instructions for particpants of the perception survey in Doetinchem.

Route & notebook ANWB safe cycling study

Bicycle route
Doetinchem



Participant in safe cycling study

Name: ______________________

ANWB membership number:

____

Dear ANWB Volunteer,

The purpose of this study is to provide the road manager with information on dangerous traffic situations for cyclists. Addressing these situations will improve traffic safety for cyclists.

You are going to follow a cycle route around Doetinchem and will cycle through smaller towns such as Hummelo and Zelhem. The route is circular, so you'll return to your starting point.

The total length of the cycle route is 23 km and it turns continually to the right, in the direction of the clock. The route follows cycle paths, cycle lanes and carriageways.

You are free to choose a day and time to cycle. This is not a puzzle trip so the amount of time you spend on the route is not important.

Please pay attention to what makes the route unsafe. Note these situations in this booklet as you go. Make sure to read the instructions about this on page 3.

Please pay attention to your own safety, especially when crossing a road and when stopping to make notes.

We greatly appreciate your willingness to work with us on this study.

Success!

March 2014

Instruction

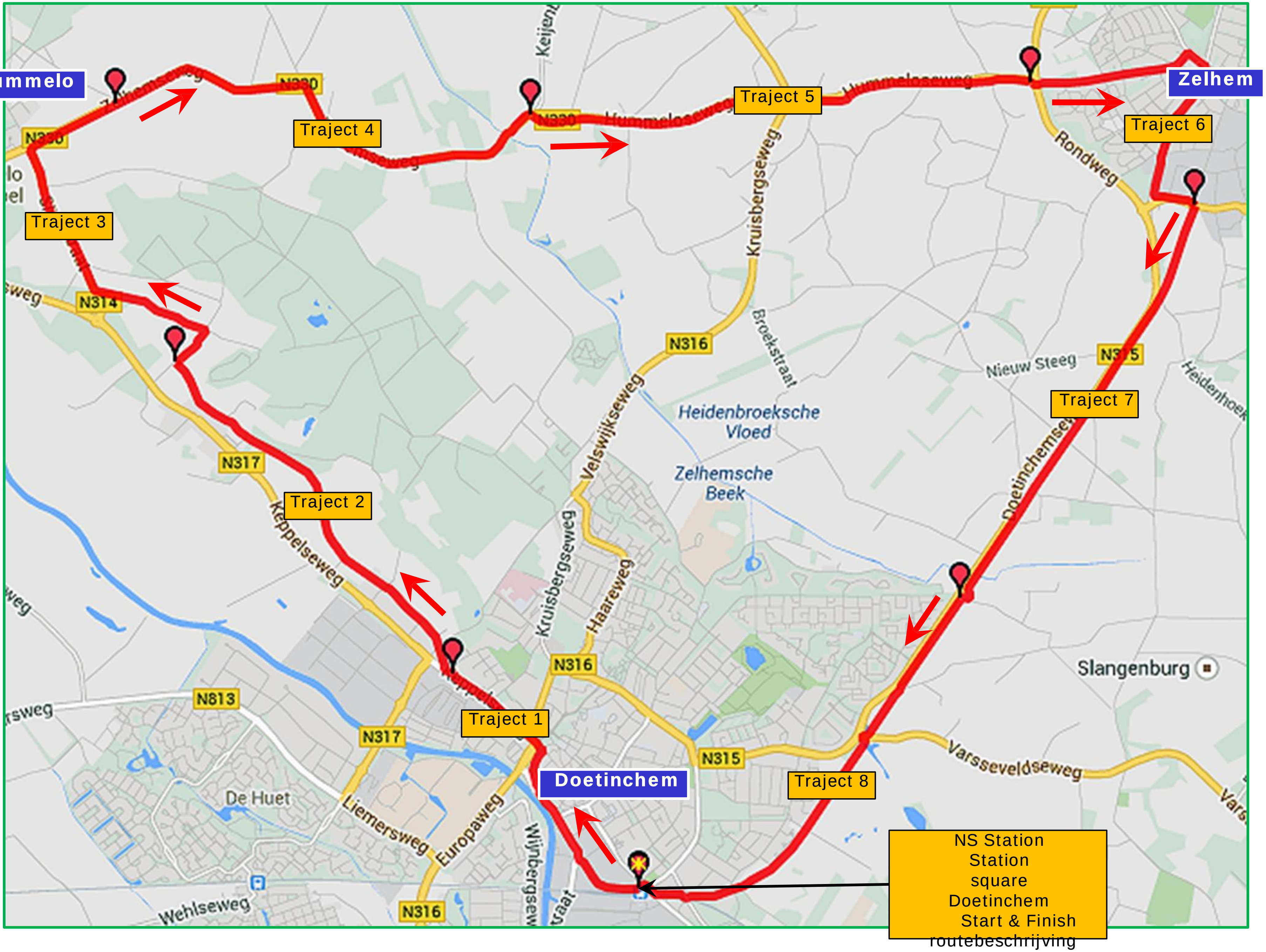
Make note of each unsafe cycling situation that you encounter on this cycle route. Do so by using the list of 'dangerous traffic situations' shown below; place the corresponding number on the location on the map (see example on page 4). There is also space to further describe dangerous situations on each map. Using the number 18, you can indicate your own dangerous situation.

If you do not encounter anything special, you do not have to note down anything. The study is not concerned with situations that influence the cycle route's attractiveness or comfort for cyclists. The route maps in this booklet differ in scale.

Dangerous traffic situations:

1. Road, cycle path or cycle lane too narrow
2. Poor road surface (e.g. cracks, holes, loose blocks, bricks, gravel)
3. Puddles on the route (e.g. insufficient drainage, drains blocked)
4. Poor road markings (e.g. none or poorly visible)
5. Irregular road surface (e.g. bumps, tram or train rails, manhole covers)
6. Obstacle on or along route (e.g. fence, hedge, lamppost, tree, parked car)
7. Dangerous verge or edge of route (e.g. curb, sloping verge, gulley)
8. Dangerous/obstructing pole in the road
9. Other traffic
10. Dangerous intersection/fork
11. Dangerous curve
12. Dangerous gradient
13. Dangerous exit
14. Insufficient signposting (e.g. none or poorly visible)
15. Construction work
16. Danger of slipping (e.g. sand, clay, gravel, oil on surface)
17. Poor or no lighting
18. Other, specifically: ...

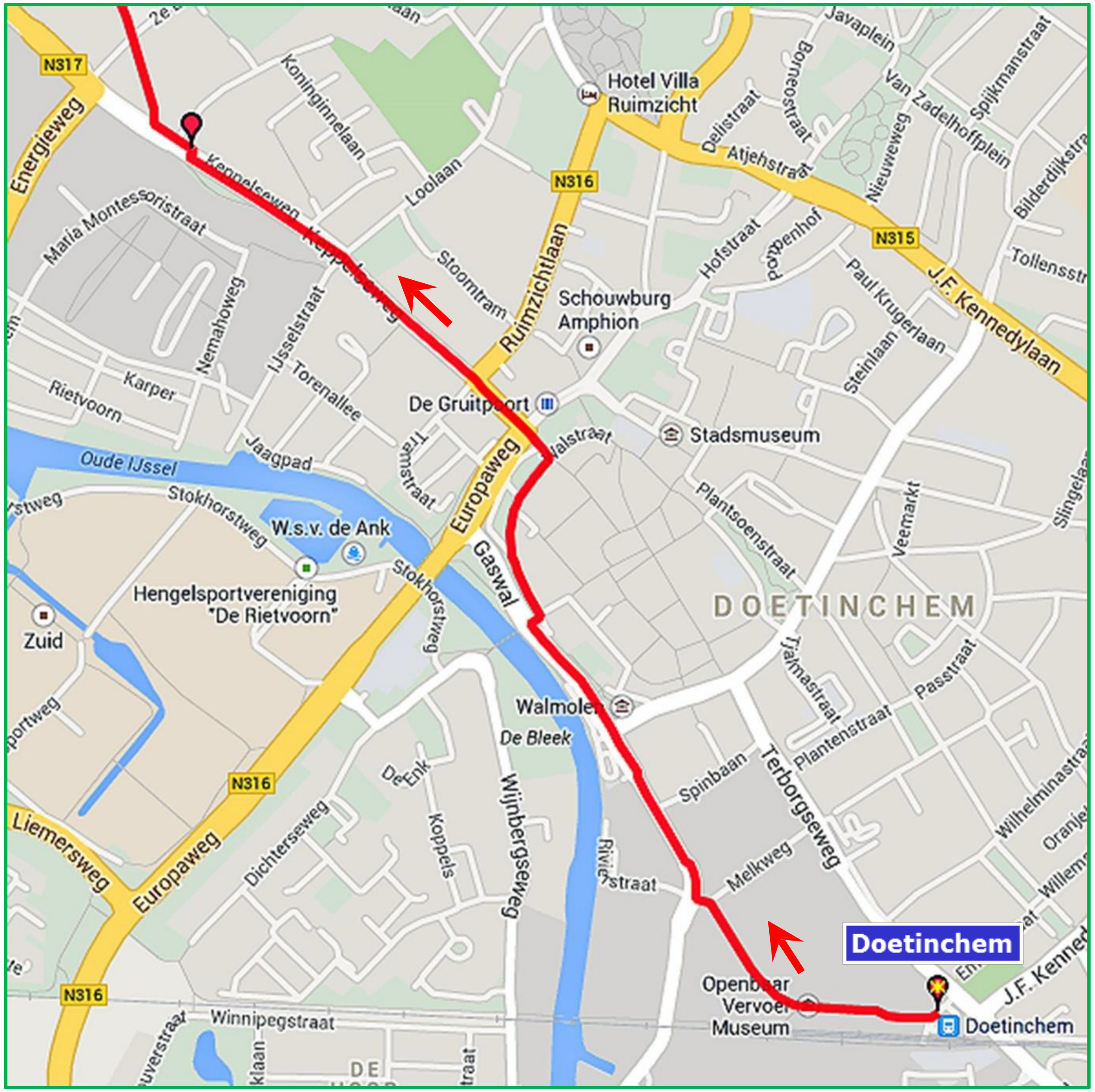
Route



Hummelo
Zelhem
Doetinchem
Traject 1
Traject 2
Traject 3
Traject 4
Traject 5
Traject 6
Traject 7
Traject 8
NS Station
Station
square
Doetinchem
Start & Finish
routebeschrijving
Heidenbroeksche
Vloed
Zelhemsche
Beek
Slangenburg
De Huet
Kruisbergseweg
Velswijkseweg
Haareweg
Keppelseweg
Liemersweg
Europaweg
Wehlseweg
Varsseveldseweg
Rondweg
Nieuw Steeg
Broekstraat
Doetinchemseweg
Hummeloseweg
N330
N314
N317
N316
N315
N813

Section 1 = 2.0 km

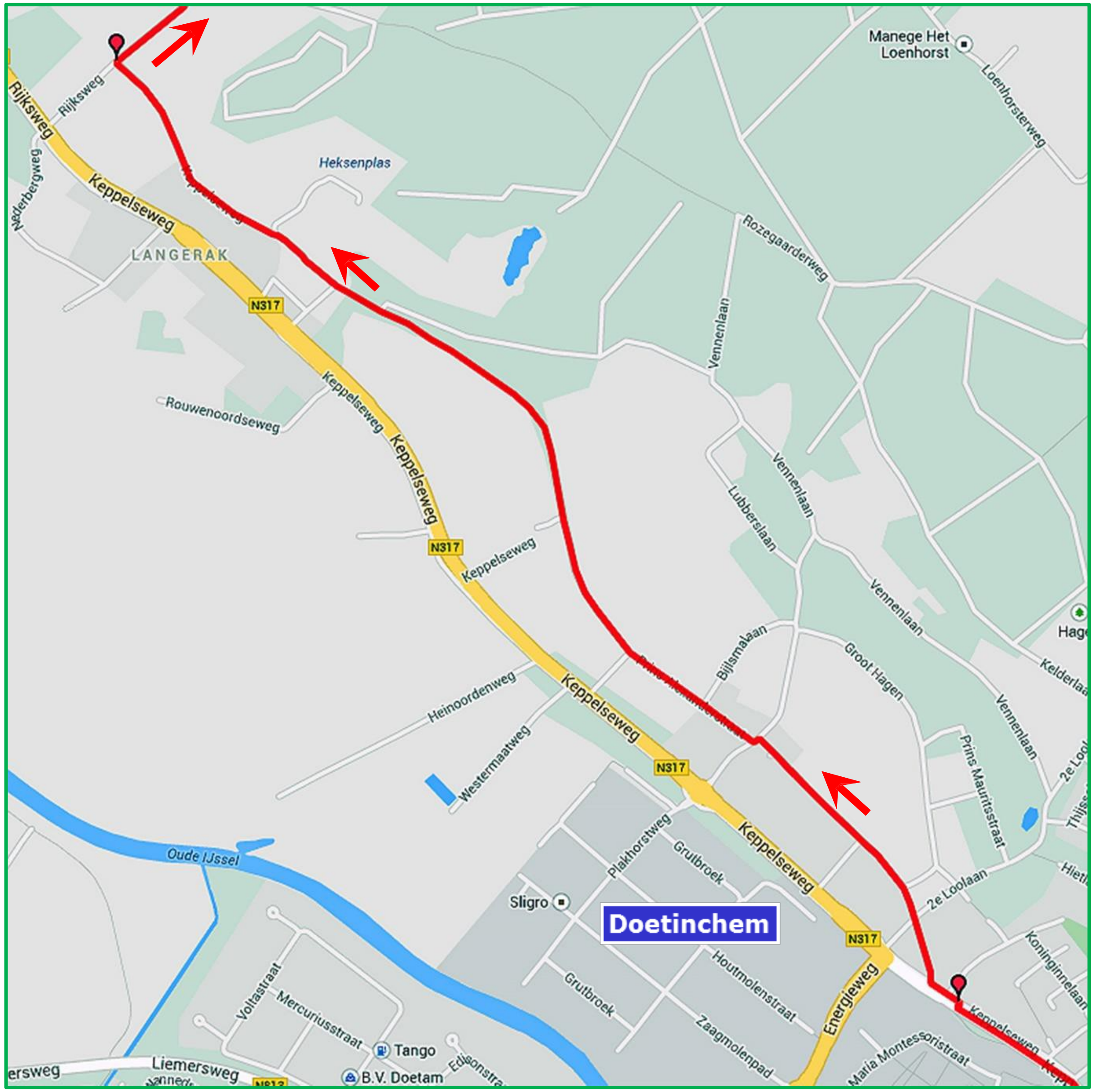
- From NS station Doetinchem follow cycle path south toward Stationsstraat
- Bicycle stall on the left
- At intersection with main road turn right into C. Missetstr.
- Exit C. Missetstraat at the ´no cycling´ sign and turn right into Waterstraat
- Take first left into Kapoeniestraat
- Left at intersection into Grutstraat
- At intersection (Europalaan) with traffic lights go straight on Keppelseweg
- Follow Keppelseweg on cycle path at left of Keppelseweg
- Cross Keppelseweg at bus stop with bicycle stall
- End of trajectory 1



Explanation dangerous situation (note number, remark)

Section 2 = 2.9 km

- Continue on Keppelsweg on the right side
- At dead-end road sign (cyclists allowed) turn right into Prins Alexanderstraat
- Left at end of road; Groot Hagen
- Immediate right into Prins Alexanderstraat
- Continue on Prins Alexanderstraat
- Keep left at junction national trunk road/ Keppelseweg
- End of road is end of trajectory 2



Explanation dangerous situation (note number, remark)

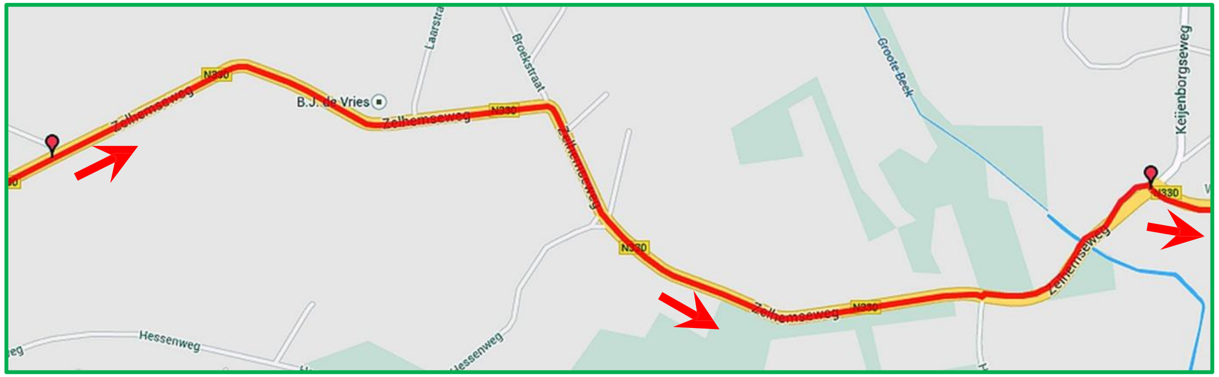
Section 3 = 2.7 km

- Turn right at end of road; national trunk road
- Turn left at intersection into Rozegaarderweg
- Cross intersection with main road
- Then turn right and follow cycle path at left of Sliekstraat N314
- At roundabout in Hummelo Zelhemseweg / N330 turn right towards Zelhem
- Follow cycle path (in two directions) on left of Zelhemseweg / N330
- At junction with side road to left Spalderkampseweg, end of trajectory 3

Explanation dangerous situation (note number, remark)

Section 4 = 3.2 km

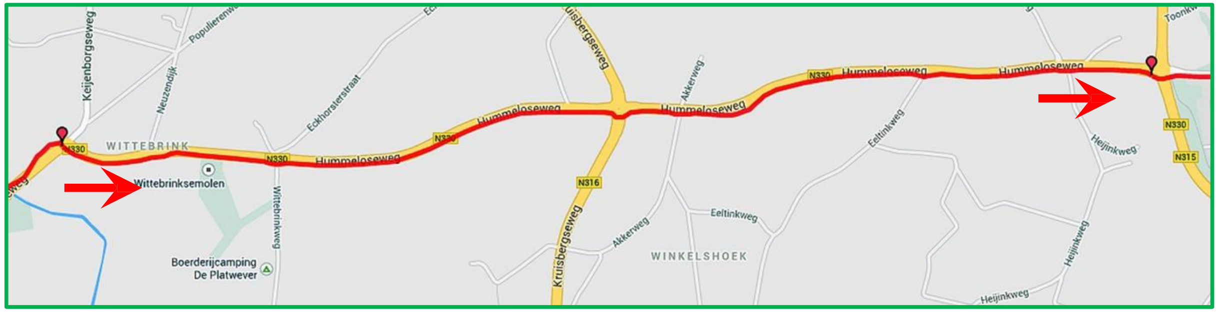
- Continue on cycle path (in two directions) at left of Zelhemseweg / N330
- After café De Tol at signpost and intersection with Hummeloseweg (sharp curve to right on main road) end of trajectory 4



Explanation dangerous situation **(note number, remark)**

Section 5 = 3.4 km

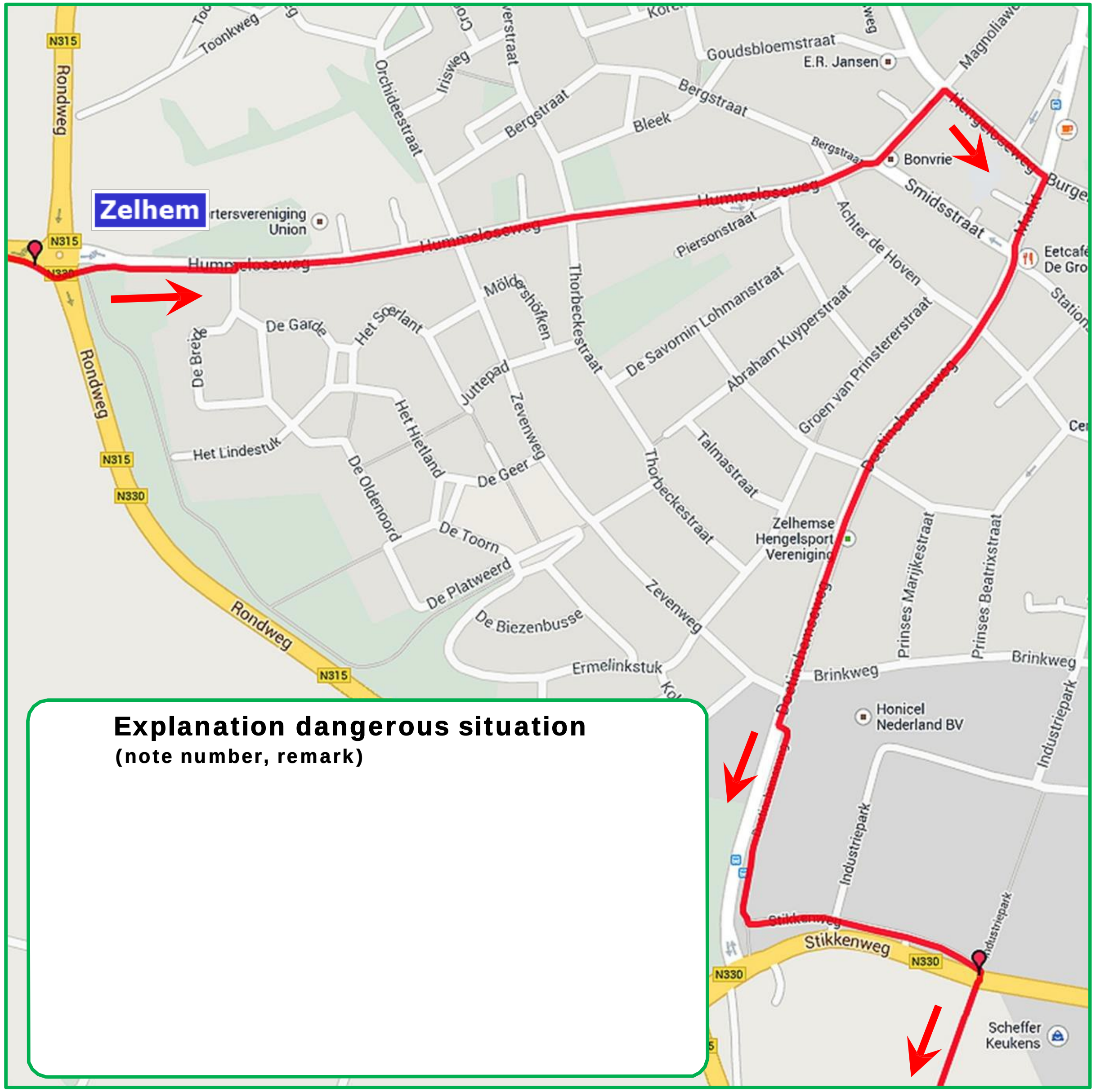
- Cross Hummeloseweg at signpost to Zelhem at intersection and follow cycle path at right of Hummeloseweg / N330
- At roundabout go straight on Hummeloseweg / N330 towards Zelhem
- At next roundabout end of trajectory 5



Explanation dangerous situation (note number, remark)

Section 6 = 2.5 km

- At roundabout continue straight on Hummeloseweg into the built-up area of Zelhem
- Continue on Hummeloseweg at end of cycle path
- Go straight at shopping centre; Magnoliaweg (one-way traffic)
- Turn right at intersection and follow Hengeloseweg towards the church
- Turn right before the church towards Doetinchem; Market (one-way traffic)
- Restaurant De Chinese Muur (on the right)
- Follow Doetinchemseweg
- Cross road at petrol station and follow cycle path at left of Doetinchemseweg
- Turn left into Stikkenweg/N330 at intersection at end of built-up area Zelhem, cycle path separated from main road by a strip of greenery
- End of cycle path is end of trajectory 6

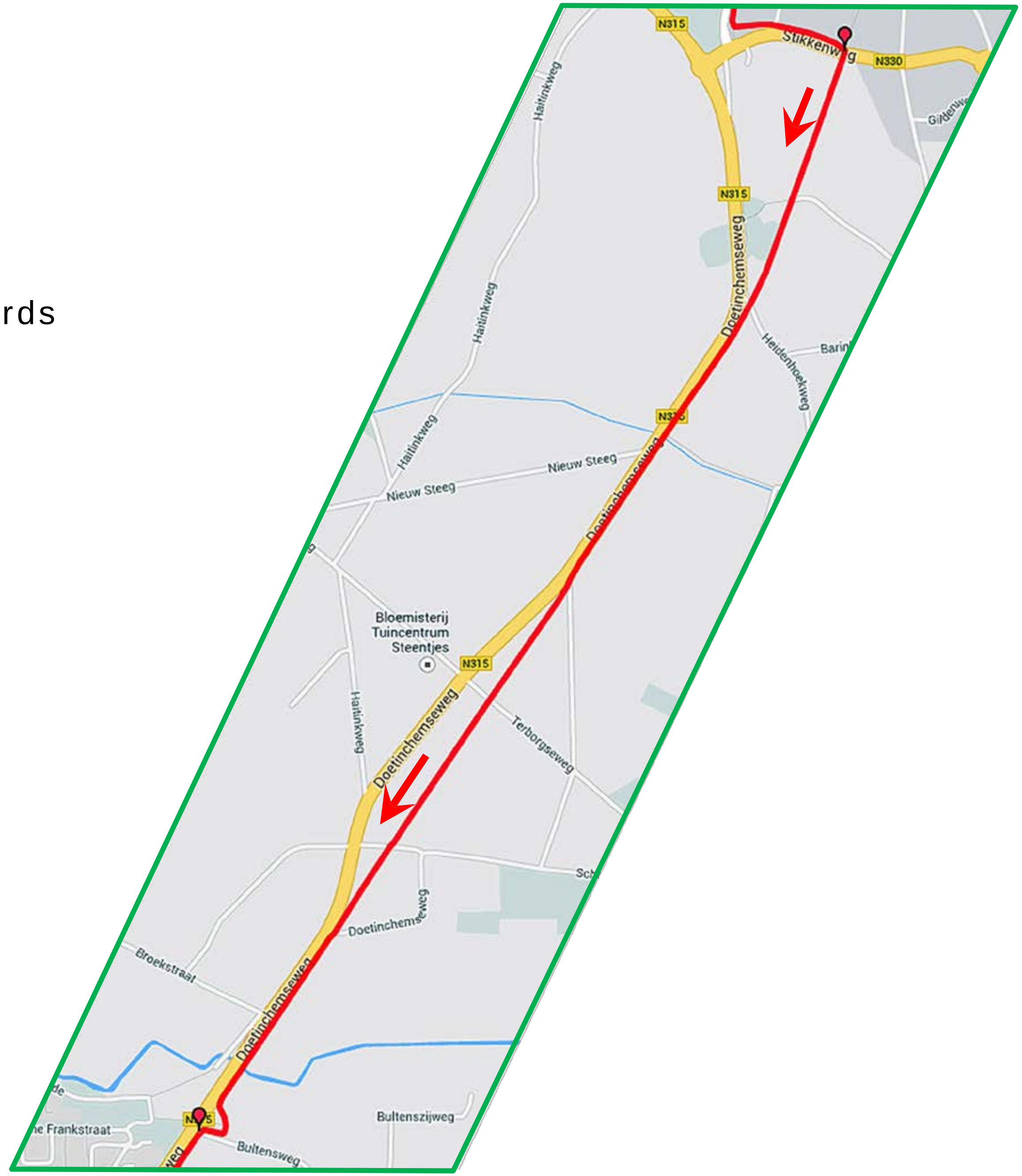


Explanation dangerous situation
(note number, remark)

Section 7 = 3.0 km

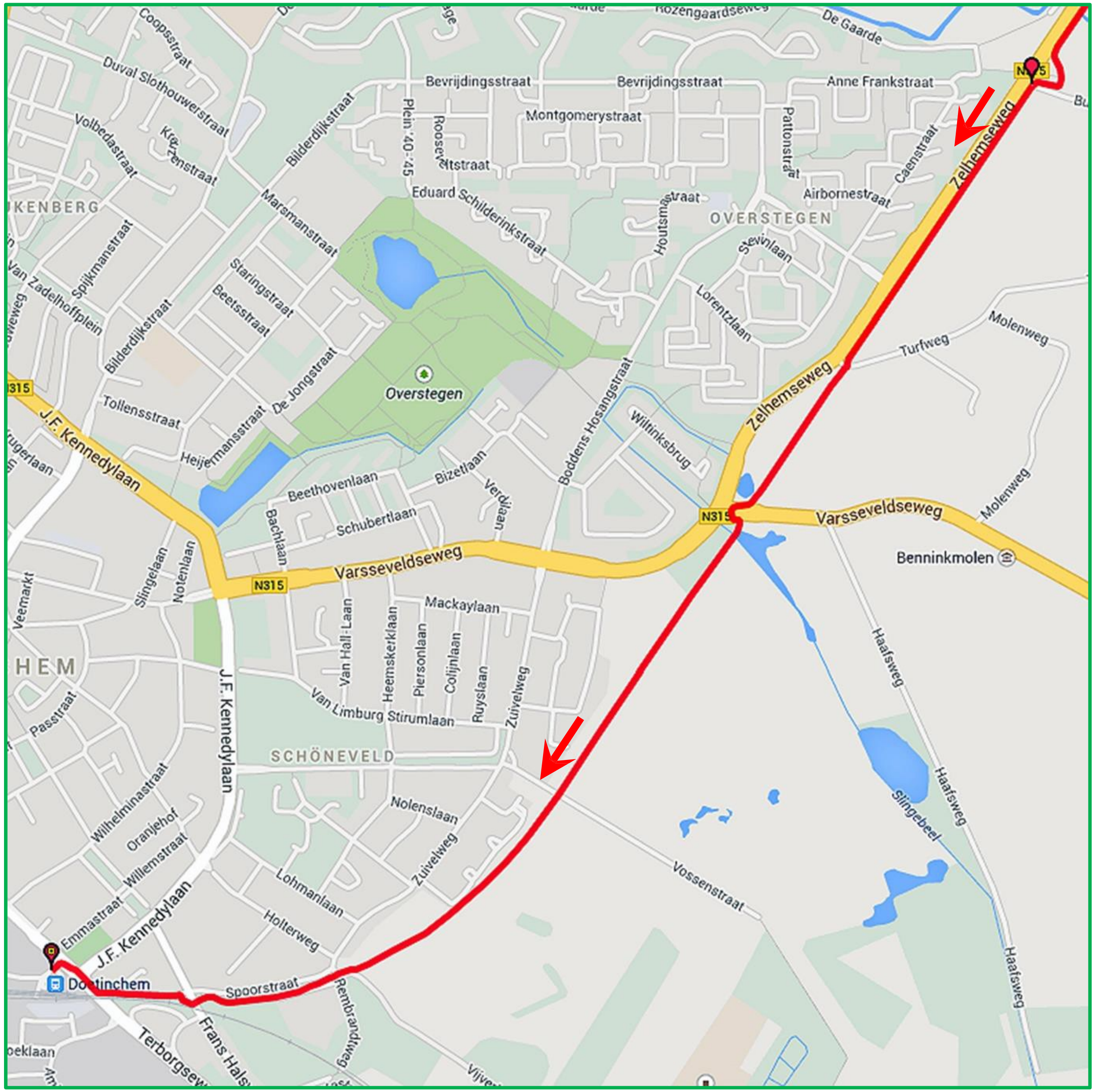
- Turn right at end of cycle path and cross Stikkenweg / N330, continue in direction of Doetinchem
- Follow cycle path with two-way traffic that goes through rural area towards Doetinchem; Old railway
- Continue on this separate cycle path towards Doetinchem
- After sharp curve to right at intersection with Bultenseweg and viaduct under Doetinchemseweg / N315, end of trajectory 7

Explanation dangerous situation (note number, remark)



Section 8 = 3.1 km

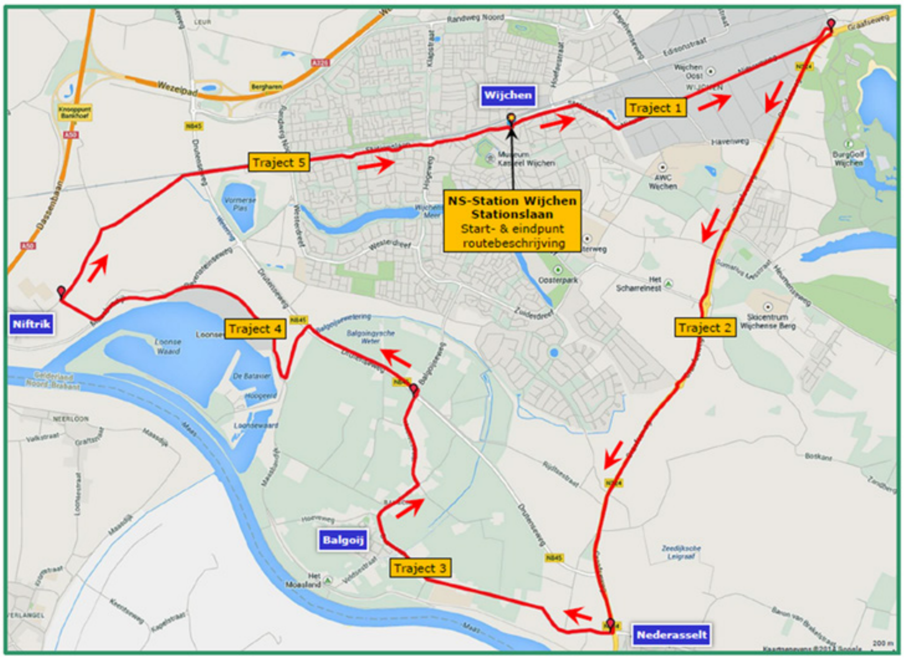
- Go straight at intersection on cycle path at left of Zelhemseweg
- At intersection with Varseveldseweg continue on separate cycle path
- Cross Vossenstraat and continue straight on cycle path
- Follow cycle path at left of Spoorstraat
- Railway on the left
- Turn right into Terborgseweg at end of road at railway crossing
- Cross intersection with traffic lights and continue towards station
- NS station Doetinchem end of trajectory 8 and end of cycle route



Explanation dangerous situation (note number, remark)

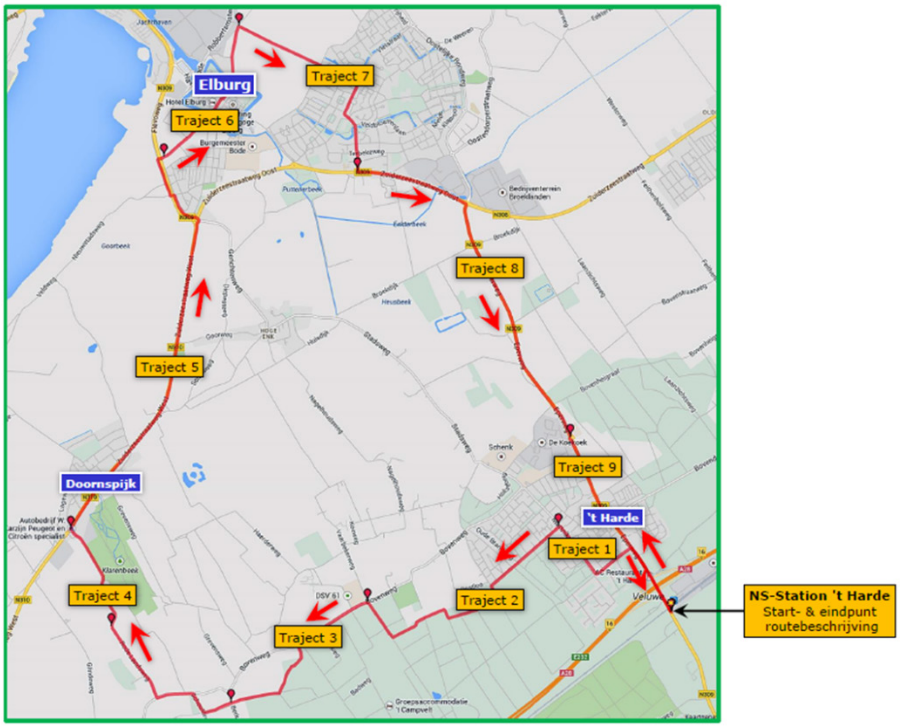
Appendix E Perception survey: Route maps

Map of route Wijchen



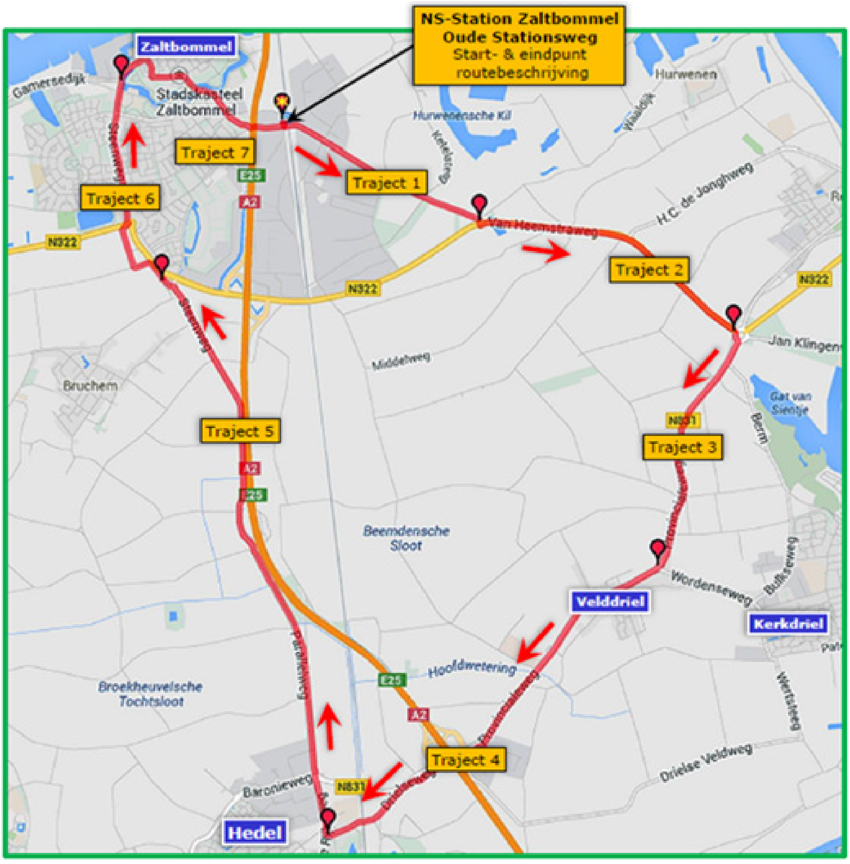
Beginning and end of route: NS Train Station Wijchen

Map of route ‘t Harde



Beginning and end of route: NS Train Station ‘t Harde

Map of route Zaltbommel



Beginning and end of route: NS Train Station Zaltbommel