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The Dutch Reference Study

Cases of interventions in bicycle infrastructure reviewed in the framework of Bikeability

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Interface for Cycling Expertise

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11. Abstract

The Netherlands have a tradition of high bicycle usage and a long history of research on effective policies for promoting cycling. Findings in Dutch studies can be useful in the Danish Bikeability-project that has the objective to increase the level of knowledge in relation to bicycle based transport and to contribute to more efficient and qualified urban planning and management. This report discusses a number of Dutch case studies on the effects of investments in bicycle infrastructure. The reviewed studies include the three 'classical' cases in the 20th century: rather large investments in the cities of Tilburg, The Hague and Delft that were evaluated extensively by before and after studies. Other, smaller and more recent cases include the evaluation of shared space, a bicycle street, and interurban highways for cyclists. A general conclusion is that policies can be effective in sustaining high levels of cycling and strengthening cycling culture.

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Summary

Increased transition of person transport from automobiles to bicycles is generally regarded as gain for society, most profoundly in terms of reduced emissions and enhanced public health. In Denmark the Bikeability research project was launched that should create more knowledge on how *bike-ability* can be enhanced, in particular in urban areas. One of the topics of the project is an analysis of bicycle infrastructure cases in Danish municipalities and the Netherlands. The Dutch cases regard interventions in bicycle infrastructure that have been evaluated. Referring to Dutch expertise is useful because the Netherlands have a long tradition of high bicycle usage, bicycle promotion by policy makers, and research in the field of cycling. This report describes the Dutch cases that are studied in the context of the project. The selected cases are the three 'classical' cases from some decades ago and some examples of recently developed typologies of infrastructure design.

The classical cases include two demonstration projects in the cities of Tilburg and The Hague in the 1970s and the Delft bicycle Plan in the 1980's. The demonstration projects were the result of a paradigm shift in thinking about traffic. The downsides of motorisation became apparent and consciousness grew about the necessity to provide good facilities for slow modes. In both Tilburg and The Hague high quality urban bicycle routes were planned across the city. In Tilburg the planned route was constructed fully and survived until today. It was later extended to a radial city-wide network. In The Hague the plan met severe opposition and construction was limited to the western part of the planned route. Large parts of the route were later dismantled.

The Delft Bicycle Plan was a city-wide upgrade of the bicycle infrastructure in the city of Delft. Three bicycle networks were defined: a network on city level, a network on district level, and a network on neighbourhood level. Each network should meet some quality requirements and the objective of the bicycle plan was to upgrade and extend the existing network in order to achieve a network that satisfies the requirements. The major part of the intended projects was implemented, but a few of the most expensive projects were skipped. A large part of the improvements can still be used today but, generally, the high quality infrastructure that was created has not been maintained properly. Today the bicycle infrastructure in Delft is moderate compared to that of other Dutch cities.

The two demonstration projects and the Delft Bicycle Plan were evaluated extensively by a large number of before and after studies. In Delft, one of the more expensive projects, the Plantagebrug, has been evaluated separately. The Plantagebrug is a bridge that added a missing link in the city level network.

The examples of recently developed typologies of infrastructure regard transforming a regular road into shared space in the city of Haren (close to the larger city of Groningen), constructing a bicycle street in the city of Haarlem, and developing bicycle 'highways' on several corridors in the Netherlands. Shared space is integrated use of public space by both motorized and non-motorized modes and the opposite of modal segregation; it is assumed to contribute to traffic safety because space sharing impels drivers of motorized modes to take full account of the slow modes. A bicycle street is a street for mixed traffic (bicycles and cars) where the bicycle is the main user and the car is guest; the main function of bicycle streets in the Netherlands is

provision of bicycle routes through residential areas that are part of the main bicycle network. The bicycle 'highway' concept is recently developed in the Netherlands in order to promote interurban cycling as a means of relieving congestion on motor highways; the bicycle highways provide high quality routes in interurban corridors up to 20 km.

The available information about the selected Dutch cases and the evaluations varies for the different cases. Still an attempt was made to review the cases along a predefined scheme. Next scheme is followed as far as possible:

- An introduction with the political and social context.
- A description of the design of the intervention.
- The organization and implementation.
- The costs.
- The set-up of the evaluation studies.
- The results of the evaluation. These include impacts on travel behaviour, traffic safety, perception of cycling quality, and economy, as well as an assessment of design elements.

General conclusions from the review are that:

- Policies matter. Bicycle use and cycling culture can be affected by policies. The three classical case studies gave cause for the definition of five main requirements for a good bicycle network: coherence, directness, attractiveness, safety, and comfort.
- Investments in bicycle infrastructure have generally a larger impact on the qualitative perception than on measurable quantities. This is valid for both safety and bicycle use. Generally, the perceived improvement of safety is not (fully) reflected by the observed decrease in accidents and casualties. Correspondingly, the general appreciation of improved infrastructure is more substantial than the observed increases of bicycle use.
- Involvement of citizens and interest groups in an early phase of a project creates civic support and enlarges the probability of successful implementation.
- Travel time is the most important explanatory variable for route choice, unlike travel distance.
- There is a positive relationship between the continuity and recognisability of bicycle facilities and the appreciation of these facilities by cyclists.
- Cyclists have a clear preference for undisturbed and convenient cycling conditions.
- Two sided one-directional bicycle tracks are on average experienced as more safe than one sided two-directional cycle tracks.

On the basis of the Dutch case studies some general recommendations can be given for promoting cycling in an efficient way:

- The promotion of bicycle use is only credible and successful if cycling is a practical, relatively fast and convenient mode of transport. The main requirements for planning and designing bicycle infrastructure should be satisfied: coherence, directness, attractiveness, safety, and comfort.
- Promotion of the bicycle should include improving the perception of the conditions by (potential) cyclists. Improving the perception of conditions

results in increased bicycle use beyond the increases associated with improving the actual conditions.
- Minimizing travel times between origins and destinations is important in designing bicycle infrastructure.
- Urban bicycle routes should preferably be traced through traffic-restrained areas because cyclists prefer cycling conditions involving less traffic stress and interaction.
- Segregation is preferred when there are large differences between the speeds of the different road users and traffic volumes are fairly high. In the urban context bicycle and motorized modes can be mixed on condition that traffic volume is not too high and speeds are harmonized.
- Good design of intersections is essential. Intersections are the most important cause for delays, and most cycling accidents happen at intersections.

A note on the recommendations is that findings for the Netherlands might not always be transferable to other countries. One important point is that the evaluated Dutch interventions were implemented in the situation that the bicycle was a common mode and a reasonably good bicycle infrastructure was already available. In countries that start “from scratch” with low bicycle use and a poor bicycle network, interventions that promote cycling may have different (probably larger) impacts.

1 Introduction

Increased transition of person transport from automobiles to bicycles is generally regarded as gain for society, most profoundly in terms of reduced emissions and enhanced public health. However, in Denmark a decrease in mode-share of cycling has been observed, leading to the conclusion by the Danish Government that the conditions for cycling must be enhanced to increase the use of the bicycle for transportation. The Bikeability research project was launched that focuses on the preconditions for cycling; the possible effects of changes of the urban environment and cycling infrastructure; and methodologies for assessment of changes to existing bicycling infrastructure based on micro-level spatially explicit data. This way the strategic focus of the project is how to enhance *bike-ability* of urban areas.

It is the overall objective of the project to increase the level of knowledge in relation to bicycle based transport and thereby to contribute to more efficient and qualified urban planning and management. The project activities are divided into 5 interrelated work packages (WP's):
WP1: Cycling behaviour and its preconditions will analyse the determinants for cycling behaviour of individuals, such as motives, lifestyles, opportunities and constraints.
WP2: Environmental determinants for bike-ability will link GIS data with objective and subjective measures of cycling in relation to the conditions of selected neighbourhoods to develop a validated *bike-ability* index tailored to the Danish urban context, but applicable in other regions.
WP3: Choice modelling for simulation of bicyclist behaviour develops an agent based modelling approach to simulate the flow of individual bicyclists in urban areas as a response to changes to the urban environment and the level of and attitude to bicycle transport.
WP4: Interventions to the bicycling infrastructure will analyze bicycle infrastructure cases in the Danish municipalities and the Netherlands; their implementation and significance in terms of contribution to the promotion of cycling, and finally identify infrastructure and elements of interventions that can help promote cycling significantly.
WP5: Planning Guidance and Dissemination serves the purpose of presenting the project's methodological advances, tools, and conclusions to policy-makers, planners and traffic engineers, as well as maintaining the dialog and interaction with end-users from the municipalities.

This report describes the Dutch cases that are studied in the context of WP4. The Netherlands have a long tradition of high bicycle usage, bicycle promotion by policy makers, and research in the field of cycling. Cycling experience, evaluated policy interventions, and other research have created a wealth of knowledge. A substantial part of this knowledge is not accessible to non-Dutch speaking persons and it is valuable to report the findings from a number of Dutch evaluated cases in the framework of the Bikeability-project.

The structure of the report is as follows. First, in Chapter 2, a brief overview of cycling, bicycle policy, and research on cycling in the Netherlands will be given. Then, in the next five chapters seven case studies are described. Chapters 3 and 4 discuss the three 'classical' cases of large scale improvements in bicycle infrastructure that were implemented and evaluated some decades ago: the construction of high quality urban bicycle routes and the upgrade of the bicycle network in one city. Chapter 4 deals with a single project that is part of the network upgrade and that has been evaluated separately. Chapters 5 to 7 cover cases in which three recently developed typologies of infrastructure design have been applied and evaluated: shared space, bicycle streets, and bicycle ‘highways’. Finally, Chapter 8 summarises the results and provides recommendations.

2 Developments in cycling in the Netherlands

In the Netherlands and in many other countries bicycle usage increased continuously in the first half of the 20th century and reached a maximum in about 1950. Then bicycle usage started to decline due to the increasing competition of the car. In some countries, like England, the bicycle nearly disappeared, while in other countries, like the Netherlands and Denmark, the bicycle survived as a frequently used mode.

Figure 2.1 depicts the development of cycling in the Netherlands since 1950. After 1950, bicycle use fell from nearly 5 km per person per day to less than 2 km in the mid 1970’s. Then it increased again to 2.5 km, and this level has been retained until today.

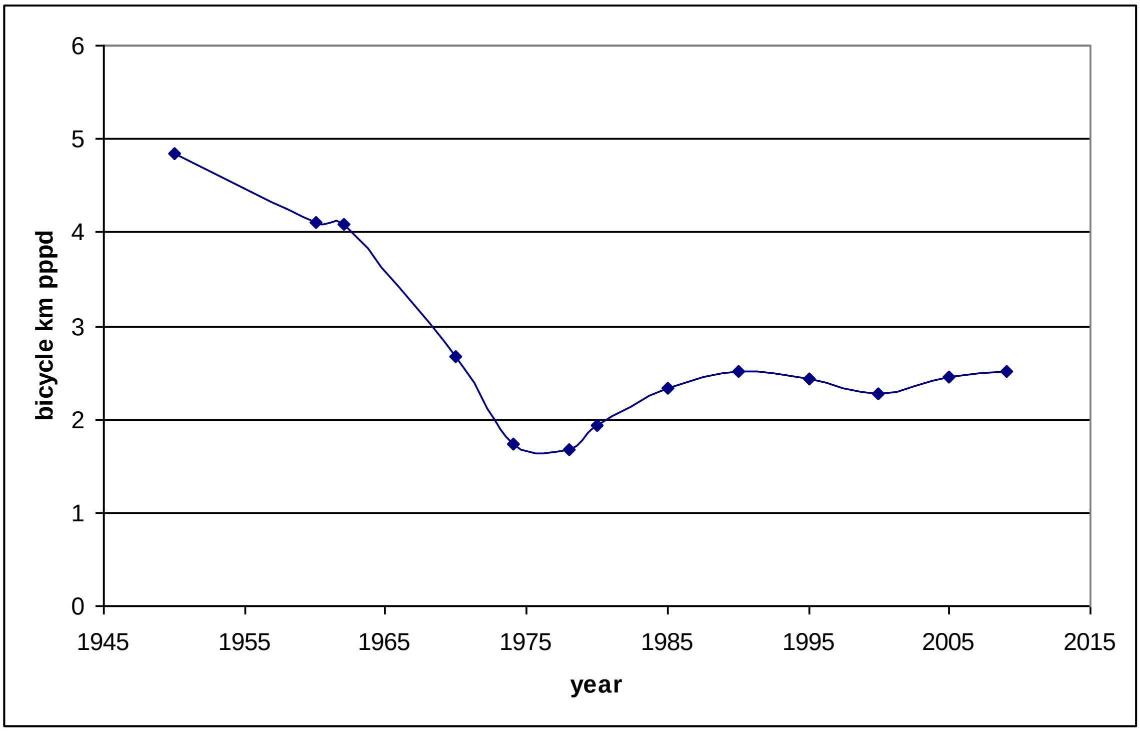


Figure 2.1: Development of bicycle kilometres per person per day in the Netherlands in the period 1950-2009 (sources: Ministry of Transport and Public Works, 1993, and national travel survey data 1980-2009)

The 1970’s marked a paradigm shift in the Dutch thinking about traffic. Whereas in the 1950’s and 1960’s traffic and transport policies were characterised by straightforward attempts to make room for the rapidly increasing motorisation, in the 1970’s people started to see the downsides of mass motorisation. The number of fatal road casualties peaked in 1972 and raised a lot of public dissatisfaction. The founding in 1973 of the citizen’s group ‘Stop de Kindermoord’ (Stop the Murder of Children) was a protest against the high number of road accidents with young children and the priority generally given to motorised traffic. In addition, the report of the Club of Rome on the limits to growth in 1972 had a major impact on the public debate in the Netherlands, and triggered more critical thinking about the environmental aspects of ongoing motorisation. About that time, the oil crises of 1973 demonstrated the vulnerability of motorised transport. In 1975 the Fietsersbond (Dutch Cyclists’ Union) came into existence. Municipal officials in Delft invented the ‘woonerf’ concept:

residential areas in which cars had to slow down to a walking pace so as to accommodate other uses of the public space than only traffic.

Bicycle promotion became permanently an issue in policy, and research on the effectiveness of measures for improving cycling conditions started as well. In the late 1970's two 'demonstration bicycle routes' were implemented in The Hague and Tilburg. In the 1980's the bicycle network in the medium-sized city of Delft was upgraded in order to create a comprehensive and integral network that meets certain standards of quality. These three projects were evaluated extensively and got the status of classical case studies in bicycle interventions; the studies are discussed in Chapters 3 and 4.

In the 1990's the central government initiated a large number of projects and studies in the framework of the "Masterplan Fiets" (Master Plan Bicycle). Research and active policy continued in the new century. New concepts were developed that aimed at humanizing traffic and promoting active modes of transportation such as cycling; they include 'bicycle streets', 'shared space', 'driving slowly goes faster' and 'bicycle highways'. These concepts did not change Dutch cities overnight, but helped make them more bicycle-friendly and thus sustain the existing levels of cycling.

Corresponding to the growth in bicycle use, the market share of use of the bicycle increased since the mid 1970's until the level of 28% in the early 1980's. Since then this level has been remarkably constant. Figure 2.2 shows the development of market shares of bicycle use for regular trips, separately for three age classes: young children < 12 years old, teenagers from 12-18, and adults >= 18 years old. Regular trips exclude bicycle use for "just go for a ride" and feeder trips to and from public transport. Data for young children are available only from 1994.

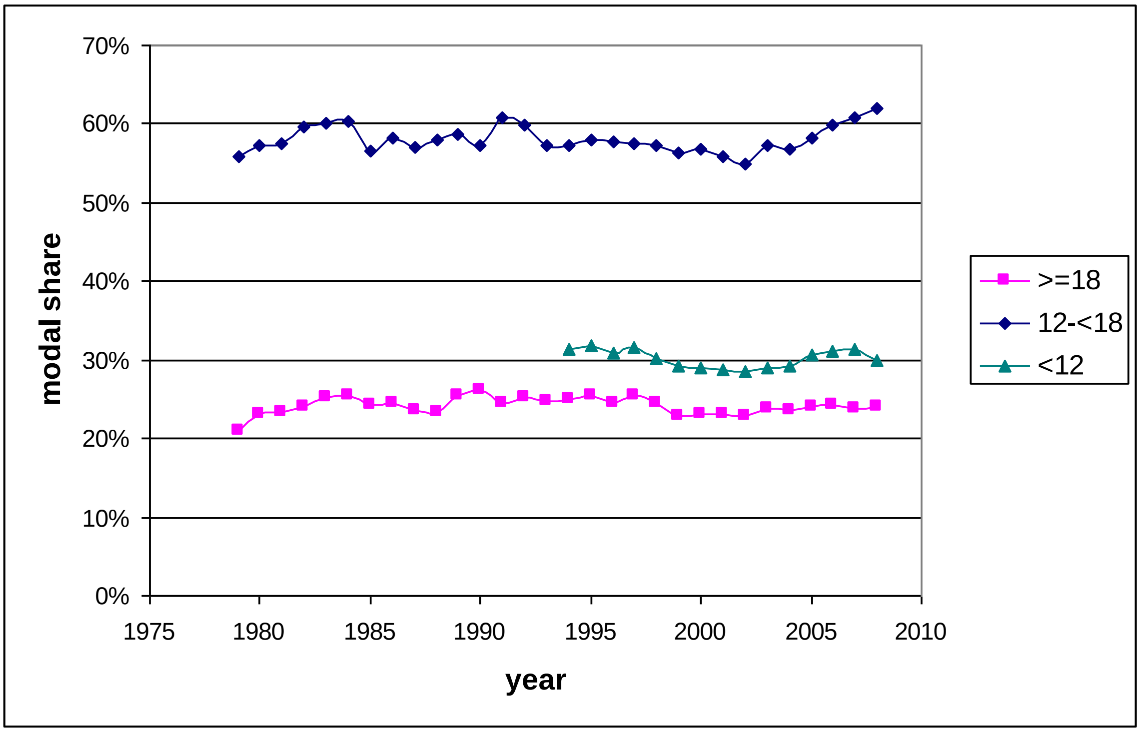


Figure 2.2: Share of the bicycle for regular trips by age class (source: national travel survey data 1979-2008)

The figure demonstrates that a) the bicycle share is by far highest for teenagers (about 60%!), and b) the trend of the shares are highly stable. The stability is remarkable because average trip distance (over all modes) has increased, inducing a relative decrease in the share of trips for which the bicycle is a feasible mode. The Ministry of Transport and Public Works (1998) argued that the competitiveness of the bicycle has increased. Other studies show that the cycling culture in the Netherlands has gained strength and acceptance in all parts of the population compared to three decades ago (DHV *et al*, 1980, Goudappel en Coffeng and Rijkswaterstaat, 1980, Mobycon *et al*, 2009).

Figures collected by the Fietsersbond (2010) show that the most important purposes for bicycle use are shopping (22% of all bicycle trips), education (18%), work (16%), leisure (14%, excluding “just go for a ride,” which has a share of 6%), and visit family or friends (11%). The number of bicycle trips is comparable for men and women except for ages from 30-60, for which women make significantly more trips. Non-natives make considerably less bicycle trips than natives. The difference is most striking for non-natives from Mediterranean countries.

In contrast to the stability of bicycle use for regular trips, usage of the bicycle for access and egress to and from public transport has increased spectacularly. The number of this kind of trip increased from about 0.02 per person per day in the early 1980’s to about 0.05 today. Most of these trips are feeder trips for the train. The increase can partly be explained by a general increase in train use and partly by an increase of the bicycle share in the access and egress modes.

3 The demonstration projects in Tilburg and The Hague

3.1 Political context

In chapter 2 we shortly described the paradigm shift of the 1970's in the thinking about traffic, resulting in more attention for (the safety of) cycling and walking. In this atmosphere of growing awareness a budget line for subsidizing cycling facilities in urban areas was introduced for the first time in the Multiyear Plan for Persons Transport 1976-1980 of the Ministry of Transport, Public Works and Water Management. Such facilities were meant to stimulate bicycle use. Municipal projects to improve cyclists' safety were eligible for an 80% subsidy.

As the construction of such facilities – in those days – appeared to be not that simple, the Minister took the initiative of funding two so-called 'demonstration bicycle routes' in The Hague and Tilburg as examples for other municipalities to follow suit. These demonstration routes would be funded 100% by the national government.

Both Tilburg and The Hague were chosen because these municipalities had formulated policies to improve cycling conditions in line with the aims of the government. These cycling policies were meant to slow down the increase of motorised traffic and to strengthen the (at that time deteriorating) position of cycling (and also public transport).

As the available budget was supposed to be spent in 1976 there was little time for preparation and design. The ministry was keen on making the demonstration route available as soon as possible in order to stimulate other municipalities to follow the given example.

And at the same time there was an ambiguity in the character of these projects: on the one hand they should show the feasibility of dedicated bicycle routes, and on the other hand these projects had to contribute to an increased knowledge and understanding of the effects of certain interventions, which implied systematic before and after studies. Thus the routes included some (at that time) experimental solutions whose effectiveness was to be assessed. The result of this ambiguity was (amongst other things) that the implementation of the routes took a bit more time than anticipated, and also resulted in an extensive research to the effects of the implemented facilities on bicycle use, road safety, the appropriateness of certain designs and the experiences of the users.

3.2 The route designs

3.2.1 Tilburg

Figure 3.1: Tilburg is located in the southern part of the Netherlands.

Tilburg is a city in the south of the Netherlands. After the industrial revolution it became a centre for textile industries, and because of the increase of the population Tilburg absorbed the adjacent villages. Thus Tilburg is an agglomeration rather than a mono-centric city. In the 1960’s and 1970’s the textile industry lost its prominent position and many industrial sites were redeveloped. At that time Tilburg had a population of about 150.000 inhabitants. (In 2010 this number has increased to 204.000 inhabitants.)

Tilburg is also a university city with an emphasis on social and economic sciences. Although Tilburg is the sixth largest city of the Netherlands, its urban form reflects a rather recent development of its urban status.

The design
The demonstration bicycle route was designed as one extended route connecting the outskirts of the built-up area in the west and the east with the city centre.

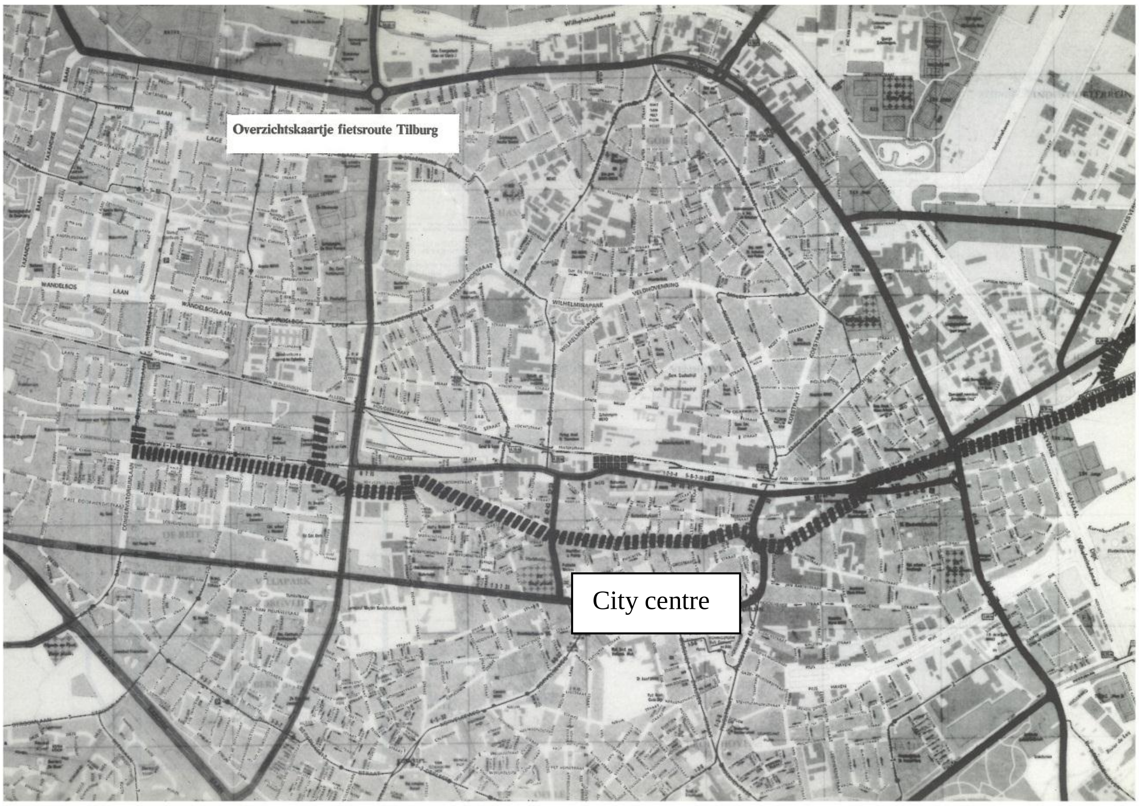


Figure 3.2: Bicycle route in Tilburg

In the eastbound direction the route was extended to neighbouring villages Berkel-Enschot and Oisterwijk. Thus this route has also a rural section. At relevant points (mainly in the city centre) the project included some (relatively short) transverse connections to open up the area. And the connection with the villages in the east looks like an ongoing alignment to Oisterwijk with two transverse connections to Berkel-Enschot.

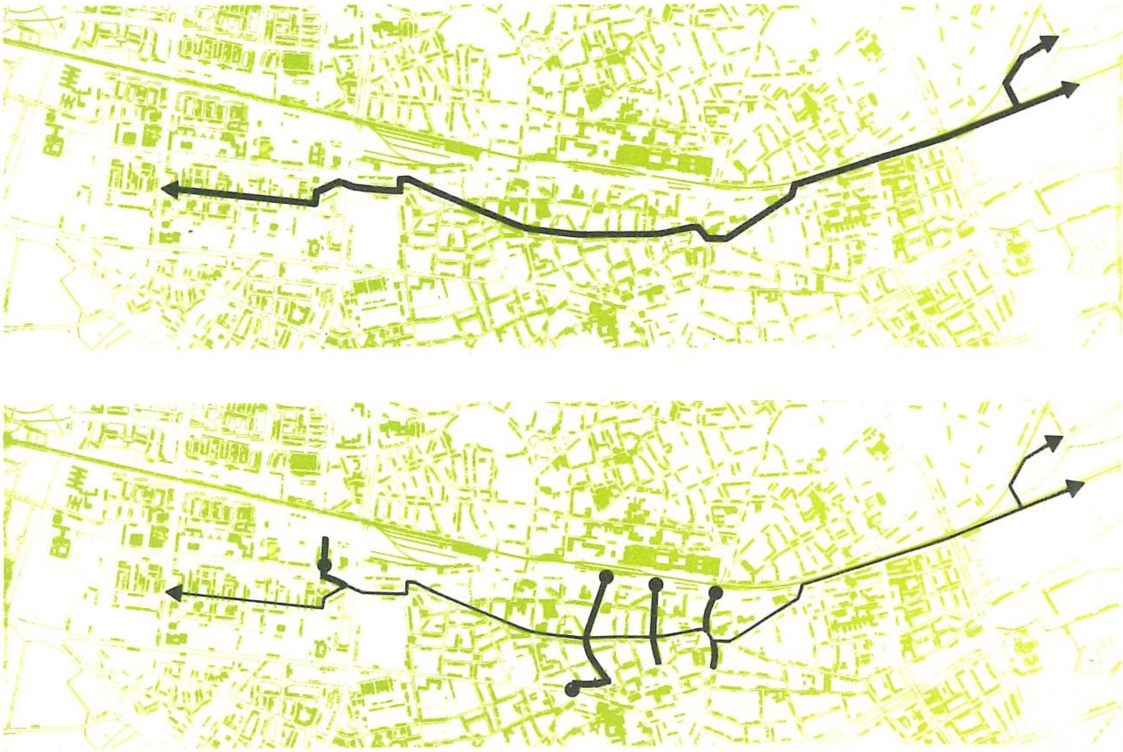


Figure 3.3: Main route (above) and transverse connections (below) inside the city of Tilburg

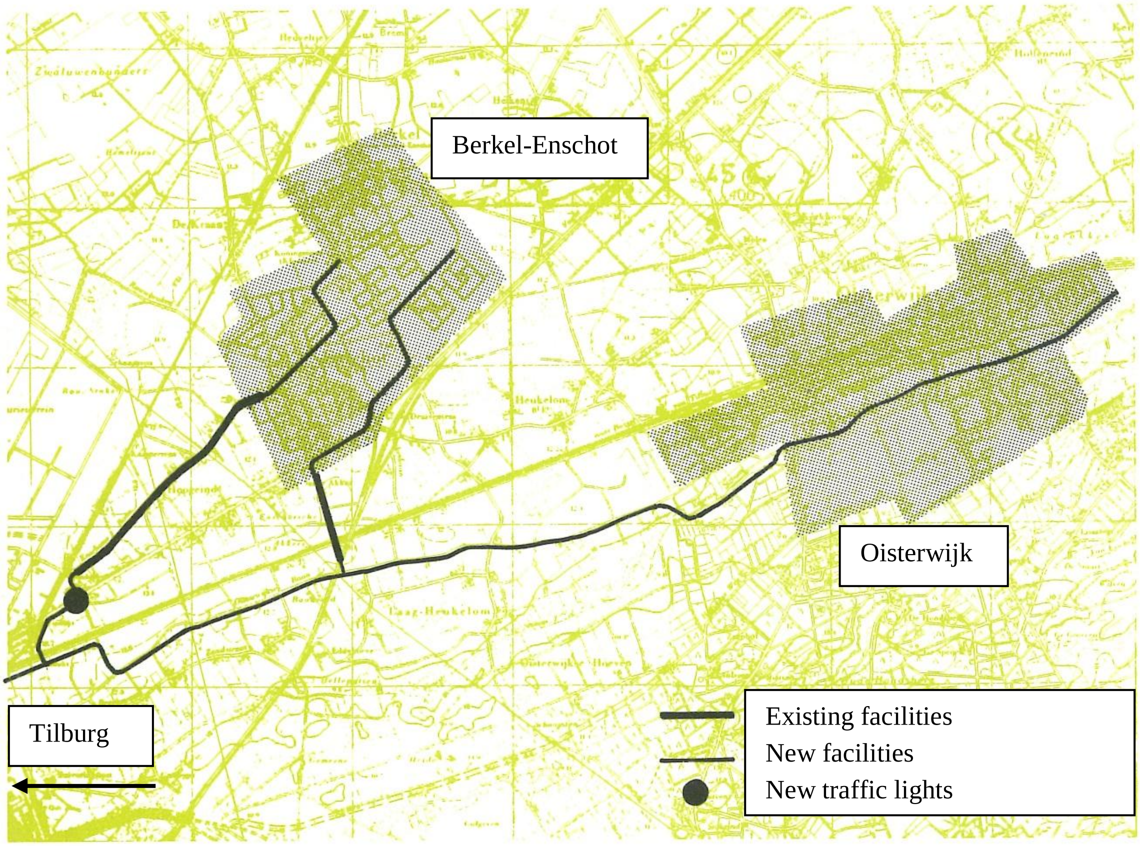


Figure 3.4: Extension of the bicycle route to the villages of Oisterwijk and Berkel-Enschot

Main features of the project (Gemeente Tilburg 1975; Ministerie van Verkeer en Waterstaat 1977):

- Segregated cycling facilities, mostly a two-directional path at one side of the main carriageway;
- Redesigned narrow streets in the city centre with restricted access for cars, and related to that a number of changes in the circulation in the inner-city, such as changes of direction in one-way streets;
- Intersection redesign so as to give priority to cyclists on the bicycle route as much as possible;
- Much effort is put into showing the continuity of the bicycle route across the intersections by using red coloured road surface for the bicycle route.
- ‘Humps and bumps’ in the road pavement were used as an experimental feature at intersections to influence the manoeuvring of car drivers.

3.2.2 The Hague

Figure 3.5: The Hague is located in the west of the Netherlands and part of the metropolitan conurbation called ‘Randstad’.

The Hague is the residence city of the Netherlands’ government (Amsterdam being the capital). Government has been residing in The Hague since the 16th century. The Hague is the third city in the Netherlands with about 500.000 inhabitants. As the The Hague territory is fully developed, its population is now smaller than 30 years ago, population growth being absorbed by neighbouring municipalities. The agglomeration Haaglanden, consisting of The Hague and its neighbour municipalities has over 1 million inhabitants, and is part of the larger Randstad, the metropolitan area in the west of the Netherlands that also includes Amsterdam, Rotterdam and Utrecht.

The Hague is situated at the North Sea and well connected with the other parts of the country by highways and rail connections. The Hague is also called the capital of international justice, being the residence of the International Court and the *International Criminal Court*.

The design

Just as in Tilburg, the demonstration route in The Hague was intended to be one straight route (through the urban fabric, between two main arterials for motorised traffic) connecting the south-west of the city (Waldeck) and the north east part (Mariahoeve) via the city centre.

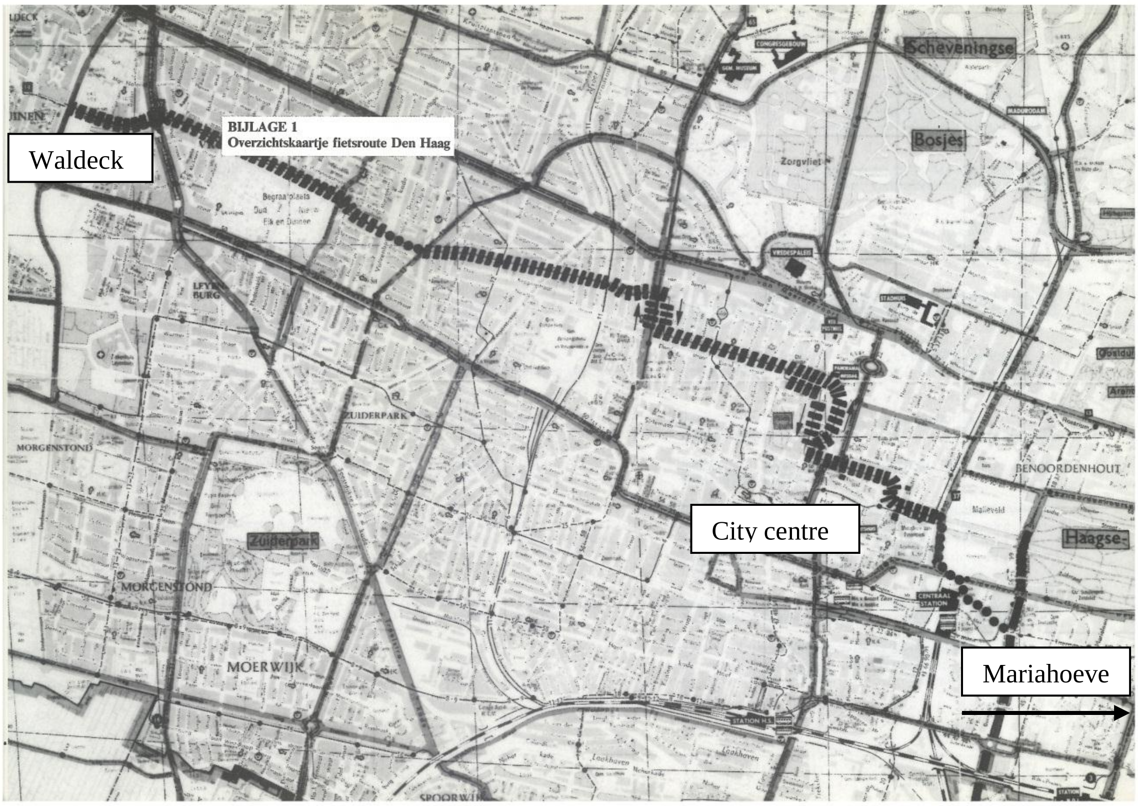


Figure 3.6: Bicycle route in The Hague

But the planned route through the city centre and the east part met so much opposition that the city centre part was only decided upon after the evaluation study, and the east part of the route was cancelled altogether. So the bicycle route that was subject of the evaluation study runs only from Waldeck, a neighbourhood in the Southwest part of The Hague to the city centre. The urban density in The Hague is somewhat higher than in Tilburg. Most parts of the route were designed as a one sided two directional cycle path, with priority of the cycle route at most of the intersections. Some parts are one way streets with cyclists mixing with motorised traffic and a contra flow cycling path in the other direction. As in Tilburg, the continuity of the route was made visible by the use of (red) coloured pavement. The experimental feature in The Hague was the design of ‘priority intersections’ that provided right of way to cyclists on the demonstration bicycle route. The bicycle route was aligned over a road hump so as to ensure that crossing car drivers slow down when approaching the bicycle route. (Dienst der Gemeentewerken’s-Gravenhage, 1978).

3.3 Organisation and implementation

Both demonstration projects stem from the desire of the national government to demonstrate the feasibility of well designed urban cycling infrastructure. As explained in paragraph 3.1 the Multiyear Plan for Persons Transport 1976-1980 had (for the first time) a budget line to subsidize urban cycling facilities. But as municipalities found it difficult to qualify for these subsidies, these demonstration routes had to show them the way. Because of the time frame of the multiyear plan the ministry wanted the projects to be implemented rather quickly. The original idea was that the implementation of both routes would be finalized in 1976.

For both projects there was a steering group of municipal officials and the (national) Department of Waterways and Public Works. Thereupon there was a ‘plenary study group’ with 5 subgroups for a proper evaluation of the projects. (See also the organization chart below.) The decision making on the project implementation was at the municipal level.

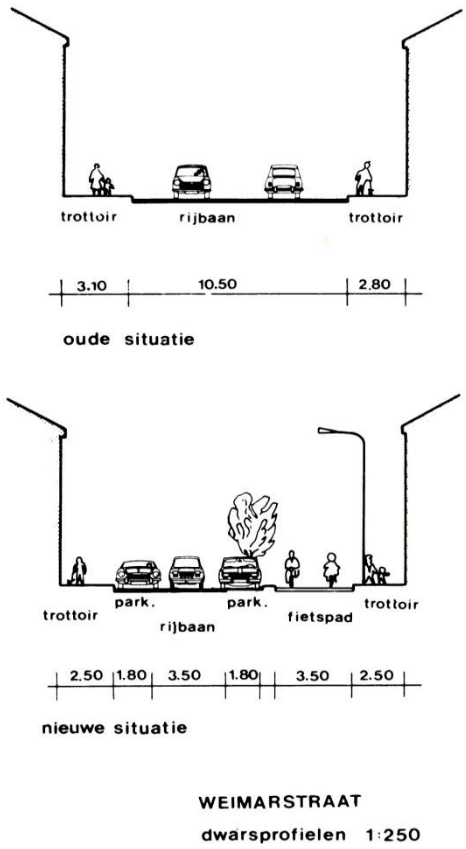


Figure 3.7: Example of before and after cross section in the The Hague bicycle route

3.3.1 Tilburg

In reality the (urban part of the) bicycle route in Tilburg was implemented between March 1976 and November 1977 (Ministerie van Verkeer en Waterstaat, 1977) after approval of the plans by the municipal council on 1 December 1975. The extensions to the neighbouring municipalities Berkel-Enschot and Oisterwijk were only decided in 1977, and these parts of the route are outside the scope of the evaluation studies.

Given the time pressure there was limited room for public information or consultation. Information and consultation sessions were organised per neighbourhood and with some stakeholder groups such as the Chamber of Commerce and the association of shop owners. Comments made could only be taken into account as far as they were within the boundary conditions of the project. This wasn’t always to the satisfaction of the people involved in this consultation process.

The technical preparation and supervision on the implementation was commissioned to some consultancies, with the final responsibility at Tilburg Public Works department.

3.3.2 The Hague

In The Hague the implementation process was less straightforward than in Tilburg. The original idea was that the municipal council would approve the plans for the entire bicycle route in one decision. But because of the opposition (mainly coming from shopkeepers) the council decided to take separate decisions for 5 different route sections. For each route section ‘information evenings’ were organised, and the plans for some sections raised substantial opposition, which resulted in serious delays for these sections. The route section in the historic city centre got approved only in 1983 after the evaluation studies were finished, and the northeast section was ultimately cancelled altogether.

The technical preparation was in the hands of the Department of Public Works of The Hague, while the political management of the project was a shared responsibility of the Town Clerk's office and the Department of Public Works.

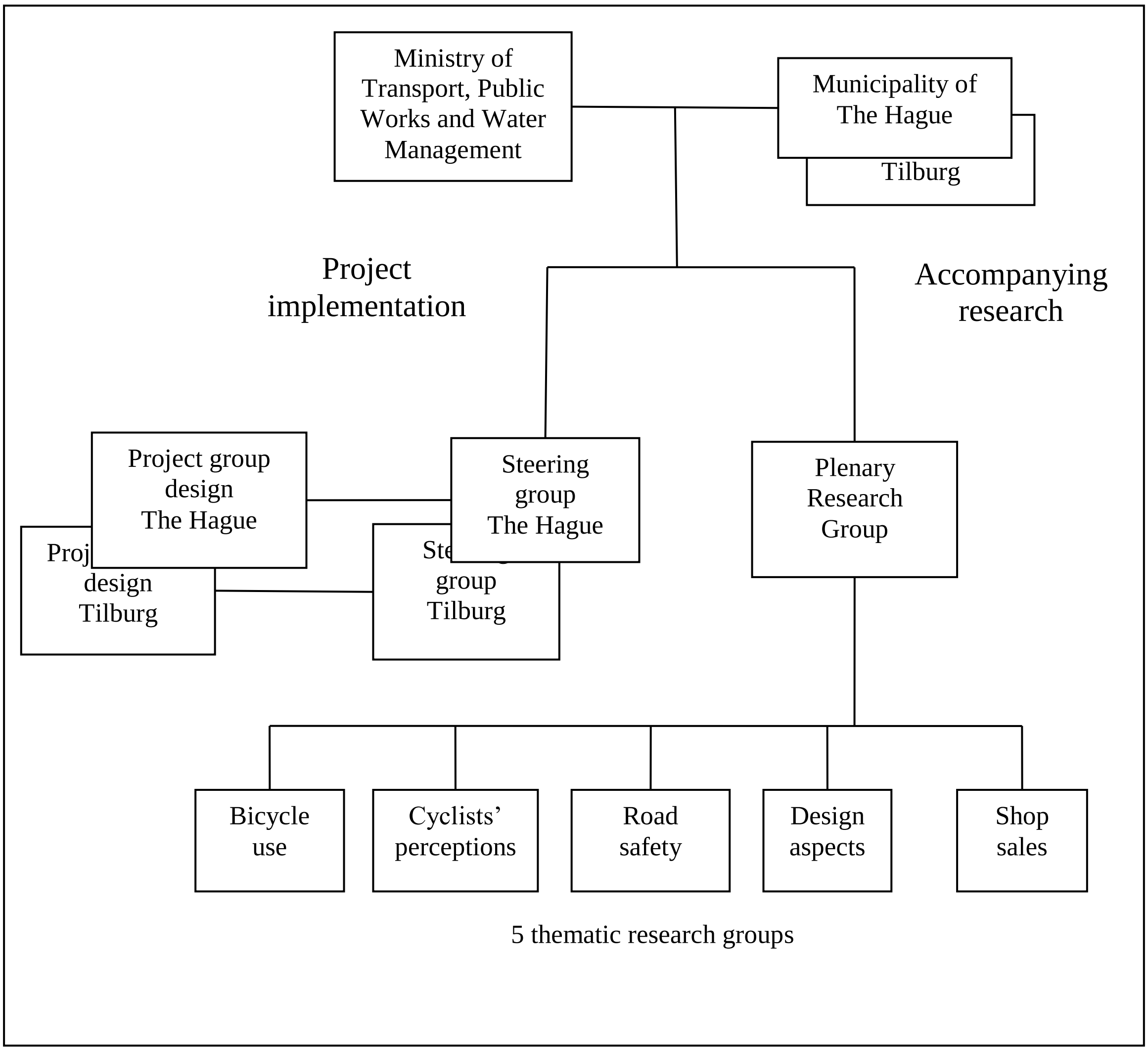


Figure 3.8: Chart of organisation and implementation of the two projects (Van den Broecke and Rijkswaterstaat, 1981)

3.4 The costs

It doesn't seem very worthwhile to go deeply into the costs of projects that were implemented more than 30 years ago. The reporting on this issue (Instituut voor Zintuigfysiologie, TNO and Rijkswaterstaat 1982) concludes that cost estimates were reasonably in line with the real costs, that it was difficult to establish a general applicable unit price for sections and intersections, that larger constructions such as bridges and underpasses do have a large impact on the total costs of such a project, and that costs are relatively low when the bicycle facilities can be implemented between the existing curbs of the carriageway. Reconstruction of the cross section 'from façade to façade' is obviously and understandably more expensive. This was also the main explanation why the bicycle route in The Hague was cheaper than the route in Tilburg: the route in The Hague could be implemented between the existing curbs, whereas in Tilburg the entire cross section was reconstructed. In the case of the two projects preparation and supervision of the construction of the bicycle routes took a substantial part of the budget.

3.5 Set-up of the evaluation studies

The demonstration projects were not only intended to show the feasibility of the implementation of cycling facilities, but also to get a better understanding of the effects of such facilities. For this reason the project was accompanied by a number of studies to evaluate the bicycle routes and to conclude whether the goals and objectives of the projects were achieved. The research was organised into five themes, researching the impacts or effects of the bicycle routes on (1) bicycle use, (2) perceptions (appreciation) of the quality of the route and its elements, (3) road safety, (4) design aspects, and (5) shop sales. These groups were supervised by a plenary research group as shown in the organization chart in Section 3.3.

Like the information and consultation process, the determination of the research questions was rather quick and dirty. As a consequence, the research questions of the 5 research groups didn't fit optimally with policy issues. Also the research themes weren't optimally coordinated, which made it difficult to draw integral conclusions. An integral evaluation was done on the technical aspects (building on the results of the 5 themes) and on the process aspects of the project (evaluating project organisation, implementation and demonstration). The next paragraphs will shortly explain the research questions, used methods and results of all evaluation studies.

3.6 The impacts

3.6.1 Bicycle use

With regard to bicycle use the research questions were:

- Did the construction of the bicycle route result in additional trips?
- Did the construction of the bicycle route result in a modal shift?
- Is the bicycle route attracting cyclists from parallel routes?
- What is the size of the *area of influence* of the bicycle route?
- Do cyclists using the bicycle route judge differently about time losses as a consequence of detours than cyclists using other routes? (Or to phrase it differently: are cyclists prepared to accept longer detours in order to get to a high quality bicycle route?)
- How do cyclists experience certain design aspects?

(DHV *et al*,1980)

These questions were answered on the basis of counts of volumes of cyclists on the demonstration routes and parallel routes before (October 1975) and after (October 1977, April 1978, October 1978 and October 1979) the implementation of the bicycle routes, and on the basis of a survey (after implementation) amongst cyclists on the bicycle routes and in the vicinity of these routes. The counts and surveys were identically executed in The Hague and Tilburg. Moped users were also surveyed, but as the number of moped users decreased substantially between 1975 and 1977 (15%

in The Hague and 30% in Tilburg) the analyses of the surveys was only done with the cyclists' responses. It is good to note here that the majority of cyclists surveyed (75% in Tilburg and 81% in The Hague) had no car available for their trips. (It is likely that today – 2011 – much higher percentages of cyclists have a car available.)

The counts in both cities were done on two corridor cross sections, including the bicycle route and the parallel routes on both sides. In both cities the volume of cyclists on the newly implemented route increased dramatically at the cost of the volumes of the parallel routes. The increase of volumes on the bicycle routes were highest in Tilburg (146% in 1978 and 140% in 1979 – both compared with the volumes as counted in 1975) but also in The Hague they were considerable (54% in 1978 and 76% in 1979). 40% of the users in The Hague and 67% of the users in Tilburg came from parallel routes.

At the same time cyclists didn't appear to be prepared to make large detours. The average detour distance (defined as the difference between 'the distance as the crow flies' and 'the distance over the road') on the bicycle route in The Hague is only 90 m longer than on the parallel routes; and in Tilburg the bicycle route is the shortest route anyway for most cyclists. The latter fact can be an explanation of the larger increase in use of the bicycle route in Tilburg: the shift in route choice in Tilburg can be explained because of an improved directness offered by the bicycle route. In case of a similar directness (no or minor detours compared to other routes) the shift in route choice can be explained by the better cycling quality of the route. Cyclists in The Hague appeared prepared to accept an average additional detour of only 90 m to use the better quality bicycle route. (DHV *et* al, 1980) Goudappel en Coffeng and Rijkswaterstaat (1981, 1) suggest that travel time could be an explaining factor for this. The perception study revealed that cyclists appreciate the feeling of being able to advance smoothly, and that the absence of traffic lights on the demonstration route could result in a shorter travel time even if the distance was a bit larger.

The total volume of cyclists in the corridor increased as well. The increase was larger on the bicycle routes than on the parallel routes. In the survey cyclists indicated that they made more cycling trips for discretionary trips (as opposed to 'obligatory' or 'non-discretionary' trips such as commuting to school or to work, which were not expected to increase). Cyclists stated to make more cycling trips to shops, family visits and recreational purposes than before the implementation of the bicycle route.

On the other hand, implementation of the demonstration bicycle routes had only a modest impact on modal choice. In 1977 cyclists (on the demonstration routes and on parallel routes) were asked what mode of transport they used in 1975. Most cyclists (90%) already cycled before (as most of them had no car available for their trip) and there was no difference in this respect between cyclists on the demonstration routes and on parallel routes. There was hardly any impact on public transport use in both cities (which had very different levels of service). There was a small shift from car to bicycle (5-8% of the cyclists who owned a car – which is only 20-25% of all cyclists – indicated that they used to use their car in 1975), and it can be concluded very cautiously that the (autonomous) shift from bicycle to other modes (i.e. shift in modal preference apart from objective factors commonly used in travel models such as travel time) was smaller for cyclists using the demonstration route than for those using parallel routes. (Goudappel en Coffeng and Rijkswaterstaat 1980, DHV *et al*, 1980).

With regard to the area of influence of the demonstration route, an analysis was made of the origins and destinations of the surveyed cyclists. It appeared that those having their origin and/or destination within 250 m of the route will use the route rather frequently, but when origin and destination are further away, the use of the route rapidly becomes very small. It could not be shown that the area of influence of these demonstration routes was larger than the area of influence of other routes. However, when trip distances were more or less equal (i.e. no detour as a consequence of using the route), cyclists chose the demonstration route more often.

In general, the users of the demonstration bicycle routes were positive about the routes. Satisfaction was larger in Tilburg than in The Hague, although some design aspects also raised some criticism. (See also Section 3.6.3, Perception of cycling quality.)

3.6.2 Road safety

With regard to road safety the researchers made a distinction between 'objective' road safety which can be measured by the number of personal injury accidents and facilities, and the 'perceived' or 'subjective' road safety: how safe do cyclists feel to be. This paragraph is mainly dealing with the objective road safety effects of the demonstration routes: to what extent did the implementation of these routes result in a decrease of personal injury or fatal accidents. Perceived safety is dealt with in the following section.

The main research questions with regard to road safety effects of the demonstration routes were:

- What is the influence of the implemented demonstration routes on the (objective) road safety within the area of influence of the routes?
- What is the influence of geometric design and traffic light adjustments of the newly implemented facilities on the road safety on the routes?

The first question was elaborated in a number of sub-questions so as to compare road safety for motorised and non-motorised road users in the routes' area of influence with a control area, and subsequently to compare the cycle route road sections and intersections with other road sections and intersections within the area of influence. The second question was also elaborated in a number of more detailed research questions but eventually handed over to the research group looking into design aspects. As the accidents per location (fortunately) are too rare to enable good conclusions on the basis of accident data, other methods of analysis had to be applied. For design-related road safety conclusions, see Section 3.6.4.

The road safety impacts in this paragraph are based on an analysis of accident data before and after the implementation of the bicycle route. (Goudappel en Coffeng and Rijkswaterstaat, 1981, 3 and 4)

With regard to the development of road safety for all road users there appeared to be no difference in the areas of influence of the bicycle routes in comparison with the control areas.

Different results were found when looking at the accidents at sections and intersections of the bicycle route compared to other road sections and intersections within the influence areas. On the road sections and intersections along the bicycle routes, single personal injury accidents and personal injury accidents with only cyclists involved were more frequent, and on intersections this was also true for cyclist-motorist personal injury accidents. However, if we compare the bicycle route with the parallel routes, there was no difference. However, accounting for the increase in use of the bicycle routes, it was also found that the risk of personal injury was lowest on the bicycle routes. This can be explained by the absence of cyclist-motorist collisions on the road sections of bicycle route because of the segregated facilities. One could say that there was a shift from cyclist-motorist accidents to cyclist-cyclist accidents, cyclists-pedestrian accidents and single cyclist accidents. The latter types of accidents are on average of course less serious than the cyclist-motorist accidents they replaced.

In general the researchers concluded that the demonstration bicycle routes had no measurable impact on the number of accidents with personal injury, and this was a disappointing conclusion. There was no clear positive effect of the bicycle routes on (objective) road safety (Dienst der Gemeentewerken ’s-Gravenhage, 1984).

3.6.3 Perception of cycling quality

One of the research themes was to determine how cyclists and other road users perceive (and experience) the bicycle routes and the various design elements, and to which extent the perception (and experience) of cycling in the city is improved by the construction of a dedicated bicycle route. The character of this research was mainly qualitative.

Research questions were:

- How do the various groups of road users appreciate/assess the current (implemented) bicycle route, and what are the reasons for a positive or a negative assessment?
- How do bicycle and moped users perceive the use of the bicycle route in comparison with cycling in the before situation?
- What can be said on a qualitative level about the effects of the bicycle route on the level of bicycle use and on route choice?
- How are the various design elements (design components) of the bicycle routes being perceived by the users?
- How do motorists perceive the priority intersections on the bicycle route?

To answer these questions a survey was executed before and after the implementation of the bicycle routes amongst three important target groups within the (expected) areas of influence of both demonstration routes. These target groups were:

- Employees from adjacent residential areas having their jobs in the city centre, who don’t need a car for their job and could or do use the bicycle for their commuting;
- Housewives from the same residential areas who could or do cycle;
- Students of schools in the vicinity of the bicycle route.

There were also surveys amongst control groups, consisting of similar employees and housewives from similar neighbourhoods but outside the areas of influence of the bicycle routes. It appeared necessary to replenish the panels that had been surveyed in the before study for the after study, especially in The Hague: because of the delays in implementation the existing panels appeared to be depleted substantially at the time of the after study. Even more so, because a large part of the demonstration route in The Hague (the north-east section) was not implemented, and as a consequence the corresponding part of the before study panel wasn't relevant for the after study.

The surveys consisted of an extensive list of questions, and the results of the before study were also used for drafting the questions for the after study.

In general, the respondents (both users and non-users of the routes) assessed the implementation of the bicycle routes positively. Non-users included both cyclists from other areas and non-cyclists; even a majority of non-cyclists were positive. The positive judgements (in 1978) were more frequent in Tilburg (82%) than in The Hague (62%). Main reasons for the positive appreciation were improved perceived (!) road safety and more room for cycling because of the provision of segregated road space. Additionally, the cyclists in Tilburg mentioned that the bicycle route made the city centre more (speedily) accessible by bicycle. Those in The Hague who were negative in their assessment of the bicycle route mentioned mainly insufficient road safety or even called the route dangerous. In Tilburg the negative assessments were mainly explained by the nuisance that the bicycle route created for other road users.

It is striking that with regard to the positive expectations, it was just the other way around in the before study in 1976: cyclists in The Hague were more positive about the plans (83%) than cyclists in Tilburg (68%). Also, more cyclists in The Hague were (in 1978) positive about the suggestion for more bicycle routes than cyclists in Tilburg (68%). An explanation for this could be that firstly the need for improvement of cycling conditions was perceived as more urgent in The Hague than in Tilburg, and secondly that higher expectations can be easier disappointed.

The next research question was how cyclists compare the use of the bicycle route with the before situation without the bicycle route. Generally they felt safer than before, allowing them to cycle more undisturbed and feeling that they can progress more smoothly.

Elements that panellists spontaneously mentioned as being 'well thought out' were the (reddish) coloured pavement of the bicycle route, the segregation from the motor traffic and the right of way at intersections. On the question what they disliked, cyclists mentioned dangerous (priority) intersections, some narrow sections, mopeds on the bicycle route and a number of very diverse other objections.

When directly asked to assess certain quality aspects as being improved or deteriorated these were the results:

Table 3.1: Perceived changes in quality

	improved		*deteriorated*	
Quality aspect	The Hague	Tilburg	The Hague	Tilburg
More pleasant cycling	71%	82%	10%	1%
Safer cycling	66%	78%	12%	4%
Progressing more smoothly (i.e. improved directness)	57%	79%	5%	4%
More attractive route	43%	56%	7%	4%

The most striking difference between the two cities is the relative larger improvement in perceived directness in Tilburg.

The effect of the bicycle routes on bicycle use and route choice were already studied in another research theme (see 3.6.1), and the results in this study regarding the perceptions of cyclists are in line with those results. Only small percentages of the cyclist respondents indicated that they cycled more often because of the bicycle routes: 2% of the employees and 7% of the housewives in The Hague, and 9% of the employees and 13% of the housewives in Tilburg. Changes in modal choice for commuting were minor, and for other trip purposes slightly higher but still very modest: 5%. In line with the results of the research on travel behaviour, cyclists indicated that they use the route only if it provides a direct connection between origin and destination.

When it comes to the appreciation of certain design aspects of the bicycle routes the following observations can be made:

- A positive appreciation of the design correlates with the extent of segregation and the width of the facilities. Cyclists are obviously less positive when facilities are not segregated and/or too narrow.
- There is also a correlation between the perception of safety and the enjoyment associated with cycling, although the perception of safety is systematically more positive than the perception of enjoyment. One could conclude that perceived safety is a precondition for enjoyable cycling, but obviously there is more to it.
- Intersections were perceived as less safe than road sections, and a bit more so in case of intersections without traffic lights.
- The two grade separated crossings in Tilburg were in general appreciated, although the (specific) design of one underpass had also some critical remarks.
- The bumps in the road surface at some intersections in Tilburg to steer the manoeuvres of car drivers were mainly assessed as too rough, whereas the road humps at intersections in The Hague were well appreciated.
- Coloured pavement to visually distinguish the space for cycling and to underline the coherence and continuity of the route were generally appreciated.
- Cyclists prefer an asphalt pavement above tile paving.

3.6.4 Design aspects

An important question is how the results of the investigations described in the previous paragraphs relate to specific designs applied in the bicycle routes. Upon that, it is important to know to what extent the behaviour of road users was in accordance with the intentions of the designers. To a certain extent these questions were answered in the research on the perceptions of road users. A specific investigation was done to evaluate the design of intersections, and more particularly the intersections without traffic lights where cyclists have the right of way.

At these intersections and a number of control intersections observations were made of the behaviour of various road users with regard to their speed, manoeuvres and interaction with other road users. Behaviour was registered and subsequently analysed. The seriousness of interactions or conflicts was assessed by calculating the ‘time to collision' (i.e. the collision that would happen if road users continue their course with unchanged speed; van der Horst and Sijmonsma, 1978).

This observation method was also applied to complement the road safety analysis based on accident data. On each individual location the number of accidents was too rare to draw any specific conclusion with regard to the safety of the location in relation to the applied design. As near misses happen much more frequently than real accidents, observations of those near misses can provide a data base that is considered to a good proxy for road accident databases as basis for an in depth road safety analysis.

Conclusions at route level:
- Given the fact that cyclists are hardly willing to make detours, the design of bicycle routes should offer connections that are as direct as possible between origin and destination. Combined with the preference of cyclists for segregated facilities, the implication is that if a heavily used arterial provides the shortest connection for cyclists, these arterials should have segregated cycle tracks.
- However, routes along arterials have some disadvantages, such as the experience of noise and emissions, traffic lights that often aren't well adjusted to the needs of cyclists, and the risk of collisions with turning motor traffic. So if direct connections can be made through traffic calmed areas, this is the preferred option.
- Another finding of the research was the importance of a logical tracing of the various links of the bicycle route. If the tracing of the route is unclear, cyclists get 'lost'. Thus, coherence is an important requirement for cycling infrastructure.

Findings and conclusions with regard to road sections:
- For both bicycle routes, the bicycle facilities were segregated from motor traffic as much as possible, and cyclists appeared to appreciate this.
- The route in Tilburg was better appreciated than the route in The Hague. In The Hague the emphasis was on creating safety, whereas in Tilburg the emphasis was on progressing more smoothly (improving directness) through traffic restrained streets.
- Where there was insufficient space to apply desired widths, in some streets the designers chose for compromised solutions. Narrowing the width for all road users with only visual separation (that is, lane lines) between cyclists and motorists was appreciated by none of the categories of road users: the design wasn't comfortable for any of them. A better option seems to be to design such a street as a residential street with limited access for motor traffic and a mixed profile. However, this is not ideal for a main bicycle route.
- Both in The Hague and in Tilburg, one-sided two-directional bicycle tracks were predominantly applied. Regarding the level of use, research showed that this hardly makes any difference compared with two-sided one-directional tracks. These one-sided two-directional bicycle tracks have a big advantage with regard to road management: overall, they are cheaper to construct and require less space than two-sided one-directional tracks. For cyclists they have only advantages when most origins and destinations are on the same side of the road, because in those cases there is less need for cyclists to cross the main carriageway. But there are also serious disadvantages: the perception of safety by cyclists is less for those riding in the 'wrong' direction (which is understandable as they are closest to the head-on motor traffic). Also, at intersections one-sided facilities have more

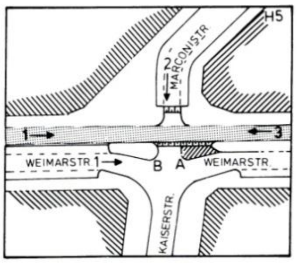
conflicts and accidents, again with these cyclists in the ‘wrong’ direction being the ‘unexpected direction’ for other road users. Also the overtaking by mopeds on these two-directional tracks is perceived as less safe and comfortable. The overall conclusion is that in urban environments two-sided one-directional tracks are in general the most preferred bicycle facilities. One-sided two-directional tracks should only be applied if it is clear that the advantages of a decreased need for crossing the main carriageway exceed the described disadvantages.

- The interaction with crossing pedestrians demands attention as well. As this often happens unexpectedly and all along the route, this requires some extra width for avoiding manoeuvres. An additional width of 0.50 m of the bicycle track is recommended at locations where many crossing pedestrians can be expected (Instituut voor Zintuigfysiologie 1981). In general and particularly at dedicated pedestrian crossings it is important that pedestrians can see where and from which directions they can expect cyclists. The coloured pavement contributes to this by enhancing the recognisability of the bicycle track.

Findings and conclusions with regard to the intersection designs

The research into the design aspects of ‘unregulated priority crossings’, i.e. intersections without traffic lights providing right of way to the cyclists on the bicycle route, is probably the most significant research about design aspects of cycling facilities of these projects. Therefore we will go into a bit more detail on the aspects of intersection design.

- On both bicycle routes, intersection designs were implemented that intended to have an impact on the speed, manoeuvring and interaction by road users. The main objective was to get car drivers to approach the bicycle route with low speeds and being alerted to the presence of cyclists so that they would give them right of way. For this purpose, bumps and road humps were applied as well as narrowings of the side streets just before the crossing with the bicycle route. Also, in some intersections areas the designers applied more or less uneven cobblestones to influence the manoeuvring of (personal) cars. The idea was that the discomfort of driving over the cobblestones would induce car drivers to avoid riding over the cobblestones, thus leading them to make the intended manoeuvre across the intersection with a smaller turning radius (and therefore lower speed) and to cross the bicycle track at a right angle, while still allowing larger vehicles (which need a larger turning radius) to still could make turns by using the area with the uneven pavement. Below are a few examples of intersection designs applied in The Hague; the hatched areas near corners A and B represent rough cobblestone pavement.



4.8a Situatieschets H5, Weimarstraat–Marconistraat

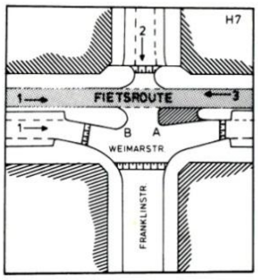
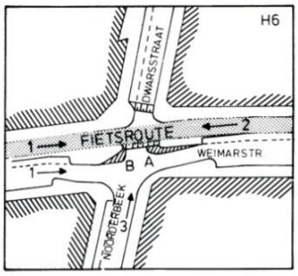


Fig. 4.8b Situatieschets H7, Weimarstraat–Franklinstraat



4.8c Situatieschets H6, Weimarstraat–Noorderbeekdwarsstraat

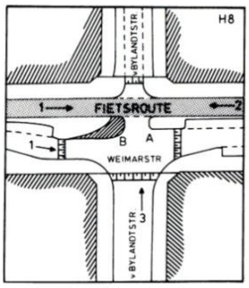


Fig. 4.8d Situatieschets H8, Weimarstraat–v. Bylandtstraat

Figure 3.9: Four examples of intersection designs

- The observation study systematically distinguished all possible interactions between one- or two-directional bicycle tracks on the one hand and one- or two-directional crossing motor traffic on the other hand. A further distinction was made between situations in which motor traffic would (a) first cross the bicycle route and then the main carriageway, (b) first cross the main carriageway and then the bicycle route, or (c) only cross the bicycle route. By systematic dividing intersections into appropriate zones, the behaviour of road users in each zone could be analysed. In an ideal situation before and after studies would have been done, but this wasn't possible as the research method was only developed after the bicycle routes had been implemented. Therefore some control intersections were selected in order to determine the effects of the applied design elements.

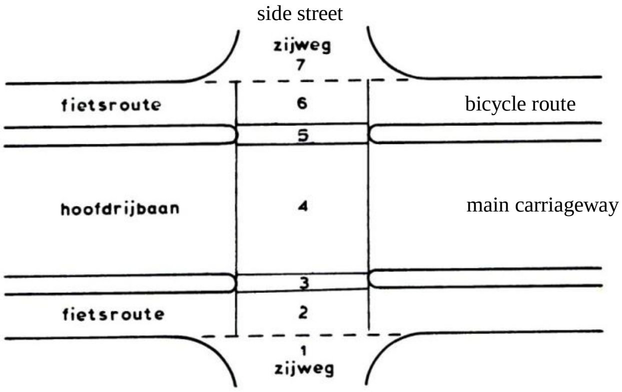


Figure 3.10: Zoning categories: in zone 1 (or zone 7) traffic from the side street is approaching the bicycle route

Next, behavioural elements to analyse were identified:

- Speed behaviour upon approaching the bicycle route (mainly in zone 1);

- The aligning behaviour of side street traffic in case they had to wait for traffic on the main carriageway parallel to the bicycle route (mainly in zone 2 and 3);
- Manoeuvre behaviour and interactions with cyclists on the bicycle route.

- Speed behaviour: The application of road humps (or table crossings) over which the bicycle route was aligned in combination with narrowings of the side streets just before the crossing appeared to work quite well. As car drivers would slow down anyway when approaching the main carriageway, the deceleration was larger in case of the hump or table crossing. But the most significant effect was the location of the deceleration. Without a speed hump the cars would slow down just before the main carriageway, whereas in the case of the road hump or table crossing with the bicycle route they would slow down before crossing the bicycle route. Having the ramp 5 m before the edge of the bicycle route had significantly better effects than having the ramp just at the edge of the bicycle route. So the effect of the humps was that car drivers will slow down more and earlier.

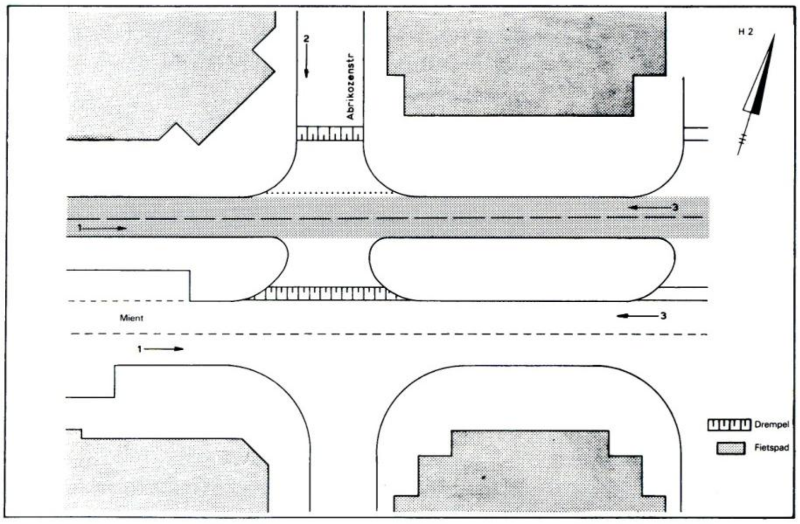


Figure 3.11: An intersection with 5m distance between ramps and the edge of the bicycle track

The speed behaviour of drivers coming from zone 7 or 4, i.e. the cars approaching the bicycle route from the other direction (the side street on the other side of the road or from the main carriage way), was observed as well. Although the minimum speeds measured were higher than the speeds of cars coming from zone 1, the speed was still significant lower than in cases without speed humps. The difference was least for cars making a right turn to cross the bicycle route.

- Alignment behaviour: Alignment behaviour was also positively influenced by the presence of the road humps. In case of humps or speed tables, cars coming from zone 1 clearly reach their minimum speed before the bicycle route, whereas in cases without humps the minimum speed is on or even beyond the bicycle route. However, the way cars from this direction aligned themselves wasn’t analysed explicitly. The way cars from zone 2 and 3 aligned themselves was looked at in cases in which they didn’t have to give way to cyclists but had to wait for cars on the main carriageway. The desired alignment would be in zone 3 without blocking the bicycle route in zone 2. Here the position of the ramp of the road hump in combination with the available width of zone 3 appears to make a significant difference. Zone 3 has to be wide enough to position a car. However, even then it makes a difference whether the ramp is at the edge of the bicycle route or 5 m before it (at the edge of the main carriageway). In the latter case, cars make significantly fewer stops blocking the bicycle route by 1 m or more. The reason is that when the ramp is 5 m from the edge of the bicycle route, they don't have to worry about their rear wheels being on the ramp.

- Manoeuvre behaviour: The intended effect of the applied areas with cobblestones did occurred only when they were paved very unevenly. Visually marked areas with a smooth surface were less effective at inducing the intended manoeuvre behaviour. The project in Tilburg showed that extreme bumps to steer manoeuvre behaviour can also be counterproductive: if the intended manoeuvre appears too difficult or uncomfortable car drivers might try to avoid these bumps in other ways, sometimes by invading the bicycle track.

Figure 3.12 and figure 3.13: Cobblestone area intended to steer manoeuvre behaviour toward a sharper turning radius

- Conflicts: the observation study also revealed that conflicts between cars and cyclists on a two directional bicycle track tend to be more serious between the car and the stream of crossing cyclists the car driver encounters upon arrival. Also, the number of serious conflicts is influenced by the most frequently occurring turning movements at the intersection. Clarity about turning movements that are expected helped, and intersections along the bicycle routes had less serious conflicts than the control intersections.
- With regard to intersections with traffic lights, it appears that cyclists hardly noticed any difference between traffic light adjustments on the bicycle route and at other intersections. What they liked most was that the number of intersections with traffic lights was diminished along the bicycle route, reducing their delay. Again this underlines the importance of the requirement of directness.

3.6.5 Economy

With the implementation of the bicycle routes the impact to shops was a big issue. Especially in The Hague shopkeepers weren't very happy with the implementation of the route (which was one of the first projects of its kind). The implementation of several parts of the route was seriously delayed because of the opposition of shopkeepers and in the end some parts that had been planned were never implemented. The fear for losing business is only too understandable. Therefore research was done on the impact of the bicycle route on shop sales along the route.

The research in The Hague compared the trend in sales at the shops along the bicycle route with the countrywide average sales trend and the trend of a similar control group of comparable shops. For the shops in Tilburg it appeared impossible to compose a proper control group and thus a comparison was made only with national trends. Nevertheless the findings in both cities were consistent.

In both cities the volume of business of shops along the bicycle routes was negatively affected in the construction phase: their sales were below the national average for similar shops, although this effect was much lower for shops in the food sector that attracted their clients from the neighbourhood. After the construction the shops in the food sector very quickly caught up and performed actually better than the national average. The trend in sales was quite different for shops in the sector of durable consumer goods (which often attract their clients from a wider area): they performed far below the national trends, and also the number of shops closing down in this sector was relatively high. It should be noted though that there are large differences between sub-sectors and also that several of these shops (especially in The Hague) were already marginal before the bicycle route was implemented.

In conclusion one can say that the construction phase of public works will very likely cause some negative impacts on sales at shops. Generally shops will catch up later and compensate for the losses in volume of business during the construction. But this is not true for all sectors. Shops selling durable consumer goods seemed (at that time) to be more vulnerable to changes in their accessibility (e.g. because of the reduction parking space) than shops in the food sector. The explanatory factor is the difference in catchment area: when clients come from the neighbourhood there was hardly any negative effect, whereas shops whose clients came from a wider area had more problems with their recovery. One could even say: there might be winners and their might be losers. In any case it is good to pay attention to specific issues that might have impact on the accessibility of shops for their existing clients (e.g. with regard to parking space, loading and unloading facilities, etc.) in order to minimise the disturbance to businesses.

3.7 Discussion

The ‘demonstration bicycle routes’ implemented in the late 1970’s in The Hague and Tilburg was the first well documented case study on the impact of cycling infrastructure. These projects can be seen as the first serious attempt to provide high quality infrastructure for cycling and to study their impacts extensively. Although the projects suffered from some ambiguity in their set up (trying to combine a demonstration of feasibility with experimental designs), the findings of the accompanying researches contained many elements which were later reflected in ‘Sign up for the bike, design manual for cycle-friendly infrastructure’, published later in 1993 and updated in 2006 under the title ‘Design manual for bicycle traffic’.

The projects showed a number of things:

- Cyclists do appreciate dedicated facilities for cycling. What they liked specifically in the two projects was the (perceived!) improvement of road safety, the experience of undisturbed cycling, improvements of directness (without detours and delays), and – with regard to design – the ‘furnishing’ of the route: the red coloured pavement and other design elements that underlined the tracing, recognisability and continuity of the route.

- Apart from providing the shortest connection between origin and destination the directness of a route can be improved by minimising delays: giving right of way to cyclists at intersections and minimising the number of traffic lights on the route.
- Regardless of how much cyclists liked the design of the route, they showed only a very limited willingness to make detours to take full advantage of the improved cycling conditions. Although the demonstration routes attracted many cyclists from parallel routes, these new routes had more or less the same length as the earlier used routes or were shorter.
- Although road safety is considered to be vital by both bicycle users and policy makers, there was a remarkable contrast between the impacts of the facilities on the factual and the perceived road safety: road safety data showed no or very minor impacts, whereas the perceived road safety improved substantially. Policy makers were disappointed by the marginal impact of the facilities on the ‘objective’ road safety figures.
- The research also suggested that one should be careful with applying one-sided two directional bicycle tracks: this type of facility can have a negative impact on both factual (objective) and perceived (subjective) road safety of cyclists. Two sided one-directional bicycle tracks are on average experienced as more safe than one sided two-directional cycle tracks. Thus one sided two-directional tracks should only be applied if there are clear advantages such as diminishing the need for crossing busy roads.
- With regard to experimental design features the project provided a better understanding of effective design of priority intersections for cyclists. The observations of road users’ behaviour at those intersections proved to be very instructive.
- The researchers also did some theoretical analyses in order to shed light on what would be the ideal mesh width in a network of cycle routes. This provided the basis for the next demonstration project in this overview of case studies: the Delft bicycle network, implemented in the 1980’s.

In general the bicycle route in Tilburg was better appreciated than the bicycle route in The Hague, and this difference in appreciation was inversely correlated with differences in expectations. Yet the The Hague cyclists were more in favour of extensions of the bicycle route than those in Tilburg. But also the opposition in The Hague appeared to be much stronger. It is ironic that when the project was over, the municipality of Tilburg began implementing a comprehensive bicycle network (which was locally known as Tilburg’s ‘star network’) with a strong emphasis on radial connections with the city centre, whereas the municipality of The Hague did not continue its efforts to substantially improve cycling conditions. Continuing complaints of shopkeepers eventually even resulted in the dismantling of large parts of the bicycle route in The Hague.

4 The Delft Bicycle Plan

Delft is a medium-sized city in the highly urbanised western part of the Netherlands. It is located between the metropolitan areas of Rotterdam and The Hague and lies within cycling distance of these two cities (Figure 4.1).

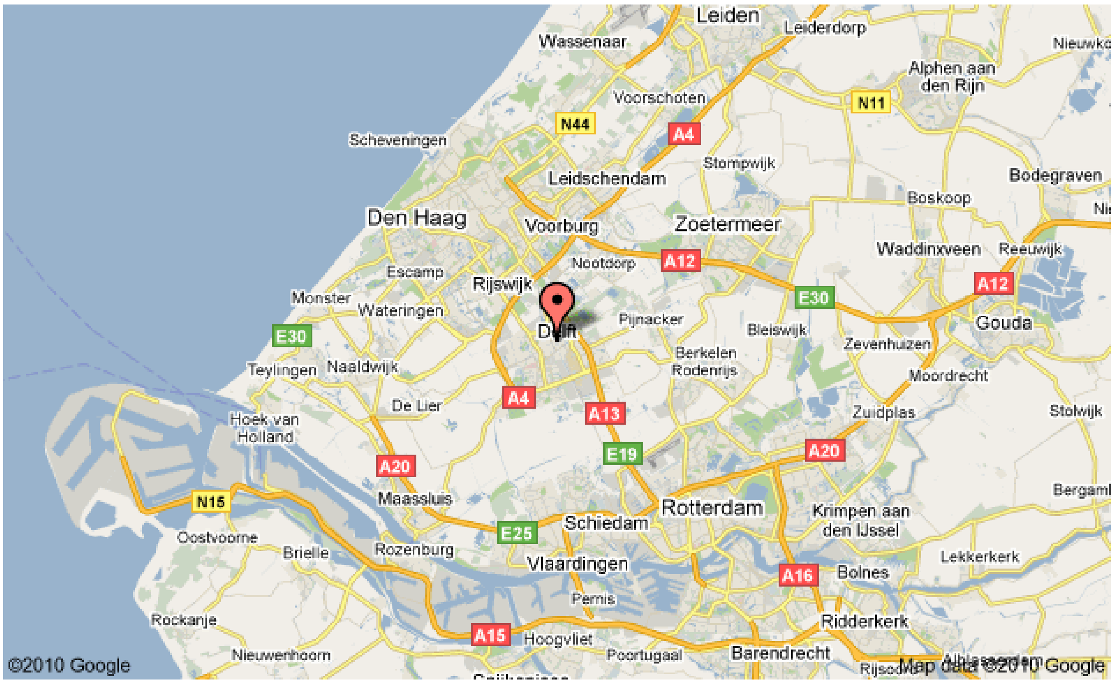


Figure 4.1: Location of Delft

The main infrastructure routes (railway, canal, and motorway) run north-south through or along the city. In the Middle Ages Delft was one of the largest cities in Holland. It has still a large medieval inner city. The city houses a technical university and a large technical research institute (TNO). It promotes itself as ‘knowledge city’.

The historic city centre with a low accessibility for cars as well as the large share of student population gives Delft a high potential for the bicycle. In 1979 the Delft Bicycle Plan was launched that aimed at realising a coherent bicycle network all over the city. At that time, the city had 85,000 inhabitants. The plan was implemented in the 1980s and evaluated elaborately. The evaluation regarded both the whole network and some larger single projects. In the next sections the plan and the evaluation of both the network and one single project (the Plantagebrug) will be discussed.

4.1 Political context

Section 2 described how in the 1970s the Dutch national policy started to give high priority to promoting cycling and improving cycling conditions. Besides, there was need for more knowledge on the impacts of interventions in bicycle infrastructure. The demonstration projects in Tilburg and The Hague were results of this policy. After these projects were finished, the national policy continued to promote cycling by providing subsidies for specific projects, and there was still demand for more knowledge. The demonstration projects proved that investments in single bicycle routes could enhance (the perception of) safety, but that the impacts on bicycle use are rather small. One assumed that improvement of a complete network would have a more significant impact on bicycle use (Ministry of Transport and Public Works, 1987; Wilmink, 1987).

In the late 1970s, the medium-sized city of Delft developed a plan for a coherent bicycle network in the whole city and requested the central government for a significant subsidy. The subsidy was granted under the condition that the implementation would be evaluated elaborately. The Delft Bicycle Plan was included in the Dutch second Programme for Person Transport for the period 1980-1984 as an evaluation project (Ministry of Transport and Public Works, 1986).

The European Economic Community was interested in the evaluation results and contributed in financing a substantial part of the costs of the evaluation studies. The regional authority, the province of South-Holland, played a minor role in the project. It provided some subsidy for the implementation. So, four levels of authority were to a smaller or larger extent involved in the project: local, regional, national and supranational (Diepens en Okkema, 1994).

4.2 Design

4.2.1 The network

In the Delft Bicycle Plan, three networks on three hierarchical levels were defined: a city network, a district network and a neighbourhood network. The networks have different functions, service qualities and densities. All networks have basically a grid-pattern. The existing infrastructure was basic in the network definition. The objective of the plan was to upgrade and extend the existing network in order to achieve a network that satisfies the requirements of the three defined sub-networks (Ministry of Transport and Public Works, 1987; Hartman, 1987).

The defined city network consists of the most important routes that traverse the entire town and connect to the regional bicycle system. The function is to accommodate the larger inter-district bicycle trips as well as the regional trips that go into or outside the city. It has high standards for capacity, velocity and convenience. Important barriers like canals, railways and main roads are crossed at a separate level. The link spacing is 400-600 m. Destinations that attract many people from the whole city like railway stations, secondary schools, and main shopping centres are directly connected to the network.

The defined district network has two functions. It provides adequate infrastructure for bicycle trips inside districts and collects and distributes bicycle traffic to and from the city network. The links are spaced 200-300 m. Facilities like primary schools and shops are connected to the network.

The neighbourhood network connects the individual houses to the other networks. It comprises the remaining streets and shortcuts for the bicycle. The link spacing is about 100 m.

The networks are displayed in Figure 4.2

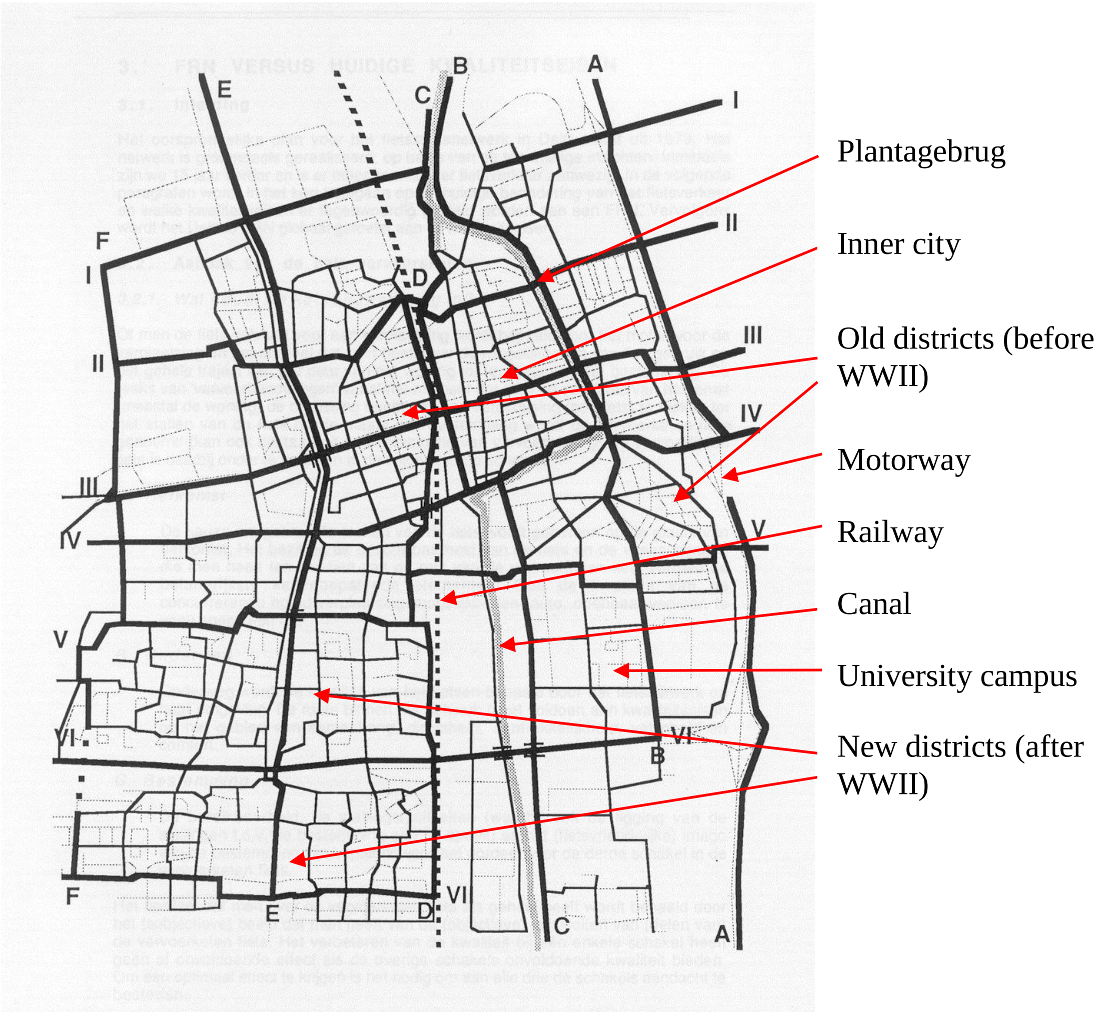


Figure 4.2: The defined bicycle network

In the before situation, 75% of the defined network already existed according to the Ministry of Transport and Public Works (1987). We assume that this figure relates only to the city network; for the whole network the figure is likely to be in the order of 90%. For completion of the defined network a large number of different projects had to be executed. Not all defined projects were implemented, and others were implemented outside the framework of the bicycle plan. Some projects would only have been realised if planned new residential quarters had been developed, a few other expensive projects were subsidised separately and not considered to be part of the plan any more (Ten Grotenhuis, 1987). Diepens en Okkema (1994) assume that some projects were not implemented because of the high investment costs.

4.2.2 The projects

Table 4.1 gives an overview of the numbers of implemented projects and the length of the infrastructure involved by project type and sub-network (Diepens en Okkema, 1993). The table demonstrates that a large number of projects with quite varying natures were executed. Most of the effort went to realising the city and district networks, in particular the city network that is highest in the hierarchy.

Table 4.1: Number of projects and infrastructure length by type of project and network

	city network		district network		intersections city/district network		neighbourhood network	
	# of proj.	length (km)	# of proj.	length (km)	# of proj.	length (km)	# of proj.	length (km)
building new bicycle path	19	10.5	4	1.3				
reconstructing bicycle path	1	1.8						
making short cut	4	0.2	10	0.75	2	0.15	1	0.05
defining bicycle lane, widening road	3	1.9	2	1.7				
abolish one way traffic for bikes	4	1.8	10	1.55			12	1.65
phasing traffic lights	1	0	2	0	4	0		
installing traffic lights	3	0	2	0	4	0		
permitting cyclists a free right turn at traffic lights	1	0	3	0	3	0		
reconstructing intersections	6	0	1	0	6	0		
providing crossover	4	0	3	0			1	0
building bridge	3	0.15	4	0.2				
reconstructing bridge	1	0.05						
building tunnel	1	0.1	1	0.05				
providing bicycle stands at transit stops	2	0						
Total	53	16.5	42	5.55	19	0.15	14	1.7

The project investments covered the period 1979 to 1991, but most of them were made between 1982 and 1987.

4.3 Organisation and implementation

One of the lessons of the demonstration projects in Tilburg and The Hague was that good communication with the residents is important for a successful project. In the Delft case this lesson was taken to heart. Communication with interest groups and residents was essential in the project.

Communication was done at two levels. First, the bicycle plan was discussed with a number of general interest groups such as the Cyclists' Union, the Traffic Safety Association, the Pedestrian Association, the Chamber of Commerce, the Shopkeepers Federation, schools, and homes for the elderly. These groups could comment on the plan and suggest adaptations. They had a positive attitude towards the plan, since bicycle improvements were generally in their favour (ten Grotenhuis, 1987).

Second, for the individual projects a discussion was organised with the residents living in the neighbourhood of a project. A positive attitude was less natural for them than for the interest groups. In communication with the residents, the strategy was not to start with informing them about the plan, but to ask what traffic-relating problems they were faced with. Starting from the problems mentioned, solutions were proposed that regarded bicycle infrastructure and that were in accordance with the bicycle plan. The discussions also led to some adaptations of the plan. This strategy contributed to a general support of the citizens towards the plan: existing problems were solved (according to interviews conducted in the framework of Transecon, 2003).

4.4 The costs

The estimated costs of the original plan were 70 million HFL (Dutch guilders). This amount was in the early 1980’s equal to 25 million ECU (European Currency Unit, the precursor of the Euro). As mentioned in Section 4.2.1, some expensive projects were not realised, or not realised in the framework of the bicycle plan. For that reason, the actual investments that were connected to the plan were considerably lower: nearly 30 million HFL (12 million ECU). Table 4.2 gives an overview of these costs by type of project and sub-network (Diepens en Okkema, 1993). For about 1 million HFL, 3% of the expenditures, the project type could not be determined afterwards.

Table 4.2: Investment costs in 1000 HFL by type of project and network

	city network	district network	intersections city/district network	neighbourhood network
building new bicycle path	3.802	1.464		
reconstructing bicycle path	1.018			
making short cut	258	888	109	0
defining bicycle lane, widening road	20	25		
abolish one way traffic for bikes	40	105		89
phasing traffic lights	0	0	6	
installing traffic lights	50	0	0	
permitting cyclists a free right turn at traffic lights	25	213	62	
reconstructing intersections	711	0	1941	
providing crossover	213	407		7
building bridge	4129	298		
reconstructing bridge	0			
building tunnel	9496	2796		
providing bicycle stands at transit stops	138			
total attached to projects	19900	6196	2118	96
employment unknown	978			
total	29288			

The municipality of Delft received subsidies of about 19 million HFL. The sources of the subsidies could be found out for only a part of this amount: the national government paid 10 million HFL, the development company of Delft paid 4 million HFL, and the province of South-Holland paid 1 million HFL. The remaining 4 million

HFL is likely to have been paid mainly by the national government (Diepens en Okkema, 1994).

In addition to the implementation of the project, there were also significant costs associated with the evaluation. A large number of evaluation studies were carried out that together cost 3.46 million HFL (1.39 million ECU). About 50% of these costs were financed by the national government, 40% by the European Community, and the remaining 10% by the municipality of Delft (Diepens en Okkema, 1994).

4.5 One single project: the Plantagebrug

One of the most expensive single projects is the Plantagebrug, the largest of the newly built bridges. This bridge is dedicated to cyclists and pedestrians. The Plantagebrug was evaluated separately and will be discussed in this report.

Figure 4.2 indicates the location of the Plantagebrug within the city. The bridge is part of the city-level bicycle network (network corridor II) and links the quarters in the north-eastern part of the town with the inner city. The bridge spans the Rijn-Schiekanaal that encloses the inner city at the east and south sides. It is built halfway between two other bridges, the Reineveldbrug and the Koepoortbrug, each about 1.2 km away. Figure 4.3 shows the locations of the three bridges.

The Reineveldbrug is part of the main access road to Delft from the north. The bridge has four car lanes, a tramway, two bicycle lanes and one sidewalk. There is no physical separation between the car lanes or between the car and bicycle lanes. Car volumes are high (about 17,000 in a 12 hour period in the time of the project) and cars move at rather high speeds. The bridge is high; the headroom is about 4 m. It was opened 15-20 times per day.

The Koepoortbrug has a more local function. It links the eastern districts with the city centre. It was at the time a narrow bridge for mixed traffic and rather high car volumes: 6,000 in a 12 hours period. It is a low bridge; the headroom is about 2.5 m. The bridge was opened about 30 times per day.

The Plantagebrug is built in order to:

- add a missing link to the city network;
- reduce the barrier effect of the canal;
- offer a more comfortable and safe connection for cyclists between the eastern districts and the centre. The Plantagebrug is more comfortable than the Reineveldbrug because there is no need to overcome long and steep slopes, and it is safer than the other bridges because car traffic is absent.

The Plantagebrug was built exclusively for cyclists and pedestrians. The headroom is about 2.5 m, just like the Koepoortbrug. The width of the bicycle path on the bridge is about 4.5 m., and there are two sidewalks of about 1.5 m. each. The length of the bridge is about 50 m. Opening and closing of the bridge are operated from the Koepoortbrug with the help of video equipment. The bridge was built from spring 1985 to summer 1986. The investment costs were 3,790,535 HFL (about 1.6 million ECU).

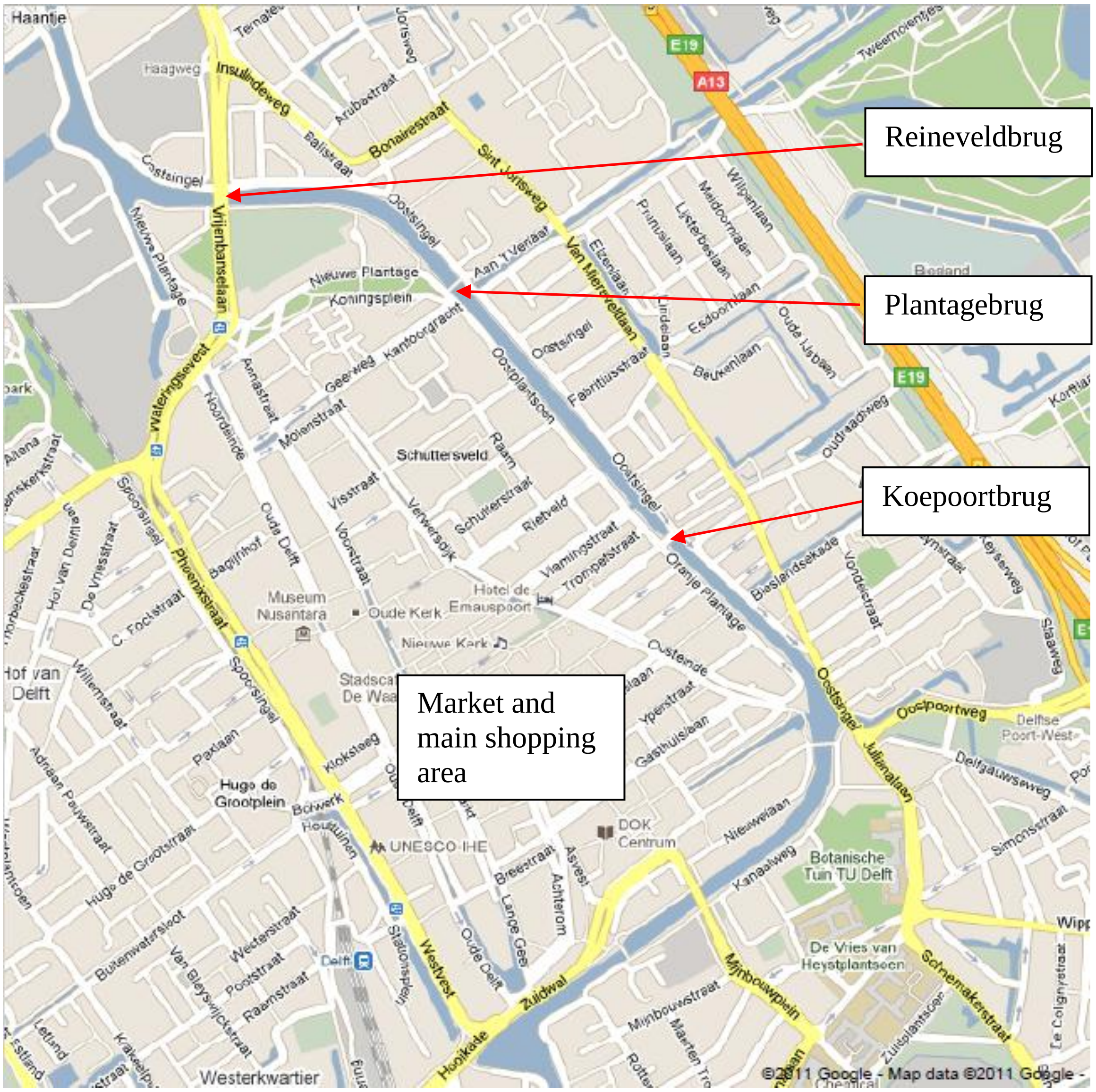


Figure 4.3: Location of the bridges spanning the Rijn-Schiekanaal

In addition to building the bridge and access roads to the bridge, some measures for improving the network for cyclists that cross the bridge are implemented. These include a reconstruction of two crossovers east of the bridge, one at the Insulindeweg and the other at the van Miereveltlaan, and building a new route for cyclists west of the bridge, along the Kantoorgracht.

4.6 Set-up of the evaluation studies

The national government subsidised part of the project under the condition that the project would be evaluated elaborately. The evaluation was intended to generate knowledge on the use and experience of urban bicycle networks that can be used for policy development by local governments. The studies were to answer the following questions:

- Does the implementation of a comprehensive bicycle network lead to an increase in bicycle traffic?
- Does the implementation of a bicycle network increase road safety?
- In which way do cyclists use a comprehensive and integral bicycle network which is perceived as such, and what are their behavioural responses?

The principal hypothesis was that a comprehensive and integral bicycle network affects bicycle use and its quality more than a number of single bicycle routes (Ministry of Transport and Public Works, 1987).

Project evaluation was done both for the network as a whole and in-depth for two separate parts of the network: the accessibility of the main railway station and the newly built Plantagebrug. In this report we discuss the set-up and results of evaluations of the whole network and the Plantagebrug.

The evaluation of the whole network includes the impacts on travel behaviour (bicycle use, modal choice, origin-destination pattern, and route choice), traffic safety for cyclists, and the perception of safety and comfort for cyclists. The evaluation of the Plantagebrug focuses on the impact on canal crossing cycling and the accessibility of the city centre.

The impacts were investigated by before and after studies. For a number of impacts of the whole network, both a short-term and a long-term after study have been performed. The latter should give evidence to what extent initial impacts continue to be valid in the long run. The before studies were carried out between 1982 and 1983, the short-term after studies between 1985 and 1986, and the long-term after studies in the early 1990's.

For estimating the short-term network impacts on travel behaviour, two experimental areas and one control area are defined (Figure 4.4). The experimental areas are the Noordwest district, an older district west of the city centre, and the Tanthof district, a new residential area at the far southwest of the city. The control area is the Wippolder district, an older district southeast of the city centre. The Tanthof-district differs from the two other districts by being significant more distant from the city centre ("centrum") and by having a significant younger population. The Tanthof residents were mainly households with young children.

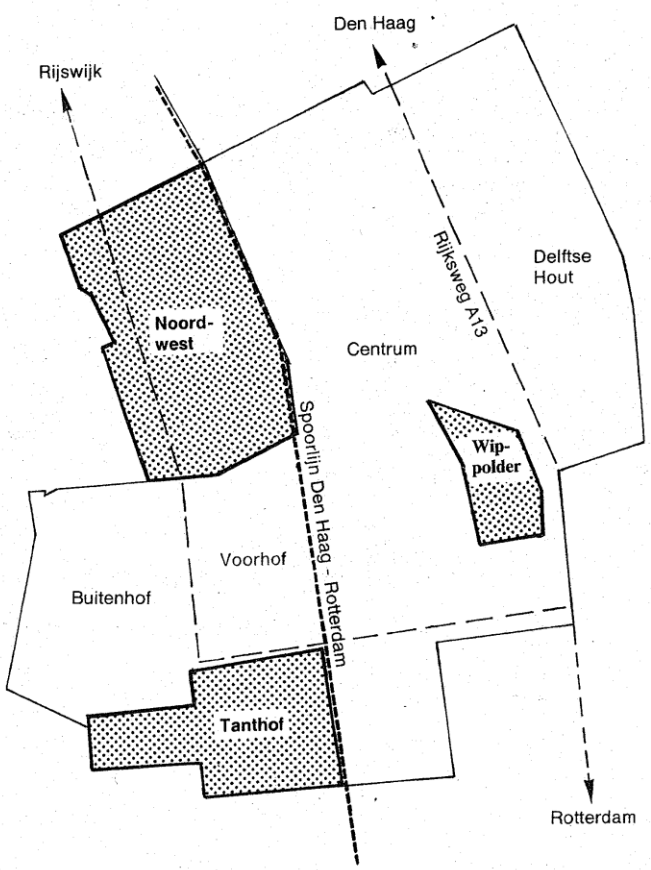


Figure 4.4: Location of the experimental and control areas within Delft (source: Katteler et al, 1987)

In the two experimental areas the measures of the bicycle plan were implemented in the few years between the data collections for the before and after studies (1983-1985); data collection for the after studies started a half year after the implementation finished. In the control district implementation of the measures started after the data for the after studies had been collected (Katteler et al, 1984, 1987).

For the results on city level, the other medium-sized cities in the Netherlands functioned as control cities. These included all municipalities with 50,000 to 200,000 inhabitants (47 cities).

4.7 The impacts of upgrading the network

4.7.1 Travel behaviour

Travel behaviour has a spatial and a temporal dimension. The spatial dimension regards the origin-destination pattern by mode and route. This is the result of choices regarding trip frequency, destinations, modes, and routes. The temporal dimension adds the time component to the spatial movements and is the result of choices regarding departure times and speeds. Both dimensions together explain volumes by network link, mode and time. The evaluation studies for the Delft bicycle project focus on the impacts on the spatial dimension of travel behaviour, in particular mode choice and route choice.

Mode choice
The impacts of the bicycle plan on modal choice were investigated on both the short term and the long term. First the short-term analysis will be described. A short description of the long-term analysis is included at the end of the section.

The short-term impacts of modal choice were examined by descriptive surveys on travel behaviour and by in-depth interviews regarding why the bicycle or an alternative mode was chosen. The descriptive surveys were conducted before and shortly after the measures were implemented. For the before survey a sample of households from the two experimental areas and the control area was addressed. A number of households from the sample was selected for the in-depth interviews that were conducted in the before period as well. In the short-term after period, the selected households were addressed again for detailed questions about their changes in modal choice and changes in the perception of the quality of the bicycle network (see Section 4.7.3). Not all of them responded, partly because they had moved between the two periods. Those who did respond are indicated as the “panel”. For the descriptive after survey, a new sample was drawn. This sample included the panel as well as households that were not addressed in the before survey.

Table 4.3 shows the gross and net samples of the descriptive before and after surveys in the three study areas. The sample was larger in the before period than in the after period.

Table 4.3: Sample sizes of the descriptive surveys (number of households)

	before period		short-term after period	
	gross sample	net sample	gross sample	net sample
Noordwest	2800	1937	1190	798
Tanthof	950	716	369	267
Wippolder	950	602	396	231
Total	4700	3255	1955	1296

The samples of households that were selected for the in-depth interviews and those that participated in the panel are displayed in Table 4.4.

Table 4.4: Sample sizes of the households that were interviewed in-depth

	interview before period	panel (before and after)
Noordwest	398	232
Tanthof	100	50
Wippolder	100	59
Total	598	341

Descriptive analysis
The descriptive surveys aimed to give a description of travel behaviour on working days in the before and short-term after periods. The sample unit was the household. Household members were asked about personal characteristics and characteristics of the household. Those aged 10 or older were additionally asked about activities outdoors and connected trips on a selected day. The questionnaires in the before and after periods were identical.

The surveys were conducted in the autumns of 1982 (before period) and 1985 (after period). Both surveys cover a two weeks period from late October to early November with a continuation up to the end of November for late responses. The weather conditions were comparable in the first three to four weeks of both periods but diverged in late November, when in the after period the temperature became significant lower than in the before period (0 versus 10 degrees Celsius). The difference in the last one to two weeks might have had just a minor effect on the results because it relates to only 5-10% of the response.

The surveys produced results on person level and trip level. Table 4.5 shows general characteristics of person travel before and after by residents of the three study areas.

Table 4.5: Travel characteristics of persons >= 10 years old on working days

	Noordwest		Tanthof		Wippolder	
	1982	1985	1982	1985	1982	1985
persons going outside*	87.7%	88.6%	91.8%	91.0%	82.9%	81.7%
trips per person per day	3.89	3.86	4.04	3.92	3.43	3.43
travel time pppd (minutes)	62	63	71	69	59	62
travel distance pppd (km)	19.8	20.6	25.4	23.0	16.6	18.9
average speed (km/h)	19.2	19.6	21.5	20.0	16.9	18.3

*Persons that leave their home at least one time on the enquiry day

The figures show some small differences between the three districts regarding travelling of their residents and differences between the before and after periods. Residents of the Tanthof had a slightly higher level of travelling (in frequency, duration and distance) than those of the other districts, while residents of Wippolder made the fewest trips and travelled the fewest kilometres. Changes between the before and after periods tend to reduce the differences between the districts. Trip frequency, duration and distance of Tanthof residents decreased somewhat, while travelled distance of Wippolder residents increased.

The study reports give no evidence about significance of the results. Assuming that the observed changes in Tanthof and Wippolder are significant, they might or might not be induced by the improved bicycle network. The reduced travel distance of Tanthof residents could be attributed to shortening bicycle routes to the city centre; the reduced travel speed could be due to modal shift from car to bicycle. However, other explanations can be given as well. Possibly, the orientation of the new suburb of the Tanthof shifted somewhat from the distant city centre to the own district, lowering the level of travelling. In the case of Wippolder (the district that had no infrastructural improvements in either the before or the after periods), the increased distance could be attributed to the fact that the residents benefited from improvements elsewhere in the town. However, there may be other factors that raise the initially low number of travel kilometres to a more normal level.

The increased travel distance in the control region cannot be observed in national figures. Table 4.6 gives corresponding figures for travelling of Dutch residents of medium-sized cities (50,000 to 200,000 inhabitants) in the period 1981 to 1984. The source is the Dutch national travel survey (OVG). We selected 1981-1984 because in 1985 the survey set-up changed considerably, making the outcomes of 1985 not comparable to those of former years. The national figures demonstrate a high stability of travel behaviour in the early 1980's.

Table 4.6: Travel characteristics of Dutch residents of medium-sized cities >= 12 years old on working days

	1981	1982	1983	1984
persons going outside	90.2%	90.0%	90.2%	90.7%
trips per person per day	3.22	3.20	3.18	3.30
travel time pppd (minutes)	58	58	57	58
travel distance pppd (km)	23.7	24.2	23.2	23.8
average speed (km/h)	24.4	25.0	24.6	24.6

The general travel figures give no clear evidence of impacts of the improved bicycle network. Focussing on the role of the bicycle might give more information. Table 4.7 presents figures on bicycle use. The figures regard only the use of the bicycle as the main mode of a trip.

Table 4.7: Characteristics of bicycle travel by persons >= 10 years old on working days

	Noordwest		Tanthof		Wippolder	
	1982	1985	1982	1985	1982	1985
persons using a bike*	49.5%	50.0%	49.7%	50.8%	46.0%	44.4%
trips per person per day	1.80	1.86	1.57	1.67	1.70	1.70
travel time pppd (minutes)	23	23	24	25	24	25
travel distance pppd (km)	4.1	4.5	4.7	5.3	4.2	5.2
average speed (km/h)	10.7	11.7	11.8	12.7	10.5	12.5

*Persons that use at least one time a bicycle on the enquiry day

These figures suggest a positive influence of the network improvements. The frequency of bicycle use increased in the two experimental areas and remained stable in the control area. Travel distance and travel speed increased in all districts. The distance increase for residents of the control area could be explained by the improvements elsewhere in the city. The speed increase might be explained by a higher quality of the bicycle network.

Looking at national figures, bicycle use was highly stable from 1981-1983 and increased in 1984 (Table 4.8). The question is whether the deviating figures for 1984 are exceptional or reflect a trend in increasing bicycle use. Probably there was a trend. Bovy and van Adel (1987) report a growth of 9% in bicycle use by inhabitants of the Dutch medium-sized cities between 1979 and 1984. The growth was found in all individual cities. Van Goeverden and Godefrooij (2010) observe an overall increase in bicycle use of Dutch residents in the 1980's, both for those living in rural areas, in small and medium-sized cities, and in large cities.

Table 4.8: Characteristics of bicycle travel by Dutch residents of medium-sized cities >= 12 years old on working days

	1981	1982	1983	1984
persons using a bike	36.8%	36.9%	37.8%	40.0%
trips per person per day	1.03	1.03	1.04	1.15
travel time pppd (minutes)	14	14	14	16
travel distance pppd (km)	2.9	2.9	2.9	3.2
average speed (km/h)	12.1	12.4	12.1	11.9

Comparing Tables 4.7 and 4.8, one could conclude that bicycle use in Delft was relatively high, even in the before period. However, one should be cautious. Both tables are based on travel surveys with different designs, and history learned that changes in the design of the Dutch national travel survey affected the outcomes regarding travel behaviour significantly. Bovy and Den Adel (1987) found that the number of bicycle trips per person per day by Delft residents reported in the national survey was close to the national average for medium-sized cities.

Another indication for a possible impact of the bicycle network improvements is the development in the modal split. Table 4.9 shows an increase of bicycle share in the two experimental areas and no increase in the control area. This result suggests that the improvements encouraged bicycle use. The increase in bicycle use was at the expense of public transport use and (only in Tanthof) car use as a driver. Decrease of public transport patronage is also observed in the control area and might be independent of the bicycle improvements. In that case the bicycle network’s impact might be that decreasing transit use led to more bicycle use rather than car use.

Table 4.9: Modal split (main modes) of trips of persons >= 10 years old on working days

	Noordwest		Tanthof		Wippolder	
	1982	1985	1982	1985	1982	1985
walk	25.8%	25.7%	17.6%	17.3%	23.0%	23.7%
bicycle	40.5%	42.6%	35.7%	39.0%	41.0%	40.4%
moped, motorcycle	1.8%	1.4%	1.9%	2.6%	2.0%	1.0%
car driver	21.0%	21.1%	31.9%	28.5%	21.3%	23.8%
car passenger	4.5%	4.9%	5.4%	6.3%	5.2%	6.2%
public transport	6.3%	4.3%	7.3%	6.3%	7.4%	4.9%
other	0.1%	0.0%	0.2%	0.0%	0.1%	0.0%

National figures support the finding of decreasing transit use by residents of medium-sized cities (Table 4.10). The figures are somewhat fuzzy regarding the modes that benefited from the lower transit share. The figures from 1983 suggest an increase in car use as a driver while those from 1984 indicate that the bicycle is the only benefiter. Bovy and den Adel (1987) compared modal shares in the Dutch medium-sized cities and found significant negative correlations between transit use and car use on the one hand and transit use and bike use on the other hand. The correlation with bike use is a little stronger than that with car use. Therefore, it is likely that bicycle use in medium-sized cities increased in the period concerned. As a consequence, the increase in the two Delft experimental districts might partly be explained by other factors than the bicycle improvements.

Table 4.10: Modal split (main modes) of trips of Dutch residents of medium-sized cities >= 12 years old on working days

	1981	1982	1983	1984
Walk	20.1%	20.6%	20.4%	20.3%
Bicycle	32.1%	32.3%	32.1%	34.3%
moped, motorcycle	1.9%	2.0%	1.8%	1.4%
car driver	29.1%	28.7%	30.2%	28.4%
car passenger	10.7%	10.2%	10.2%	10.4%
public transport	5.6%	5.8%	5.0%	4.8%
Other	0.4%	0.5%	0.3%	0.4%

When modal splits in the Delft survey are compared for different person characteristics, the increase in the share of the bicycle in the two experimental areas is particularly large for men, middle-aged persons, retired persons, and employees. Regarding ownership of a drivers' license the results differ in both districts. In Noordwest bicycle use increased substantially by non-owners of a license, while in Tanthof those who possessed a license used the bicycle more frequently. At trip level, the increase in the share of the bicycle is observed mainly in commuting trips to work or school and, only in Tanthof, in transporting/escorting persons.

In-depth analysis

A selection of the households that responded to the before survey was approached for an in-depth interview in the before period and, to the extent that they responded again, for the short-term after period as well. The before interviews should explain why people use or use not a bicycle for actually made trips and estimate the potential for increasing bicycle use. The after interviews should register changes in motives for bicycle use and its potential, and give information about modal shifts.

The interview periods were September and October 1983 (before period) and late 1985 + early 1986 (after period). The interviews were conducted with the household members aged 10 years or older in one setting. The interviewers were attentive to spontaneous responses and tried to generate them by encouraging interaction between the interviewed persons. The average duration of the interviews was 1.5 hours in the before period and 1.25 hours in the after period. The variation was large, partly dependent on the number of trips that were discussed and the number of participants.

One of the results from the interviews is knowledge about hindrances for bicycle use. Starting from the trips that were not made by bicycle, a large number of reasons for not using the bicycle was reported. The reasons were classified into six categories: no opportunity for using a bike (for instance no bicycle was available, distance is too long); practical matters that hamper bicycle use (e.g. luggage transport) or require use of an alternative mode (e.g. one should have the car available at the destination); (perception of) travel time; (perception of) insufficient infrastructure and the traffic situation; (perception of) inconvenience and insecurity of cycling; and personal preferences regarding use of the bicycle or other modes. There is a remaining seventh category consisting of non-bicycle trips with no hindrance for bicycle use.

Table 4.11 shows the magnitude of the different hindrances in the before and after periods, starting from the most objective hindrances and going to the most subjective ones. The latest category shown is the category without any hindrance, indicated as 'freedom of choice'. Two kinds of hindrances are distinguished: general hindrances that always are valid for a certain trip (for instance the distance is too large) and incidental hindrances that are valid only on the enquiry day (e.g. unlike on other days, the traveller was accompanied by grandmother who doesn't cycle any more).

Table 4.11: Hindrances for bicycle use in percents of non-bicycle trips

hindrance	before			after		
	general	incidental	total	general	incidental	total
bicycle no option	12.1%	1.6%	13.7%	6.7%	1.1%	7.7%
practical matters	35.6%	10.6%	46.2%	23.8%	21.2%	44.9%
travel time	45.4%	5.2%	50.6%	34.4%	9.4%	43.8%
infrastructure and traffic	0.8%	-	0.8%	-	0.3%	0.3%
inconvenience, insecurity	16.8%	4.8%	21.6%	7.9%	5.2%	13.0%
personal preferences	17.4%	-	17.4%	12.3%	-	12.3%
freedom of choice	15.7%	-	3.0%	33%	-	7%

Practical matters and travel time are the most important reasons for not using a bicycle. The magnitude of both hindrances decreased slightly between the before and after periods. A larger decrease is observed for each of the other hindrances. Especially infrastructure and traffic exhibit a relatively large decrease. This is not surprising because the bicycle plan aims predominantly to improve the infrastructural and traffic situation. However, in the before situation, this hindrance was marginal. Looking at Table 4.11, other kinds of measures might be more efficient for increasing bicycle use.

The large increase of the freedom of choice category for non-bicycle trips is mainly valid for trips where walking or car is the actual mode. For walking trips, the *general* freedom to choose the bicycle increased from 14% of all walking trips to 32%, for car trips the increase was from 13% to 34%. A much smaller increase was observed for trips by public transport: from 29% to 36%.

In addition to the freedom to choose the bike when actually another mode is used, there can be a freedom to choose another mode when actually the bicycle is used. Where the former are relevant for the potential for bicycle use, the latter indicate the vulnerability of bicycle use. Table 4.12 shows the hindrances for walking, car use, or public transport patronage for trips that actually are made by bicycle. The presented figures are the general hindrances; figures about the actual hindrances on the enquiry day (that have a lower freedom of choice) are not available. Divergent from Table 4.11, the accumulative impact of the hindrances on the bicycle trips that remain free of choice is displayed. In 1982, for 3% of the bicycle trips walking is no option, leaving 97% free of choice. Next, practical matters generate hindrances for a part of the remaining bicycle trips, which part equals 11% of all bicycle trips. Then 86% is still free of choice. After skimming the trips for all hindrances in this way, 17% remain where no hindrance is applicable in general (but might still be applicable on the enquiry day).

Table 4.12: Accumulative impact of general hindrances for other modes in percents of bicycle trips

hindrance	walk		car		public transport	
	1982	1985	1982	1985	1982	1985
all bicycle trips	100%	100%	100%	100%	100%	100%
mode no option	-3%	-0%	-44%	-42%	-24%	-13%
practical matters	-11%	-15%	-5%	-12%	-2%	-4%
travel time	-49%	-42%	-8%	-8%	-23%	-31%
infrastructure and traffic	-0%	-0%	-2%	-1%	-3%	-2%
inconvenience, insecurity	-3%	-2%	-4%	-6%	-17%	-21%
personal preferences	-17%	-11%	-11%	-4%	-21%	-13%
freedom of choice	17%	30%	25%	27%	10%	16%

The main hindrance for walking is travel time; the main hindrance for car use is the unavailability of a car. For using public transport there are a number of larger hindrances: mode availability, travel time, inconvenience, and personal preferences. The freedom to shift from the bicycle to walking or public transport increased substantially. The (initially large) freedom to shift to the car is nearly unaffected.

Figure 4.5 gives an overview of the potentials for shifting between bicycle, walk, car and transit in 1985. The modal percentages are percents of all trips made by the mode; the numbers in the arrows between the modes are percentages of all trips. For instance, 34% of car trips are vulnerable for shifting to the bicycle; this number is equal to 10% of all trips. The other way around, 27% of the bicycle trips are vulnerable for shifting to the car; these equal 11% of all trips. Again, the figures represent the general freedom of choice, not the freedom of choice on the enquiry day.

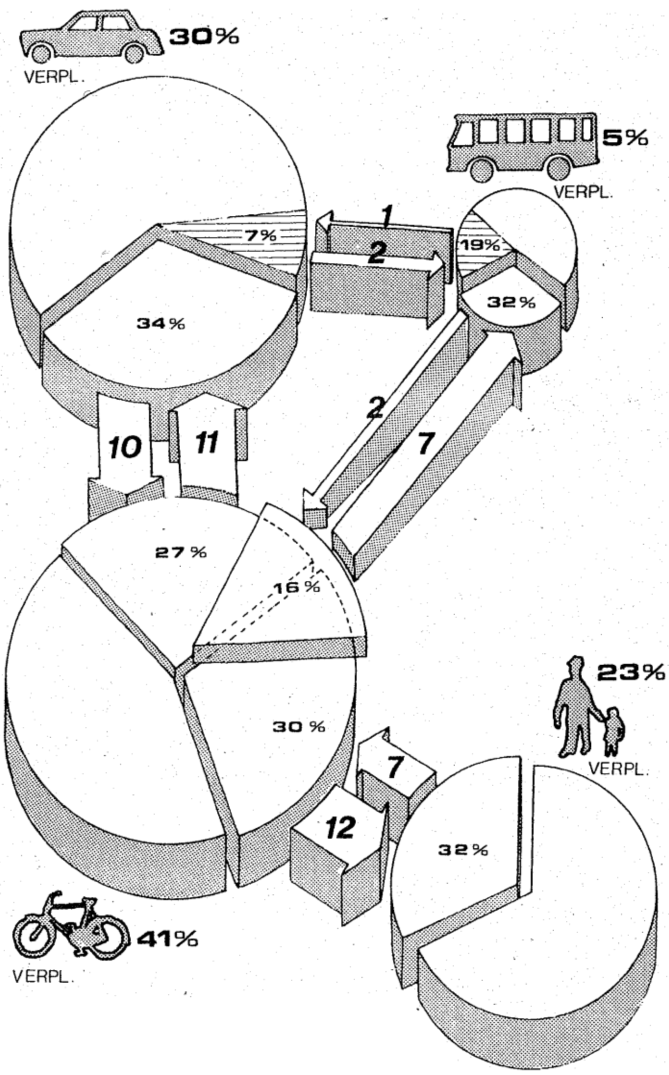


Figure 4.5: General intermodal potentials in 1985 (source: Katteler et al, 1987)

Next examined question is which modal shifts really took place as a result of the bicycle network improvements. The panel participants were asked about their modal use in both the before and after situations to activities that they continued to visit in the two periods. The distinguished activities were work, school, shopping, other personal business, leisure. About 20% of the activities performed in 1982 were not continued in 1985 by the same respondents. These 20% are left out of the analysis.

Tables 4.13 and 4.14 show the modal shifts between 1982 and 1985 in trips for unchanged activities for the two experimental districts. Corresponding figures for the control area Wippolder are not available.

Table 4.13: Modal shifts in travelling for unchanged activities by residents of the Noordwest district

mode in 1985	mode in 1982							share in 1985
	walk	bicycle	moped	car driver	car pass.	public transp.	other	
Walk	23.1%	0.5%	-	-	-	0.1%	-	23.7%
Bicycle	1.9%	39.3%	0.2%	0.6%	0.8%	0.3%	-	43.1%
Moped	0.4%	-	1.3%	0.1%	-	-	-	1.8%
car driver	0.1%	0.2%	0.1%	20.0%	-	0.5%	-	20.9%
car passenger	-	0.1%	-	0.1%	3.5%	0.2%	-	3.9%
public transport	0.4%	0.2%	0.2%	0.2%	0.3%	5.2%	-	6.5%
Other	-	-	-	-	-	-	0.4%	0.4%
share in 1982	25.9%	40.3%	1.8%	21.0%	4.6%	6.3%	0.4%	100%

Table 4.14: Modal shifts in travelling for unchanged activities by residents of the Tanthof district

mode in 1985	mode in 1982							share in 1985
	walk	bicycle	moped	car driver	car pass.	public transp.	other	
Walk	11.6%	-	-	-	-	-	-	11.6%
Bicycle	5.9%	33.6%	-	0.2%	-	-	-	39.7%
Moped	-	0.6%	2.0%	0.9%	-	-	-	3.5%
car driver	-	-	-	30.2%	-	0.6%	-	30.8%
car passenger	-	0.2%	-	-	5.5%	-	-	5.7%
public transport	-	1.1%	-	0.5%	-	6.6%	-	8.2%
Other	-	-	-	-	-	-	0.6%	0.6%
share in 1982	17.5%	35.5%	2.0%	31.8%	5.5%	7.2%	0.6%	100%

Respondents who changed a mode were asked why they did so. The most frequent reported reason was destination change. The main reason for the large shift from walk to bicycle in particularly the Tanthof-district is the switch from primary school to the more distant secondary school. The shift from bicycle to moped in Tanthof might be explained by the increasing age of the panel respondents; some pupils that were too young to drive a moped were allowed to do so in 1985.

Still, the figures for Noordwest hint that the improved bicycle network had a modest positive influence on bicycle use. Except for walking, the shifts from each alternative mode to the bicycle are larger than the other way around. The differences between the opposite shifts are especially large for the car, both car drivers and car passengers. The improved network seems to have tempted car users to shift to the bicycle.

Long-term impacts

The short-term analyses make it plausible that the improvements in the bicycle network raised bicycle use somewhat. The question is whether the higher level of bicycle use was retained in the long run or possibly raised even further. Three kinds of descriptive analyses have been done for examining the long-term impacts (MuConsult, 1993). The first is a comparison between Delft and the other medium-sized cities in the Netherlands regarding the development in bicycle use in the period 1979-1991, based on the national travel surveys. The second is executing a new survey in the whole city of Delft in 1993 and comparing the results with those of the short-term after survey in 1985 that was executed in the two experimental areas and one control area. The third regards counts of passing cyclists at cordons around Noordwest and Wippolder in 1993 and comparing these with counts in 1985. In the two analyses that are based on travel surveys, the impacts of several explanatory socio-economic variables on bicycle use are estimated in order to find out whether a significant impact of the bicycle plan remains after eliminating the impacts of the other factors. Unlike the short-term after studies, these analyses include both the impacts on bicycle trip numbers and bicycle kilometres.

The analysis of bicycle use in Delft compared to that in other medium-sized cities gave no firm results regarding the long-term impact of the bicycle plan. There were two problems: a) the samples of Delft residents in the national travel surveys are too small for a good trend analysis of travel behaviour (100-150 persons annually), and b) in the period considered, investments in bicycle infrastructure were implemented in several other cities, partly encouraged by the success of the Delft bicycle plan. The improvements in other cities were not included in the analysis of the impacts of other socio-economic factors.

The long-term after survey in Delft should give information on differences between developments in different districts. The survey was executed in May and June 1993. The sample was 785 households. The questionnaires were similar to those of the short-term after survey. However, the survey periods were different: May/June in the long-term after survey versus October/November in the short-term after survey. The impact of the different seasons is estimated using data of the national travel surveys. A significant impact was observed for the whole Dutch population but no impact could be found for the Delft residents. A complication in analysing the results of this survey is that the Wippolder district doesn’t function as control area in the long run. After the short-term after survey was organised, improvements in bicycle infrastructure were implemented in this district as well.

The bicycle counts were carried out at a large number of spots on a Wednesday in May between 7:00 a.m. and 7:00 p.m. Again, the season differs from the short-term after counts which were executed on a Wednesday in September.

The main results are presented in Table 4.15 in a qualitative way. Presentation in this way is induced by the low reliability of most of the results. The table summarises the results of the three kinds of analysis, and includes the assumed impacts of the bicycle plan on both trips and trip kilometres made by bicycle, car as a driver, and car as a passenger.

Table 4.15: Long-term comparisons in developments of modal use

mode	indicator	National surveys, development 1979-1991. Delft compared to:		Delft survey, dev. 1985-1993. Noordwest compared to:		cycle counts, 1985-1993. Noordwest compared to:
		other medium-sized cities	remaining country	Wip-polder	Tanthof	Wippolder
bicycle	trip numbers	0	0	0	0	(+)
	kilometres	(+)	(+)	+	0	n.a.
car driver	trip numbers	(-)	0	0	0	n.a.
	kilometres	(-)	(-)	0	0	n.a.
car passenger	trip numbers	(-)	0	0	0	n.a.
	kilometres	0	0	0	0	n.a.

The symbols '0', '+', and '-' indicate no change, increase, and decrease respectively. Observed changes that are not statistically significant are put within brackets. The table shows only one statistically significant change: bicycle kilometres of Noordwest-residents increased significantly compared to those of Wippolder-residents. This result suggests a long-term impact of the bicycle plan on bicycle kilometres in addition to the short-term impact. However, interpretation of this result is complicated by the fact that the improvements in Noordwest were implemented before 1985 and those in Wippolder after 1985, in which period the growth is observed. The increasing difference between Noordwest and Wippolder could be either an additional long-term increase in Noordwest that exceeds a possible short-term increase in Wippolder, or a decrease in Wippolder (due to the implemented measures?). A policy-induced decrease in Wippolder is not plausible, because the analysis of Delft compared to the other medium-sized cities suggest a positive influence of infrastructural improvements on bicycle kilometres.

The analyses give no evidence on impacts on bicycle trip numbers, except from a relative increase of counts of cyclists entering or leaving Noordwest compared to those entering or leaving Wippolder. Assuming that trip numbers increased somewhat in Wippolder after 1985 due to the implemented improvements, the increase before 1985 that was observed in the other districts seems not to be followed by a decrease and might even be followed by a further increase. Therefore, it is likely that the initial short-term increase in bicycle trips has been retained in the long term. There might even have been an additional increase in the long run. However, this can only be small assuming the fact that the analysis with the national travel surveys that describes the development in the whole project period (1979-1991) gives no indication of any impact on bicycle trip numbers.

Looking at the car, negative effects on car use are observed for the whole period 1979-1991 when Delft is compared to other medium-sized cities; however, the effects are not statistically significant. These include both the short-term and the long-term effects. The large fluctuations in the annual results regarding car use of inhabitants of Delft, which stems from the small Delft samples, make it impossible to make separate statements about short-term and additional long-term developments.

Route choice

In addition to the modal choice analysis, short-term impacts on route choice have also been estimated. The route choice studies were performed in the experimental Noordwest-area. Both before (1982) and after (1985) the measures in Noordwest were implemented, the number of cyclists that entered or left Noordwest were counted at a large number of spots at a cordon around this district. In addition, in 1982 a number of cyclists departing the Noordwest-district were interviewed about some personal and trip characteristics; registered variables were age, gender, origin and destination addresses, trip purpose, and time of the interview. Some of them were given questionnaires on which they were asked to draw their route on a map. In 1985, the on-street interviews were skipped, but again questionnaires including questions on personal and trip characteristics and the route were distributed among departing cyclists. The decision to skip the on-street interviews was motivated by the high response on the distributed questionnaires in 1982 and hence a low added value of the on-street interviews. The counts, interviews and distribution of questionnaires were done on the last Wednesdays in September between 7:00 a.m. and 7:00 p.m. Questionnaires were handed out only to persons whose apparent age was at least 12. Table 4.16 shows the number of counted cyclists and cyclists that were interviewed or responded to the questionnaire.

Table 4.16: Number of counted and approached cyclists at the Noordwest-cordon

	1982	1985
counts entering Noordwest	24912	26032
counts departing Noordwest	25291	27969
on-street interview	4100	-
questionnaire response	2200	3000

For analysing the collected data, a data bank of link characteristics of the bicycle networks in the before and after periods was created. These data include coordinates of nodes, type of pavement, type of cycling infrastructure (mixed traffic, bicycle lane, bicycle path), slope, one/two way traffic, traffic lights, and other objects for delay (a bridge that can be opened, crossing with a railway line). Length and average travel time per link are calculated from these data.

After the before data were collected, several analyses on route choice and utilisation of the bicycle network were executed (Bovy, 1984). In contrast to the studies on the demonstration projects in Tilburg and The Hague, both the impacts of travel distance and travel time on route choice were analysed. Regarding utilisation of the bicycle network, it is examined whether and to what extent cyclists are willing to travel longer distances if by doing so they can shift from travelling on low level networks to the more comfortable high level networks.

The analyses are partly based on detour factors. Two kinds of detour factors are defined: link level detour and route level detour. The link level detour of an observed trip is defined as the ratio of the trip distance if the shortest route was chosen and the distance between origin and destination as the crow flies. The average link level detour is 1.21 and is dependent on distance. The detour is highest for distances between 1000 and 1500 meter (1.25). It decreases slowly at increasing distances, to a value of 1.18 for longer distances. It decreases at decreasing distances too, first slowly, but at increasing speed at the very short distances.

The route level detour was calculated for both length and duration of trips. This factor equals the ratio of the actual trip length/duration and the length/duration of the shortest route (shortest in distance or time). Table 4.17 presents the frequency distribution of the two route level detour factors.

Table 4.17: Characteristics of detour factors on route level

class of detour	length		duration	
	frequency	cumulative freq.	frequency	cumulative freq.
1.0	9%	9%	21%	21%
1.01-1.05	35%	44%	30%	51%
1.06-1.10	27%	71%	21%	72%
1.11-1.15	13%	84%	10%	82%
1.16-1.20	6%	90%	7%	89%
1.21-1.25	4%	94%	4%	93%
1.26-1.30	2%	96%	2%	95%
1.31-1.35	1%	97%	1%	96%
>1.36	3%	100%	4%	100%
average	1.09		1.08	
median	1.06		1.05	

One may conclude from the table that cyclists mainly choose the shortest route or a route with only a small detour. Moreover, they are more inclined to choose the shortest route in time than the shortest route in distance. The latter observation is supported by a statistical analysis of factors influencing the route choice. Travel time proves to give a significant better explanation of the observed route choices than travel distance.

In addition to route choice, the data gave information about network use. An analysis of the extent to which actual routes overlap the shortest routes, demonstrated that cyclists prefer cycling on higher level roads. The average overlap of all trips is 56%. However, the overlap differs substantially by road type. The overlap is only 27% for residential roads, 39% for neighbourhood roads, 47% for district roads, and 64% for city-level roads. Apparently cyclists are inclined to minimize the distance travelled on the lower level roads.

The outcomes of the route analyses presented so far are just based on the before study. The after study (Gommers and Bovy, 1987) analysed to what extent the bicycle interventions influenced route choices. Comparing the routes of complete trips in the before and after periods was not possible because only very few trips had the same origin and destination. Therefore, the analysis was done for trip sections. A number of pairs of locations were selected that are passed by a lot of cyclists. The route choices before and after between these pairs were studied for all trips that passed both locations. The routes between 60 pairs of locations were analysed. Significant changes in the chosen routes were observed. New network links tempted a lot of cyclists to reroute their trips via these links. New bicycle paths along roads proved to be very attractive as well. The volume of cyclists on bicycle paths increased significantly while the volume on bicycle lanes (not physically separated from the road) and on roads with mixed traffic decreased. There was no change in the division of bicycle kilometres over the three networks: neighbourhood, district and city. Absence of a change is not surprising because the measures were implemented at all networks. Route choice changes seem to take some time. A new bridge appeared to attract only a small share of the cyclists who could have shortened their route by using this bridge. The reason could be that the bridge was opened just one week before the data for the route choice analysis were collected.

Finally, the route choice studies suggest a large increase in bicycle use between the before and after periods (see the cycle counts in Table 4.16). Analysing the origins and destinations, the increase is mainly due to a huge increase (28%) in cyclists that traverse the Noordwest-district. Trip numbers of Noordwest-residents seem to have decreased somewhat, those of Noordwest-visitors increased a little. The decrease of trips by Noordwest-residents can be explained by demographic changes and one major change in land use: a secondary school moved from outside to inside the Noordwest-district. The large increase of traversing cyclists might suggest that the bicycle plan is particularly beneficial for the longer distances. Though it is likely that this happened, an alternative explanation is that cyclists shifted their routes from fully outside the Noordwest-district to partly crossing the district. The route shift could be induced either by the bicycle measures, and would then still be an indication of the attractiveness of the measures, or by other factors like traffic diversions due to maintenance works.

4.7.2 Safety

The impacts of the bicycle plan on traffic safety were studied for both the short and the long run. Bovy and Gommers (1988) assume a priori that the measures would have two kinds of opposite impacts. Firstly, the measures increased use of the vulnerable bicycle mode, which will have affected traffic safety negatively. Vulnerability of cyclists is apparent from Dutch statistics concerning casualties per million person kilometres (CBS, 1994, 1 and CBS, 1994, 2). Both the rate of fatalities and the rate of injured persons among cyclists were about three times the average for all modes in the early 1990’s. Secondly, the measures made cycling safer and so affected safety positively. Nearly all accidents result from conflicts between road users. The measures reduced the number of conflicts due to building new bicycle paths that separate cyclists from motorized traffic, and installing traffic lights at some intersections that should make crossing safer.

The vulnerability of cyclists compared to other road users is subject for debate. Certainly, the number of accidents and casualties per *km* are high for cyclists. However, related to travel *time*, the numbers are comparable for the different modes. Based on the finding in fundamental research that people tend to spend a constant part of their time budget on travelling (see for instance Schafer, 1998), accidents and casualties per minute might be a better measure for vulnerability than numbers per km. In that case interventions that increase bicycle use will not directly increase the risk of accidents.

Short-term impacts

Between 1980 and 1986 the total number of traffic accidents in Delft was stable. These were about 1500 annually, according to the (incomplete) registration by the police. The number of casualties (persons injured or killed) decreased in the same period from about 310 to 260, a reduction of about 20% (Bovy and Gommers, 1988). The national figures show a similar decrease of annual casualties in this period despite a substantial increase in traffic volume: the number of fatalities decreased by 24%, the number of injured persons by 21%. At first sight, the bicycle plan did not contribute to traffic safety on balance. However, a more detailed analysis of the figures gives different conclusions.

The short-term decrease of traffic casualties in Delft can fully be attributed to the bicycle and moped modes. The number of cycle casualties decreased from about 100 in 1980 to about 70 in 1986, that of the moped casualties from about 80 to about 60. The number of casualties by other modes remained stable. The decrease of about 30% for cyclists and moped riders is larger than the national decrease of 20% for these modes. The national decrease for the car and most other modes is not observed in Delft. The relatively large decrease in casualties among cyclists and moped riders in Delft, both users of the bicycle infrastructure, is an indication of increased safety by the bicycle measures. One problem in the analysis is that the Delft numbers are too low for an accurate estimation of developments in a few-years period. The numbers by mode display rather large annual fluctuations. Still, the decrease in casualties of both cyclists and moped riders is statistically significant.

The probability for cyclists to be involved in an accident depends on gender and age. The probability is particularly high for teenagers. No change of the relative probabilities is observed between the before and after periods. The relative decrease of bicycle casualties was similar for all gender and age classes.

Most bicycle accidents involve a collision of vehicles. In most cases the collision ‘partner’ of a bicycle is a motor vehicle. The number of collisions with motor vehicles decreased somewhat from about 70% of all bicycle accidents to about 65%. The number of other kinds of bicycle accidents remained stable. One should note here that bicycle use increased and use of motorized modes (mainly car) did not change.

The number of accidents where a bicycle is involved decreased in Delft by about 10%. This reduction is smaller than the relative decrease of cycle casualties, which can be explained by the relatively large decrease of collisions with motor vehicles. The decrease of bicycle accidents is fully due to a decrease of accidents at intersections. The number of bicycle accidents at intersections decreased by 25%, lowering its share in all bicycle accidents from 55-60% to 45-50%. Still, intersections remain relatively unsafe for cyclists. For other modes the share of accidents at intersections is smaller, on average 35%.

Considering type of road, the decrease of bicycle accidents is observed only on bicycle lanes. There was no change in accident numbers on bicycle paths and roads with mixed traffic. However, because of the large changes in bicycle traffic volumes on the different kind of roads, one could better compare the risk of involvement in an accident per million km. This risk decreased significantly on bicycle paths and bicycle lanes and increased a little on roads with mixed traffic. Bicycle paths, which were already the safest kind of link, strengthened their position as safest facility for cycling, and bicycle lanes, which were by far the most unsafe kinds of cycling facility, came close to the safety level of roads with mixed traffic, but remained the most unsafe kind of cycling facility. The relatively high probability of being involved in an accident when cycling on bicycle lanes can be explained by the fact that bicycle lanes generally are provided along busy roads where dedicated bicycle infrastructure is desirable but room for separated bicycle paths is lacking.

The observations mentioned before suggest that the bicycle plan had a positive influence on safety. Safety increased particularly for cyclists, and the increase in safety is connected to infrastructural elements (relatively large on bicycle paths, in bicycle lanes, and at intersections). An interesting additional observation for answering the question of whether the interventions improved traffic safety is the development of safety in different districts, including the experimental and control areas. Figure 4.6 shows the probability of involvement in an accident per million kilometres in the experimental area Noordwest, the southwest area of the city including the experimental Tanthof district, the control area Wippolder, the city centre, and the remainder of the city. In Noordwest the probability decreased significantly by 35-40%. This area lost its position as the most unsafe district of Delft for cyclists. In southwest only a small decrease is observed (about 10%). In the control area Wippolder and the city centre the decrease is slightly larger (about 15%), and in remainder of Delft, where measures of the bicycle plan were partly implemented, the decrease is comparable to that of Noordwest (about 35%).

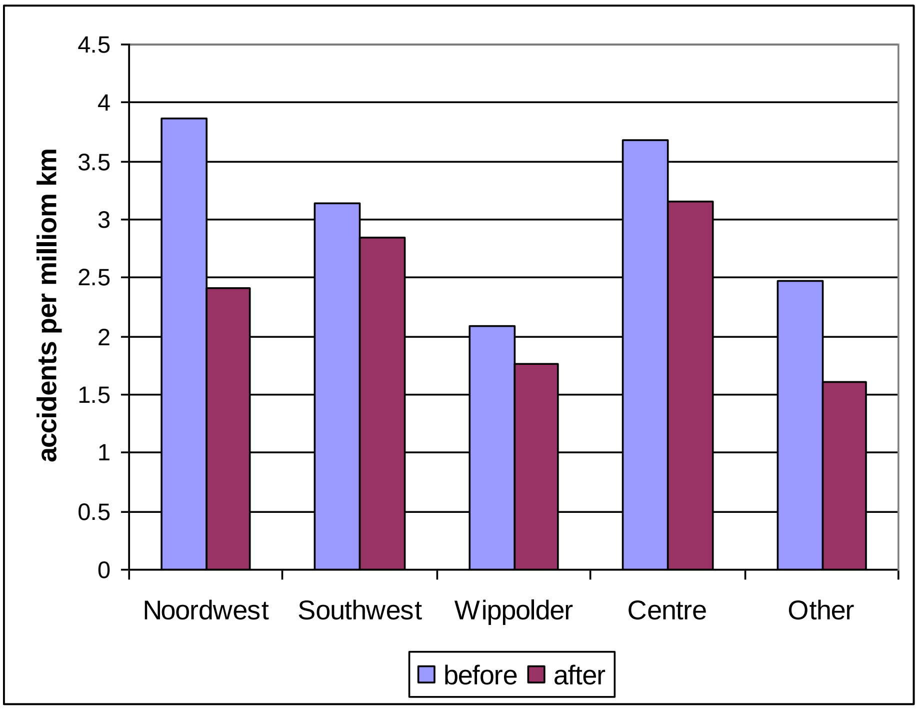


Figure 4.6: Probability of involvement in accidents by cyclists in different districts

The relatively strong decrease in Noordwest suggests again an influence of the bicycle plan. The low decrease in Southwest, which also benefited from the measures, seems to suggest the opposite. A possible explanation is that an increase in safety due to the measures was partly offset by demographic factors. The southwest districts are new districts where many households had young children. The children got a few years older between the before and after situation and changed from walking to the primary school to cycling to the secondary school or from cycling accompanied by parents to unaccompanied cycling.

A statistical test on the differences in developments between the experimental Noordwest district and the control area Wippolder produced no significant results. Assuming a Poisson distribution of the probability of being involved in an accident, the observed decrease in number of accidents in Noordwest does not differ significantly from the smaller decrease in Wippolder. The main problem for the analysis is the small number of observations. Though there are strong indications that the bicycle plan increased safety, it cannot be proved.

Long-term impacts

Statistics on traffic accidents and casualties in the period 1985-1992 were analysed in order to gain knowledge about long-term impacts of the bicycle plan (AGV, 1994). Long-term developments in Delft are compared to national developments, developments in the province of Zuid-Holland where Delft is located, and developments in other medium-sized Dutch cities. Additionally, some characteristics of the developments within Delft are discussed.

In both The Netherlands and Zuid-Holland, the numbers of traffic accidents and casualties per million person km decreased significantly between 1985 and 1992. The reductions are 15-20% for accidents with injured persons and 30-35% for fatalities. In Delft no significant development can be observed. The main problem is the low numbers. The statistics suggest a small decrease of accidents in Delft as well, possibly between 0 and 10%. Regarding the number of fatalities nothing can be said. These fluctuate between 1 and 9 annually. Safety developments in Delft seem less beneficial than in the whole province or the whole country. A possible explanation is that the safety increase was relatively small in medium-sized cities. It would be interesting to compare the development in Delft with that in other medium-sized cities. This has not been done in the evaluation study, except for the observation that the number of fatalities in the medium-sized cities increased a little between the periods 1983-1985 and 1989-1992. This is an indication that the general increase in safety occurred mainly in the countryside and possibly in the large cities, too. This observation deprives us of the possibility to draw conclusions about the long-term influence of the bicycle measures on overall traffic safety.

The evaluation pays additionally attention to developments of the safety of cyclists, but limits it to the short period 1990-1992. In this period both in the whole country and in the province of Zuid-Holland the numbers of bicycle accidents and casualties decreased. The decrease of accidents and casualties per million km is at the same pace as the decrease for all modes. Safety in Delft seems to have been unchanged. However, the observed numbers are too low for a firm conclusion regarding the development in Delft. Comparison with the development in other medium-sized cities is limited to fatalities. The number of cyclists who died in the medium-sized Dutch cities due to an accident decreased between 1983-1985 and 1989-1992. For Delft, the numbers are far too low for any conclusion on the development.

Looking at the developments within Delft, some significant changes that were observed in the short run are partly cancelled out. The share of accidents at intersections that decreased significantly in the short run, increased in the long run to a level that is still somewhat lower than in the before period. The number of bicycle casualties in the experimental area Noordwest increased , but remains significantly lower in the long run than in the before situation. There is one district where the decrease of casualties continued: the city centre. The continuing decrease can probably be explained by implementing measures that limit car traffic in this district.

The overall conclusion is that it is very difficult to say something about the long-term impact of the bicycle plan on traffic safety. There are indications that travelling has become safer in both the short and the long run, but that the long-term impact is smaller than the short-term impact.

4.7.3 Perception of cycling quality

Participants of the panel that was convened for the in-depth analysis of modal choice (Section 4.7.1) were asked in 1985, shortly after implementation of the measures, how they assessed the changes in the bicycle network. The assessment was asked on household level, person level and trip level. Table 4.18 presents the results on household level for the two experimental areas. Households were asked to report improvements or deteriorations of the network for a number of quality aspects. The questions included both an assessment of the bicycle network as a whole and an assessment of individual spots where measures were implemented.

Table 4.18: Assessment of network changes due to the bicycle project on household level

		Noordwest		Tanthof	
		positive assessment	negative assessment	positive assessment	negative assessment
safety	network	16%	4%	32%	0%
	specified spots	75%	73%*	46%	38%*
velocity	network	10%	2%	30%	2%
	specified spots	37%	8%	38%	4%
visibility	network	1%	0%	-	0%
	specified spots	1%	22%*	6%	16%
space for cyclists	network	1%	2%	-	4%
	specified spots	3%	14%	4%	8%
convenience	network	12%	3%	22%	0%
	specified spots	27%	10%	28%	8%
not specified	network	5%	1%	8%	4%
	specified spots	15%	22%	2%	10%
total		203%	161%	216%	94%

* most relate to one intersection of major roads (Hugo de Grootstraat and Westplantsoen)

The measures were assessed predominantly positively, in particular regarding safety, velocity and convenience. The positive assessment is generally larger for Tanthof-households than for Noordwest-households. Interestingly, some measures of the bicycle project were assessed negatively. Outstanding was one intersection that was experienced to be worse after reconstruction. Based on the result of the interviews the municipality reconstructed this intersection again.

The panel respondents were at least ten years old at the start of the panel and the figures presented so far exclude younger persons. An interesting question is to what extent the network raised the cycling quality for younger children, in particular safety. Therefore, households with children from 6-9 were asked whether cycling became safer for them on the route to school. From those households that answered that one or more measures were implemented on the route (72%), 54% answered that the implemented measures did not increase safety, and 46% answered that cycling on the route to school had become safer.

The assessment on a person level gave similar results in the sense that the assessment was predominantly positive and was significantly higher for Tanthof-residents than for Noordwest-residents. In contrast to the assessment on household level, the personal assessment is rather similar for the different quality aspects.

On the trip level, Noordwest-respondents reported that the quality improved for 28% of the bicycle trips and diminished for 23% of the trips. For Tanthof-respondents the figures are 43% and 11%. The number of positive changes per trip was 0.39 and 0.81 for Noordwest- and Tanthof-residents respectively, and the number of negative changes per trip 0.25 and 0.11. The share of bicycle trips where one or more problems were encountered fell from 45% to 34% for Noordwest-residents and from 51% to 30% for Tanthof-residents. The relatively bad results for Noordwest can partly be explained by the intersection mentioned in the note of Table 4.18. If problems with this intersection are excluded, the share of trips in Noordwest where problems were encountered would have fallen from 45% to 28%.

The general conclusion is that the measures gave a better perception of the quality of the bicycle network. The increase in perception is substantially higher for Tanthof, a new residential area some kilometres from the city centre, than for Noordwest, an old district close to the city centre. Another conclusion is that measures that are aimed at improving the bicycle network sometimes lower the perception of the quality of the network.

4.7.4 Economy

Economic impacts of the bicycle plan were not included in the evaluation studies. However, in the framework of the Transecon-project that analyses the socio-economic impacts of investments in urban infrastructure, afterwards an attempt to estimate the economic impacts of the Delft bicycle plan has been made (Transecon, 2003). The analyses include a quantitative estimation of the regional added value and opinions of key actors about socio-economic impacts.

The estimation of the added value includes three indicators. The first is the regional GDP indicating production of goods and services in the region, the second is the regional income reflecting wealth of the people, and the third is the regional employment. The estimated values are limited to the construction phase of the project. These are estimated with an econometric model that use global and economic conditions and demographic factors as input, together with the investment cost of the project per economic sector and year (Schneider et al, 1988). The estimated added values per annum for the Delft project are:

- GDP: 2.3 million ECU;
- income: 1.5 million ECU;
- employment: 29 persons.

The construction phase covers the period 1979-1991. The average annual investment in this period on both the implementation of the measures and the evaluation studies was 1.02 million ECU. All mentioned ECU amounts are at current prices. As mentioned before, the calculated added values relate only to the construction phase. In the operating phase that follows the construction phase the improved infrastructure makes a city more attractive and may be beneficial for economic activities. Added values in the operating phase are on average about 3 times the values in the construction phase (Transecon, 2003). The factor 3 is argued for large infrastructural investments like a metro line that have significant impacts on land use and economic activity. It is doubtful whether it can be used for bicycle investments as well. According to the opinions of key actors, to be discussed next, the bicycle plan had no large long term economic impacts.

A number of key actors were interviewed about the socio-economic impacts of the bicycle plan. The interviews gave qualitative information about the impacts. Some results of the interviews:

- A state agent had the opinion that the measures of the bicycle plan "certainly" did not affect housing prices.
- A bicycle dealer assumed that the plan increased the demand for bicycles. He sold significantly more bicycles after implementation of the measures. However, there is an alternative reason for the increase. In the same period a number of other bicycle shops closed, raising the business of the remaining shops.
- A number of the interviewed persons had the opinion that the economic position of the city centre was strengthened and that the economic decline of the centre that had been observed in the period before the measures were implemented was reversed. At the time of the project old buildings in the inner city and at the edges of the inner city were being redesigned and reconstructed as luxury apartments. New apartments were built as well. The improved bicycle infrastructure could have played a role in this development.
- The plan improved the perception of the city by its residents; it increased civic pride.

The measures sometimes were beneficial for undesired economic activities, too. In a neighbourhood that is fully surrounded by water and that was accessible via just one bridge in the before situation, a second bridge for cyclists was built in the framework of the bicycle plan. Afterwards theft proved to increase. The assumed reason is that the new bridge created better opportunities for housebreakers to flee.

4.8 The impacts of building the Plantagebrug

In Section 4.5 the building of the Plantagebrug has been described. This bridge is built halfway between the Reineveldbrug and the Koepoortbrug (Figure 4.3). It was assumed that the Plantagebrug would attract many cyclists that otherwise would have used one of the two neighbouring bridges. Additionally, lowering the severance of the canal for cyclists might generate new trips and affect shifts of destination and mode. These impacts were examined with three studies. One study explores the potential of the Plantagebrug before it was actually built. This study is based on a household survey and interviews (Kropman and Neeskens, 1986). The two other studies collect data from bicycle counts at bridges and enquiries among passing cyclists in both the before and after situations in order to examine several kinds of impacts of the Plantagebrug (Gommers et al, 1985, and Veeke and Jansen, 1987).

4.8.1 Potential of the bridge

Before the Plantagebrug was built possible impacts on travel behaviour were investigated. The research questions were how the bridge would affect destination choice, modal choice, and route choice; and whether the bridge would contribute to perceived safety and comfort.

The analysis is based on a travel survey and interviews about why observed travel choices are made. A sample of households was selected for both the travel survey and the interviews. Only households living in the residential districts on the east side of the canal and the bridges were approached. Therefore, the study is limited to the potential of the Plantagebrug for those who live in these districts. These are only part of all potential users. Of 161 addressed households, 81 gave a full response. Interviews were conducted with 157 members of these households, only members that were 10 years or older. The travel survey and interviews were organised in June 1984. First, household members were asked to report their trips on a certain working day, and a few days later they were interviewed.

The travel survey gave the same kind of figures as the travel surveys in the three study areas (in particular the Tables 4.5 and 4.9). The results differ in a few respects. First, in the Plantagebrug survey nearly all respondents went outside on the enquiry day (99%). The shares in the other surveys range from 83% to 92% in the before situation. The explanation could be a possible selective sampling and the small sample size of the Plantagebrug survey. A related difference is the number of trips pppd: 4.9 compared to 3.4 to 4.0 in the other surveys. The modal split was different as well. The share of the bicycle is relatively high (46% versus 36% to 41% in the other surveys), that of car users as a passenger is high as well (9% versus 5%), and the share of car users as a driver is relatively low (16% versus 21-32%).

The interviews aimed to give information about how people assess the new bridge, which hindrances they encounter when cycling to the inner city (crossing the canal), to what extent the hindrances could be removed by building the Plantagebrug; and which impacts can be expected on travel choices regarding destination, mode, and route.

Assessment of the Plantagebrug
A majority of the respondents had the opinion that building the new bridge is a good thing; 54% report only advantages, 25% report both advantages and disadvantages, 14% report only disadvantages, and the remaining 8% report nothing. The most reported advantages are better accessibility of the inner city, higher safety, and nicer and more varied routes. The most reported disadvantages are superfluity of the bridge, a waste of money if used for building, and hindrance for shipping and rowing. Based on the predominant opinions, 74% of the respondents can be indicated as supporters of the bridge and 23% as opponents.

The respondents were asked to put forward measures that should accompany building the new bridge. They mentioned in total 270 different measures that mainly aimed to increase safety on the routes leading to the bridge. There was a large match between the mentioned measures and accompanying measures that were planned by the municipality (the respondents were ignorant of these).

Hindrances for cycling to the inner city

In the travel survey, respondents reported that they encountered hindrances for 45% of trips to the inner city. The most mentioned hindrances relate to safety, in particular traffic volume and speed, and problems when crossing roads. Interestingly, the two most frequently reported problematic spots are the two existing bridges, or more exactly: the Koepoortbrug and the road Vrijenbanselaan that leads over the Reineveldbrug. Addition of the Plantagebrug, a bridge dedicated to cyclists and pedestrians, has a large potential for reducing hindrances. The number of trips with hindrances would be reduced from 45% to 34%.

For trips that were not made by bicycle or not to the inner city, the respondents were asked why these were not made by bicycle to the inner city. The predominant reason (applicable for 40% of these trips) was that choosing the destination in the inner city is no option. The second most important reason is practical matters (22% of the trips), other reasons of some importance, all relating to 13-15% of the trips, are inconvenience, travel time, and ‘bicycle use no option’. Problems regarding the traffic situation were mentioned for only 2% of the trips. Freedom of choice for converting the trip into a bicycle trip to the inner city applies to 4% of the trips. These results lead one to expect a rather small potential for the Plantagebrug, expecting its main contribution to be improving the traffic situation and reducing travel time. These kinds of hindrances are rather unimportant. Moreover, if these hindrances would be removed, or if the trips that were free of choice would be made by bicycle to the inner city, a limited number of the trips would use the Plantagebrug. In many cases routing via one of the other bridges is shorter. One should note that the reason “travel time” is valid for a much smaller proportion of trips (14%) than in Table 4.11, which presents the reasons why the bicycle is not used for non-bicycle trips (51% in the before situation). Possibly, in the Plantagebrug survey the travel time hindrance relates mainly or only to trips to the inner city. For these trips the bicycle is generally competitive regarding travel time.

Impacts on travel choices

In order to get understanding about the impacts on travel choices, the respondents were asked whether and how they would change their trips if the Plantagebrug was built. From 767 observed trips, in just one case another destination would have been chosen (in the inner city instead of outside the inner city). The impacts on modal choice and route choice are summarized in Table 4.19. The figures concern numbers of round trips and share in all observed round trips (767). A round trip is the sequence of trips, starting at home, visiting one or more outdoors activities, and returning home.

Table 4.19: Changes in modal choice and route choice

before		after (via Plantagebrug)		
mode	bridge	walk	bicycle	moped
walk	no bridge* Koepoortbrug	2 (0.3%) 5 (0.7%)		
public transport	Reineveldbrug	1 (0.1%)		
bicycle	Reineveldbrug Koepoortbrug other bridge		31 (4.0%) 32 (4.2%) 1 (0.1%)	
car (driver)	Reineveldbrug other bridge		5 (0.7%) 1 (0.1%)	
public transport	Koepoortbrug		2 (0.3%)	
moped	Reineveldbrug			4 (0.5%)
total		8 (1.0%)	72 (9.4%)	4 (0.5%)

*possibly trips that use two different bridges in the after situation

Summarizing: the impact on destination choice is marginal (just one trip), the impact on modal choice is larger but still small (9 trips, about 1% of all trips), the impact on route choice is substantial (75 trips, 10% of all trips). Modal shifts are mainly from car to bicycle, and to a lesser extent from public transport to both bicycle and walk.

Based on the reported number of 72 bicycle trips that will use the Plantagebrug, the total number of bicycle trips of residents of the districts at the east side of the canal that will use the bridge on a working day are estimated. The result is 1850 trips. This number regards single trips in two directions. Because it concerns only trips by residents that live east of the canal, the total number of cyclists using the Plantagebrug will probably be significantly higher. A more complete estimation can be made with data of the second before study that will be discussed next.

4.8.2 Before and after studies

For evaluation of the impacts of the Plantagebrug on use of the different bridges, accessibility, and safety a before and after study were performed. The after study also pays attention to familiarity with the new bridge. Data for the before study were collected by counts of cyclists at the Reineveldbrug and Koepoortbrug on a Wednesday in June 1984, and for the after study by counts at the same bridges as well as at the Plantagebrug on a Wednesday in September 1986. The intention was to organize the after counts in June, but a delay in building the bridge called for the counts to be postponed. The after counts were performed one month after the bridge was put into use. One of the complementary measures that should contribute to the attractiveness of the bridge, i.e. building a new route for cyclists along the Kantoorgracht west of the bridge, had not been finished yet. Absence of this route and possibly unfamiliarity with the new bridge due to the rather small period of operation meant that the observed demand underestimates the potential demand.

Both the before and after counts were executed between 7 a.m. and 7 p.m. In addition to the counts, questionnaires were handed out to a number of cyclists that travelled in the direction of the inner city (south or west). They were asked to report origin and destination addresses, travel purpose, residential municipality, normal use of the different bridges, possibility to use an alternative mode, and some personal characteristics. Moreover, they were asked to draw their route on a map. In the after enquiry, a question about familiarity of the Plantagebrug was asked to users of the two other bridges, and possible use of the alternative bridges was asked to users of the Plantagebrug.

In the before situation 7475 cyclists travelling in the direction of the inner city were counted on both bridges, 4350 questionnaires were handed out, and 1142 completed questionnaires were returned. The response was lower than expected and for that reason returned questionnaires without route information were used for the analysis as well (304 questionnaires). In the after situation 6253 cyclists entering the inner city were counted on the three bridges, 4372 questionnaires were handed out and 1417 completed questionnaires were returned. The larger number of completed surveys eliminated the need for using questionnaires without route information. The large difference in counted numbers can be explained by the difference in season. The before counts were on a hot day in June and included a lot of cyclists travelling to and from the recreation area Delftse Hout east of the city that is accessible via the Koepoortbrug. In the after counts only few cyclists travelled to or from the Delftse Hout.

Use of the different bridges
Based on the questionnaires, the numbers of cyclists that use the bridges during the enquiry periods are estimated by using projection factors. Table 4.20 shows the estimated figures for the three bridges in the before and after periods per direction.

Table 4.20: Cyclists crossing the bridges between 7 a.m. and 7 p.m. on the enquiry days

	entering the inner city		leaving the inner city		both directions	
	before	after	before	after	before	after
Koepoortbrug	4950	3341	5047	3225	9997	6566
Reineveldbrug	2495	1906	2815	2159	5310	4065
Plantagebrug	0	1006	0	831	0	1837
all bridges	7445	6253	7862	6215	15307	12468

The Koepoortbrug serves mainly local traffic. In the before situation 89% of the passing bicycles made local trips: both origin and destination were inside Delft. The Plantagebrug seems to have strengthened the local function of the Koepoortbrug: In the after situation the share of local bicycle traffic on this bridge increased to 91%. The Reineveldbrug is more important for cyclists that travel longer distances. The shares of local traffic were 61% (before) and 65% (after). The local function of this bridge seems to have been strengthened a little as well. The function of the Plantagebrug is between that of the two other bridges. The share of local bicycle traffic was 79%.

Looking at travel purposes, two major differences were observed between the before and after enquiries. The number of leisure trips decreased significantly, that of school trips increased. For all bridges together, the share of leisure trips fell from 19% to 5%, and the share of school trips increased from 10% to 22%. The explanation for the fall in leisure trips has to do with the season and the weather. As mentioned before, the before enquiry was performed at a hot day in June, the after enquiry at a day in September. Why fewer pupils and students travelled to school during the before enquiry in June is not clear. If leisure and school trips are not considered, the distribution of purposes is similar in both periods, both for each of the two bridges that existed in the before period, and for the total of all bridges. The Koepoortbrug is mainly used for work and shopping and, in the before period, for leisure. The Reineveldbrug is mainly used for mandatory activities (work and education). The most common trip purpose for cyclists crossing the Plantagebrug is work. The shares of work and shopping are between the shares observed for the two other bridges, the share of education is equal to the low share of the Koepoortbrug, and the shares of the other distinguished purposes (visit family/friends, leisure, other) are higher than those of the two alternative bridges in the after situation.

Familiarity with the Plantagebrug

The after enquiry included questions about familiarity of the Plantagebrug and competition between the bridges. Table 4.21 summarizes the results. The first row mentions the shares of Koepoortbrug and Reineveldbrug users that were familiar with the Plantagebrug. The Plantagebrug is better known for Koepoortbrug users than for Reineveldbrug users. The second row reports the shares of Koepoortbrug and Reineveldbrug users that already used the Plantagebrug. Again, the share is higher for Koepoortbrug users. The two lowest rows indicate which alternative bridge Plantagebrug users would have used if the Plantagebrug had not been built. A majority would have used the Koepoortbrug (third row). However, if the numbers of those indicating that they alternatively would have used the Koepoortbrug or Reineveldbrug are compared to the actual bicycle users of these two alternative bridges, the figures are similar (fourth row). This suggests that the attractiveness of the Plantagebrug is similar for users of the two other bridges. Possible explanations for the difference in familiarity are a) that a relatively large share of Reineveldbrug users do not live in Delft and might be less familiar with projects that are implemented in Delft, and b) that the Plantagebrug is visible from the Koepoortbrug and not from the Reineveldbrug.

Table 4.21: Familiarity with Plantagebrug and competition between bridges

	Koepoortbrug	Reineveldbrug	other bridges
familiar with Plantagebrug	82%	62%	-
use of Plantagebrug	51%	35%	-
alternative for Plantagebrug (1)	59%	40%	1%
alternative for Plantagebrug (2)	18%	21%	-

(1): share of all Plantagebrug users
(2): percentage of the actual users of the alternative bridge

A general conclusion is that it can take some time before (nearly) all potential users of a new bridge or other infrastructural work are familiar with the project.

Expected and observed use

After collection of the before data, the number of cyclists crossing the Plantagebrug was predicted. The enquiry gave a lot of information about origins and destinations of trips by bicycle, and route choice. Using the network data in the before and after situation that were recorded in the data bank described in the route choice part of Section 4.7.1 and the model that was calibrated on data regarding route choice of cyclists leaving the Noordwest district, 4100 cyclists were predicted to use the Plantagebrug at a working day. This number could be in accordance with the estimated number of 1850 for bicycle trips made by residents living in the districts east of the canal (Section 4.8.1). However, the observed number in the after study, about 1800 (Table 4.20), is considerably lower. Three reasons can be mentioned for the gap between predicted and observed numbers, though it is doubtful whether they can explain the whole difference. One reason is that in the before situation the overall number of cyclists was higher than in the after situation. This is mainly due to the large volume of leisure travel on the before day. The Plantagebrug proves to attract a relatively large part of leisure traffic and is likely to be more exposed to fluctuations in volume of this traffic than the other bridges. The second reason is the unfamiliarity of the Plantagebrug by a number of the potential users. The third reason is that, contrary to assumptions made in the prediction, some of the projects on access routes to the bridge had not yet been finished. This is particularly true for the bicycle route along the Kantoorgracht.

Accessibility
The Plantagebrug reduced the detours that had to be made by the canal crossing cyclists. The average link level detour factor decreased from 1.23 to 1.21. For those using the Koepoortbrug in both the before and after situation, the decrease is from 1.25 to 1.24, and for those using the Reineveldbrug the detour is constant at 1.17. For cyclists that used the Plantagebrug in the after situation, the detour factor fell from 1.30 to 1.22. Not surprisingly, the Plantagebrug attracted particularly cyclists that had to make a large detour in the before situation where the Plantagebrug offers a more direct route. The reduction in detour factors is mainly observed for shorter distance trips. For canal crossing trips less than 1400 m, the detour factor reduced from 1.36 to 1.27, for trips between 1400 m and 3600 m, the reduction was only from 1.23 to 1.22, and for longer trips no reduction was observed.

Comparing the predicted travel times in the after situation with the before situation, the Plantagebrug would have saved 0.2 minute (2%) on average for all canal crossing bicycle trips. For trips starting in the residential districts at the east side of the canal, the average savings are 0.3-0.4 minutes (3-4%). For trips that were predicted to use the Plantagebrug in the after situation, travel time would be reduced by 1.0 minute (8.5%).

The Plantagebrug does not contribute to the accessibility of the most important destination of those living east of the bridge: the market and surrounding shopping area. The bridge connects with the less attractive northern side of the inner city while the market is in the southern part. Likewise, the new bridge does not improve the accessibility of the central train station that is located south west of the inner city.

A third important destination is an industrial estate north of the inner city and about 1 km west of the Plantagebrug. The Plantagebrug improves the accessibility of this estate for people living east of the canal substantially and is used frequently by them in the after situation. The relatively large numbers using the Plantagebrug for travelling to the industrial estate explain the high share of work-related trips.

Safety
Probably the Plantagebrug will have increased traffic safety for cyclists. Both the Koepoortbrug and the Reineveldbrug were experienced as unsafe because cyclists were not physically separated from the large numbers of cars crossing the bridges. A number of cyclists shifted their route from one of these unsafe bridges to the much safer Plantagebrug. This will have increased general safety. However, the impact on

safety has not been studied. A study on differences in accidents would have been difficult because of the very low number of accidents in such a small area.

4.9 Discussion

The Delft bicycle plan had two objectives: to improve the infrastructural facilities for cyclists and generating knowledge about the impact of the upgrade of a whole cycle network. The first was mainly the objective of the municipality; the second mainly the objective of the national government. Regarding the second objective, next questions should be answered:

- Does the implementation of a comprehensive bicycle network lead to an increase in bicycle traffic? The hypothesis was that providing a comprehensive and integral network affects bicycle use and its quality more than improving a number of single bicycle routes.
- Does the implementation of a bicycle network increase road safety?
- In which way do cyclists use a comprehensive and integral bicycle network which is perceived as such, and what are their behavioural responses?

Do the evaluation studies give answers on the questions? In answering the questions one should consider that the upgrade of the Delft bicycle network concerned improvements of an existing network with initially a reasonably good quality in a city where the bicycle was already used frequently. The answers may not be valid for cities with initially a poor bicycle network and low bicycle use.

The studies demonstrate that the measures induced a short term moderate increase in the number of bicycle trips and probably a larger increase in the distance travelled by bicycle. They suggest that the increase is retained in the long term, but due to problems relating to small samples and the influences of other factors, a firm conclusion regarding the long term effects cannot be drawn. In addition, a significant increase in the perceived quality of the network was observed, in particular regarding safety, directness and convenience. A similar result was found for the demonstration projects of single bicycle paths described in Section 3. The impact on the perceived quality is more pronounced than the impact on actual bicycle use.

Was the increase in bicycle use larger than it would have been if the same money was spent on improving a number of individual routes? The studies do not answer this question. We guess that the answer is negative, assuming that the alternative spending is in the most efficient way and that the initial network enables cyclists to move from each origin to each destination (as was the case in the studied Dutch cities). Considerations behind the guess are the rather small observed impacts of the Delft bicycle plan, and, for providing an integral grid network with a homogeneous quality, the need to employ part of the money for relatively large investments on routes with relatively low bicycle volumes. The Plantagebrug is an example of an expensive project on one of the main corridors of the defined grid network, but not lying along one of the most extensively used bicycle routes. One should note, however, that if the money that is spent on upgrading an a priori defined network is instead spent on improving individual routes in the same city, these routes are likely to form a network as well. The latter network may not be identical to the defined network for the upgrade, though both networks will have a number of links in common.

The increase in the perception of safety is confirmed by an increase in safety itself. The studies give evidence of a clear increase of road safety in the short run, despite the growth of bicycle use, one of the more vulnerable modes. The long-term impact is less clear and could be smaller than the short-term impact. The main ingredient for the safety increase was separation of cyclists from motorized traffic. The separation is partly spatial by building off-road bicycle paths and partly temporal by installing traffic lights.

Cyclists prove to assess the subnetworks at the city, district and neighbourhood level differently. They prefer use of higher order networks and are willing to make a detour in order to shift travel to a higher order network. Cyclists have a clear preference for off-road bicycle paths. The most important factor for route choice is travel time. New network links that shorten the distance (and duration) can be very attractive.

Apart from answers to the three research questions, other interesting things can be learned from the Delft project. Firstly, good communication with interest groups and residents in an early phase is important for a wide support of the project and a successful implementation of measures. Secondly, the bicycle has the potential to attract car users; improving bicycle infrastructure is a possible measure for a policy that is directed at lowering car use. Thirdly, the most important reasons for not using the bicycle for a trip have to do with practical matters and travel time; infrastructural problems and the traffic situation are rarely reported as reasons for not using the bicycle. These findings suggest that investing in bicycle infrastructure is not necessarily the most efficient way for enhancing bicycle use. Again, it should be noted that this result is valid for a city that had already a fairly good network. For other cities the result is likely to be different.

The studies investigated the impacts in the short and the long run. Could something be said about the impacts in the very long run? The Dutch Cyclists Union (Fietsersbond) developed a method for assessing local cycling conditions for a number of aspects and applied it to a large number of Dutch cities including Delft. This method, called the “Fietsbalans”, enables one to compare cycling conditions in the examined cities. Thus, the Fietsbalans study allows once to compare the more recent quality of the Delft bicycle network to the network qualities in other cities. The examination in 2000 (Fietsersbond, 2001) demonstrated that Delft, compared to other medium-sized cities, ranked:

- high regarding traffic safety of cyclists,
- above average regarding directness (measured by detour factors, delays at traffic lights and other obstacles, and speed),
- below average regarding inconvenience caused by other traffic (this includes the need to ride behind each other and exposure to traffic noise),
- very low regarding pavement quality.

Generally, Delft takes a medium position between the cities. The bicycle plan gave Delft a less-than-excellent position in the long run. One of the reasons is that in many other cities investments in bicycle infrastructure were made, partly encouraged by the positive results for Delft. The relatively good performance regarding directness in Delft may still be attributed to the bicycle plan. Possibly this is also true for the high score regarding safety. The very low score for pavement indicates that Delft did not maintain the bicycle infrastructure properly. The Delft soil conditions bring about a rather quick deterioration of the quality of the tile pavements commonly used on bicycle paths and good quality demands rather extensive road maintenance.

5 Shared space in Haren

Shared space is defined as integrated use of public space by both motorized and non-motorized modes. It is evolved out of the ‘woonerf’ concept, which is a residential area with mixed use of traffic and other activities where cars have to slow down to a walking pace and so accommodate other usage of the public space. Shared space is the opposite of modal segregation. In the Netherlands, shared space is part of the concept of “duurzaam veilig” (sustainable safe) that aims to design traffic infrastructure such that it is inherently safe. Shared space impels drivers of motorized modes to take full account of the slow modes. This is assumed to lead to safer and socially responsible traffic behaviour.

The municipality of Haren, one of the more wealthy municipalities in the metropolitan area of Groningen, the largest city in the north of the Netherlands, implemented and evaluated shared space in the Rijksstraatweg in 2002. The Rijksstraatweg is the main road traversing the town and used to be the major road connecting Groningen to the south (“Rijksstraatweg” means national road). However, since a parallel motorway has been built, the function of the road is mainly local and to some extent regional. Still, it is the most heavily used road in Haren. In 2004 8,200 motor vehicles were counted on a working day. The road passes through the centre of Haren. Figure 5.1 shows the location of Haren in relation to Groningen. The Rijksstraatweg is indicated in the figure.

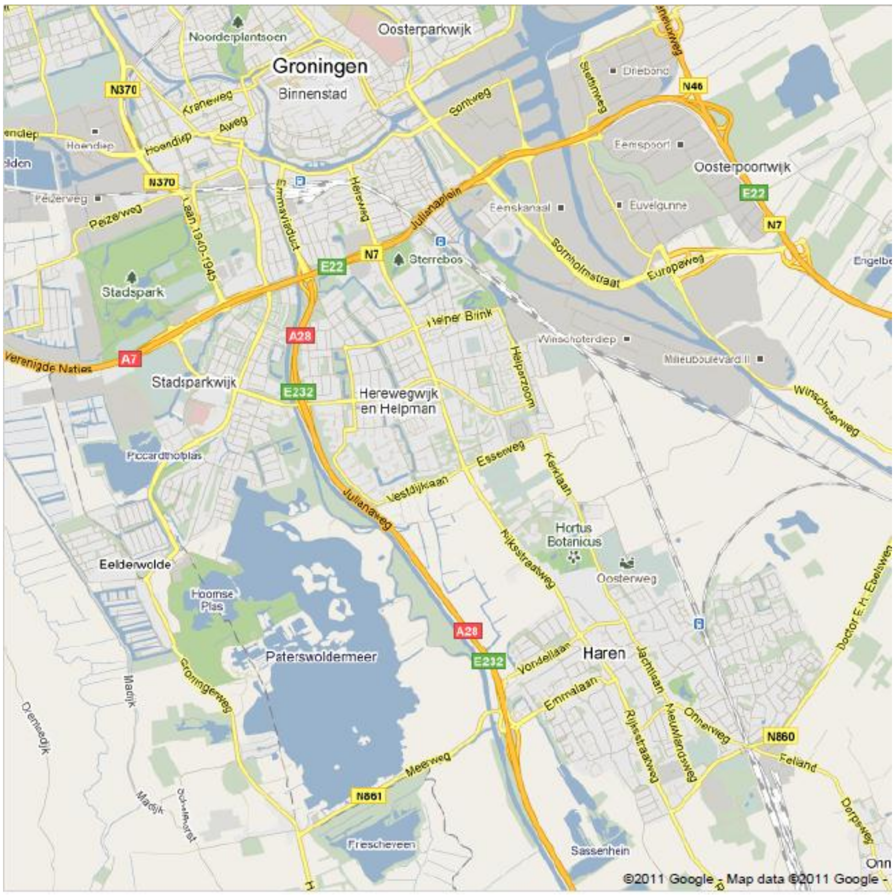


Figure 5.1: Location of Haren southeast of the city of Groningen

5.1 Design

The project objective was to make the road an integral part of the centre. Before, the typical function of the road was facilitating through traffic and the road created severance inside the town. The measures to achieve the intended integration were:

- Removing differences in height in the cross section of the road.
- Making the road optically narrower.
- Installing street furniture that is typical for avenues.
- Reducing the maximum speed from 50 km/h to 30 km/h.

Figure 5.2 shows two sections of the road before and after the redesign.

Figure 5.2: Two sections of the road before (above) and after (below) implementing shared space (source: van der Velde and Bos, 2008)

5.2 Organisation and implementation

The municipality encouraged participation of citizens in developing the project. Experts and citizens together deliberated over the new design. During the whole process from planning to completion interested parties were informed. This policy created a large support among the citizens for the project. The implementation of the project was in 2002.

5.3 Evaluation

A few evaluation studies have been executed. These are summarized by van der Velde and Bos (2008). Evaluated topics are use of the road, the impact on safety, and the experience of users of shared space.

5.3.1 Use of shared space

In the initially implemented design, cars were guided to use the zone in the middle of the road, pedestrians to primarily use the side zones, and cyclists had no guidance about which zone to use. One of the evaluation results was that cyclists' usage of both the middle zone and the side zones produced an unclear situation and increased the perception of unsafety. Based on this result, the space for cyclists was restricted to the middle zone that they were to use together with cars.

Regarding use of the shared space it was observed that:

- Slow modes cross the road all over. They usually choose the most direct route to a destination on the other side of the road. Pedestrians frequently do not use the crosswalks, even if a crosswalk is close by.
- Cars drive slowly and anticipate crossing pedestrians. They generally give priority to pedestrians who use the crosswalks, and sometimes to those who cross elsewhere. This implies a good social interaction.
- Cars take account of bicycles riding in front of them. They usually stay behind when there is no good opportunity for overtaking.
- Car drivers generally do not yield priority to cyclists that enter from side streets, and the cyclists do not expect priority to be given. The reason might be different pavements that suggest that one road has priority over the other. This unintended result did not create conflicts.
- The volume of motor vehicles on the Rijksstraatweg did not change noticeably.

Figure 5.3 gives an impression of the integrated use of the road after implementation of shared space.

Figure 5.3: Use of the shared space (source: van der Velde and Bos, 2008)

5.3.2 Safety

Increasing safety is a main objective of shared space. The impact on safety is examined by comparing the numbers of accidents and casualties in the periods before and after the implementation of shared space.

In the before period (1994-2001) the average number of annual accidents was nearly 11. The number fluctuated between 6 and 14. In the after period (2003-2007) the annual average was 5 with fluctuations from 3 to 9. The highest number of 9 accidents was observed in 2003, shortly after the implementation. Possibly users need time to become familiar with the new situation. Despite the low absolute numbers, there is clear evidence that safety increased significantly.

An even stronger decrease is observed for the number of casualties (fatalities and injured persons). In the before period the annual average was about 2.5 and the number fluctuated between 1 and 5. In the after period only one casualty was registered in the whole 5-year period.

The nature of the accidents changed somewhat. In the before situation the most observed category of accidents were those related to insufficient distance to vehicles in front (26% of all accidents); rear-end collision was a typical accident. In the after situation the most observed accidents were those related to not giving priority, wrongly turning a corner, and driving too far to the right (for 20%, 12%, and 12% of the accidents respectively).

In both the before and after periods most accidents were due to collisions between cars. The numbers of collisions between cars and bicycles and collisions between bicycles were relatively small in both periods. The change from segregated infrastructure with separated bicycle paths to shared space with mixed use of the main zone by cars and bicycles did not increase the relative unsafety of cyclists. In connection with the overall increase in safety, the absolute numbers of all types of collisions decreased.

5.3.3 Perception of shared space

A number of residents were interviewed by phone about their opinion on changes due to the redesign of the Rijksstraatweg. Corresponding with the observed changes, the respondents have the opinion that vehicle speeds lowered, traffic volume is unchanged, and road users take more account of each other. In contrast with the observed statistics, the respondents felt a decrease of safety. This feeling was mainly due to the unclear position of the bicycle that was allowed to use both the main zone in the middle of the road and the side lanes. After adjusting the rules regarding where bicyclists ride, the feeling of unsafety might have been reduced.

According to the respondents, the centre looks better and has become more attractive. The Rijksstraatweg is considered to be more integrated in the centre. The Rijksstraatweg used to be an important barrier inside the town and the centre, but after implementation of shared space the severance reduced substantially. Lowering of the severance was one of the main objectives of the redesign.

5.3.4 Economy

One of the results reported in the preceding section was an increase of attractiveness of the city centre. Nevertheless, the respondents did not indicate visiting the centre more frequently. Possibly, the centre benefits from more visits by people from outside Haren; however, this has not been studied.

5.3.5 Conclusion

Shared space can be highly beneficial. It has the potential to increase safety significantly and lower the severance of a road. The increase in safety is remarkable, because modes that have quite different speeds in normal use are mixed. The main explanation for the increased safety is that the design tempts the faster vehicles to drive with low speeds. The example of Haren learns that shared space can be applied for roads with a rather high volume of motor vehicles.

However, one should note that the observed positive effects are not primarily the result of space sharing but of measures that homogenise traffic and let road users taking more account of each other. Without such measures, changing segregated use by cars and bicycles into shared space might have reverse effects. Generally, it should be stressed that ‘shared space’ has its specific contextual conditions of application. The public space should have a substantial ‘habitat’ function. And the concept is likely to be more successful if adjusted driving behaviour is already part of the local traffic culture.

6 Bicycle street in Haarlem

A bicycle street is a street for mixed traffic (bicycles and cars) where the bicycle is the main user and the car is guest. The concept of the bicycle street was first applied some decades ago in both a few German and Dutch cities. Recently, in the Netherlands it evolved to be a general frequently applied concept. The main function of bicycle streets in the Netherlands is provision of bicycle routes through residential areas that are part of the main bicycle network. Bicycle streets offer alternative routes for the main roads. The benefits for the cyclists are that they are not exposed to the polluting emissions of the cars, may have a more direct route, and can avoid traffic lights. In the case that no bicycle paths are provided along the main roads, an additional benefit is avoidance of the inconvenient and unsafe mixed use of roads with high car volumes (Andriesse and Hansen, 1996).

Bicycle streets are links in the main bicycle networks and should meet high quality standards for cyclists. Hindrance by cars using the streets should be minimal. For that:

- Through car traffic should be inhibited; only local cars preferably use the streets.
- The number of cyclists should be large compared to the number of car users.
- Cyclists have priority; they don’t need to go aside in order to allow a car behind them to overtake.
- The design of the street clarifies that the street is a bicycle street and not a main road for cars. Bicycle streets should not be too wide. In the Netherlands, bicycle streets usually are paved with red asphalt that is typically used for bicycle paths.

The number of cyclists of a bicycle street should be high but not too high. If the number of cyclists exceeds 600 per hour and per direction, there is hardly room for car users. In that case cars should be admitted only for a short road section, no longer than 300 m (Andriesse and Hansen, 1996).

Andriesse and Hansen recommend allowing cars to use a bicycle street in only one direction (unlike the bicycles). The corresponding cross section is 3.5 to 4 m (Andriesse and Ligtermoet, 2006). If cars are allowed to move in both directions, the proposed width is about 4.5 m. Generally, Dutch bicycle streets consist of a roadway in the middle is paved with red asphalt and additional narrow strips at each side that could be paved with bricks; the width of the later should not exceed 1.1 m. Cyclists are expected to use only the comfortable roadway; the side strips are there to ensure sufficient space for cars.

Many bicycle streets have been recently built in the Netherlands, but only few have been evaluated. One of these is the Venkelstraat in the city of Haarlem. Haarlem is a city of about 150,000 inhabitants located 20 km west of Amsterdam. The Venkelstraat is a street through a residential area and part of a main bicycle route to the city centre (Figure 6.1). The street was reconstructed as a bicycle street and became the first bicycle street in the city. Design and use of this street have been evaluated (Kho, 2006).

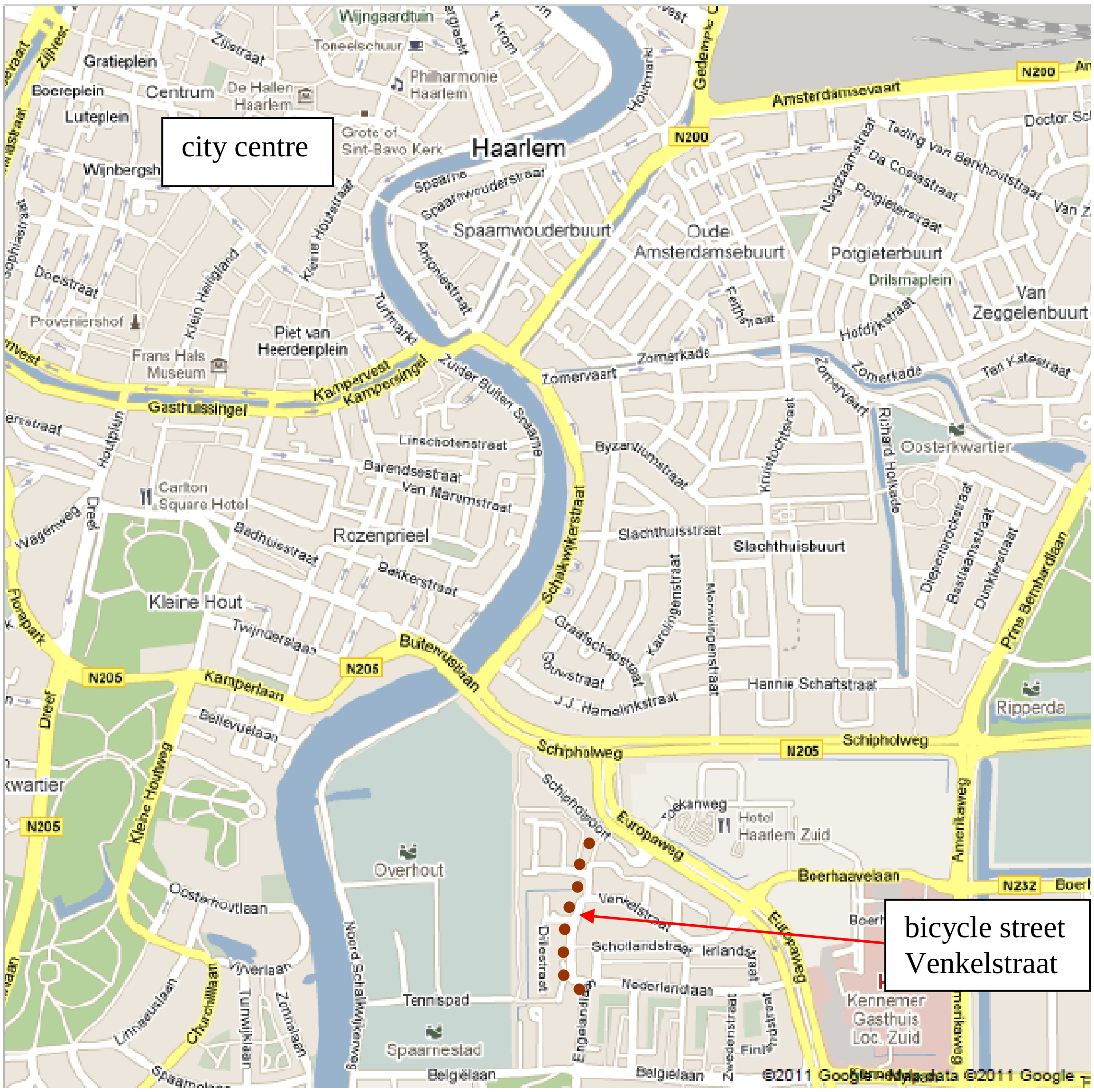


Figure 6.1: Location of the bicycle street Venkelstraat

6.1 Design

The Venkelstraat has the typical design for Dutch bicycle streets. There is a wide zone with red asphalt in the middle of the road and there are narrow side strips one each side, paved with bricks. Cyclists are expected to use the red zone in the middle; the side strips give cars enough space to meet each other (Figure 6.2). The street is accessible in both directions to both cars and cyclists.

Figure 6.2: Venkelstraat in Haarlem (source: Kho, 2006)

6.2 Evaluation

The evaluation is restricted to the design and the way the street is used by both car drivers and cyclists. Impacts on travel behaviour like modal choice are not studied. Questionnaires were distributed to people living at or near the Venkelstraat and to pupils and employees of the Rudolf Steinerschool, a school for both primary and secondary education located at the southern end of the Venkelstraat. The number of distributed questionnaires was 1500: 750 to residents of the street and surroundings, and another 750 to pupils and employees of the school. The number of returned questionnaires was 335, about 200 from the residents and about 130 from those connected to the school. Most questions in the questionnaire were multiple-choice, though there was room for additional remarks and suggestions.

The results demonstrate that people generally are satisfied with the bicycle street; 58% of the respondents reported that they were satisfied or very satisfied, 16% was dissatisfied or very dissatisfied. The remaining respondents had no clear opinion. An even higher share of respondents was satisfied with the look of the street (72%), where only 10% was dissatisfied. A majority had the opinion that noise nuisance was not affected, while more respondents that felt that noise nuisance decreased (21%) than increased (6%). According to most respondents current provisions regarding speed ramps and lighting are sufficient.

The respondents were asked whether they use the street as a car driver or as a cyclist. Something less than a half (42%) report using the street as a car driver, a large majority (91%) indicate that they use the street as a cyclist or moped rider. Both car drivers and cyclists were asked about the way they use the street.

Most car drivers (82%) are aware that cyclists have priority and need not to go aside to allow cars to overtake them. Interestingly, a large share of cyclists (61%) answer that they actually go aside when a car approaches on the back. Nearly half of the car drivers (44%) cannot conclude from the design of the street that cyclists have priority.

Most of the car drivers (61%) use the street wrongly: they drive fully on the red lane in the middle. The share of cyclists that know that the red asphalt is dedicated for them is smaller, only 55%. These results indicate that many users do not know how the bicycle street should be used. This can be explained by the fact that 67% of the respondents had not read information about the bicycle street. Both communication and design of the street should be improved.

A number of respondents suggested that marking the middle of the street would increase clarity about function and usage. The street gets the look of a bicycle path and gives car drivers the feeling that they have to ride at the right side of the road. The municipality complied with this suggestion and put road signs informing that the street is a bicycle street. Figure 6.3 displays the situation after marking and signposting.

Figure 6.3 Venkelstraat Haarlem after marking and signposting (source: Ligtermoet, 2006)

General conclusions from the Venkelstraat evaluation are that a good communication with users is important; that users generally are satisfied with the street; that the way the street has to be used is not self-evident; and that marking the street as a two-way bicycle path and signposting increase clarity about how the street should be used.

With respect to marking the middle of the street, it should be added that a number of bicycle streets in the Netherlands are provided with a domed median that can be driven over by vehicles.

7 Interurban highways for cyclists

7.1 Context

Recently, the Netherlands has seen initiatives to promote interurban cycling as a means of relieving congestion on motor highways. In the Dutch pattern of urbanisation there is a large share of interurban commuting for distances below 20 km. If these commuters go by car they use the motor highway system, and congestion on these highways has been a growing problem for years. Regional car trips (for relatively short distances) appear to contribute substantially to the congestion problems. Now the idea is that by making high quality bicycle connections in some highway corridors, a number of commuters would be prepared to shift to cycling to avoid the congestion on the highways. This type of projects is implemented within the framework of the project 'Fiets filevrij' (Cycle Congestion Free), and combines infrastructural improvements of interurban bicycle infrastructure with promotion activities to seduce 'short distance' car drivers to shift to cycling.

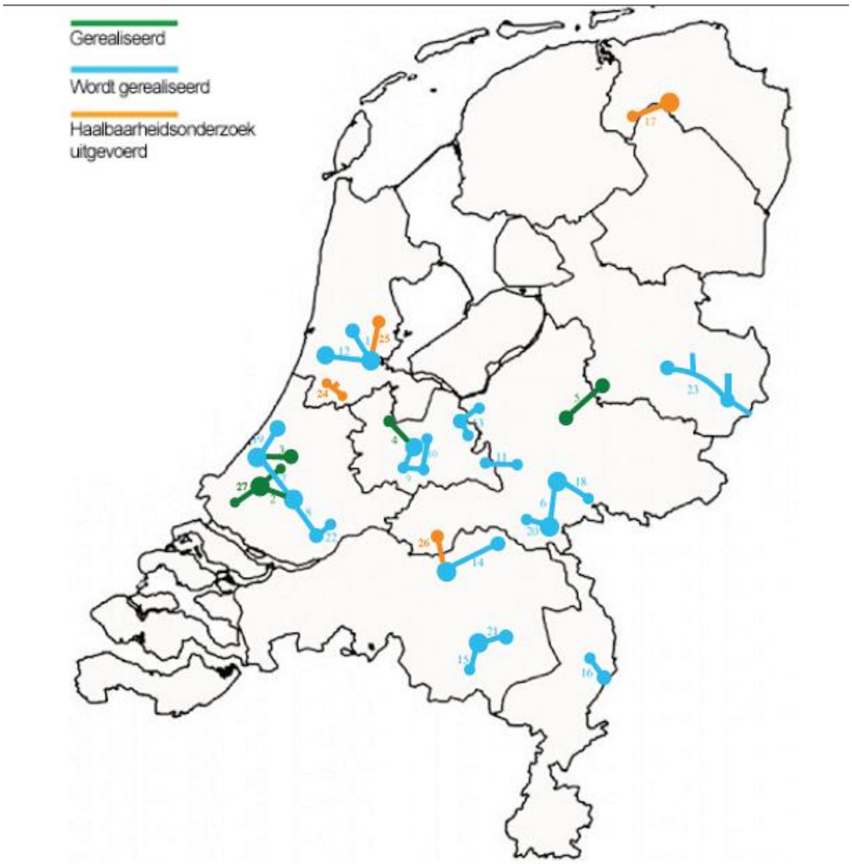


Figure 7.1: Map showing in green the implemented bicycle highways, in blue the planned ones and in ochre those for which a feasibility study is going on.

7.2 Design

Rotterdam - Delft

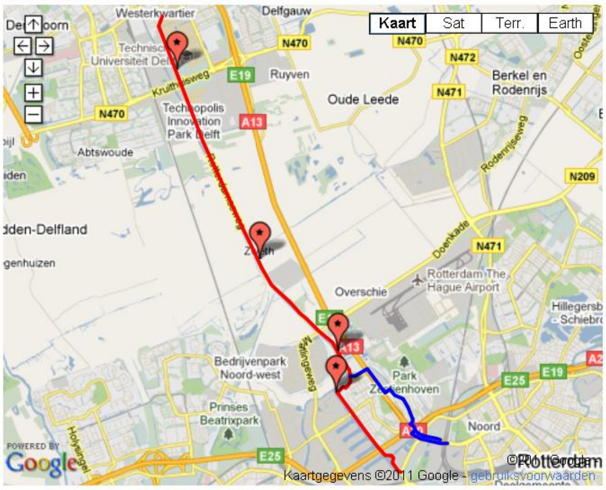


Figure 7.2: Bicycle highway Rotterdam – Delft

We take as an example the route between Rotterdam and Delft. The route is a direct and ‘fast’ bicycle route. The 10 km route is for the most part implemented as an off road bicycle track, and it has only a few intersections and no traffic lights at all. So cyclists will have no delay, even more so because at the few remaining intersections the cyclist has right of way. The bicycle track is two directional and for most parts conveniently wide and paved with (smooth) asphalt. It provides an alternative (by bicycle) for motorists commuting between Rotterdam and Delft and using highway A13.

7.3 Organisation and implementation

Fiets Filevrij is one of the 40 projects of the ministerial programme ‘File proof’ (Congestion proof). The project is coordinated by the Fietsersbond (Dutch Cyclists’ Union) and provides a framework for co-operation of road authorities that are relevant in the specific situation (municipalities, provinces, national government if applicable) and interested other organisations to jointly implement the interurban bicycle highway, including a dedicated marketing programme to induce car drivers to shift to cycling for one or more times per week.

7.4 The costs

In principle all road authorities pay the costs of interventions on their own roads. The national government is prepared to pay 20% of the costs of the project.

7.5 Evaluation

In a recent model study Goudappel Coffeng (2011) calculated that investments in fast bicycle routes will have societal benefits with regard to mobility, economy, health and climate. The calculation was done for the 27 planned and implemented bicycle highway projects shown in Figure 7.1, covering 675 km in 8 provinces. These projects will create fast and undisturbed bicycle connections between (sometimes a chain of) towns and villages. The calculations are executed by Goudappel’s National Transport Model and based on the assumption that the average cycling speed increases from 15 km/h to 18 km/h. A summary of the most striking model outcomes suggests that the construction of these bicycle highways would result into:

- 0.7% less trips by car and 1.3% more trips by bicycle in the Netherlands at large.
- Decreased car use resulting in an annual reduction of 80 million kg CO_2 emission.
- Improved public health resulting in yearly savings of € 100 million on health care and avoidance of premature deaths.
- A decrease of travel delay in rush hours of 15,000 h per day, which would result in savings of € 40 million per year.

Bicycle highways are very suitable for the relatively fast electric bicycles (type pedalec) which are becoming increasingly popular. The study calculates that if 50% of the bicycles would be pedalecs, the effects would have been two- to threefold greater, based on the assumption that the average speed of these pedalecs would increase from 20 km/h on regular bicycle tracks to 24 km/h on bicycle highways.

8 Synthesis of Dutch findings and implementation in other countries

The Netherlands have a tradition of high bicycle usage and a long history of policies that promote cycling. Because the intention to promote the bicycle raised the demand for knowledge on the effectiveness of alternative policy measures, a large number of studies in the field of cycling have been undertaken. These created a wealth of knowledge that is partly inaccessible for non-Dutch speaking persons. It is valuable to transfer this experience and knowledge to other countries and to provide recommendations for a good cycling policy.

Recommendations for good cycling policies that are based on the Dutch research are limited in one respect. The bicycle research carried out in the Netherlands was conducted when adequate cycling facilities and networks as well as a bicycle ‘culture’ already existed all over the country. Consequently, studies on the effectiveness of policy measures give information that is valid in this situation and may not be (fully) applicable for countries where the bicycle is hardly used. Other differences between the contexts in other countries and the contexts in The Netherlands may reduce the transferability of the Dutch results.

This section gives an overview of the main conclusions that can be drawn from the Dutch experience and research and which recommendations can be given to other countries.

8.1 Conclusions

General conclusions are:

1. Policies influence bicycle use and can be effective in sustaining high levels of cycling and strengthening cycling culture.

The influence of policy measures is evident from many studies. One of the most influential of these studies is the benchmark study of the Dutch Cyclists’ Union that showed a positive correlation between bicycle use and the quality of cycling facilities in Dutch cities.

The interesting question of what preconditions are necessary for a cycling culture (as far as they are within the sphere of policy) cannot be answered fully by the reviewed studies. Certainly, the ‘technical’ requirements that a) the locations people visit generally are accessible by bicycle and b) there is an infrastructure for selling and repairing bicycles are preconditions. We assume that a proper level of safety is another one. The strong decline of bicycle usage in some countries after the increase in car usage, leaving a marginal role for the bicycle, might be explained by the fact that cycling became too risky due to the increasing car volumes or that at least the perception of the risk discouraged people to continue cycling.

In the Netherlands, generally five main requirements for a good bicycle network are considered: coherence, directness, attractiveness, safety, and comfort. These are directly derived from findings of the extensively evaluated projects in The Hague, Tilburg, and Delft.

Sometimes the bicycle benefits from restrictive policies applied to alternative modes. Most notable are car restraint policies in the centres of many Dutch cities, and a severe parking policy. We know little about their effects on bicycle use for urban trips, but they could in some instances exceed the impacts of bicycle-directed policy.

If there is a cycling culture, policy and culture will influence each other. Infrastructure design is both part of building a 'traffic culture' and the expression of that culture. The cycling culture has obviously many more elements to it than only the infrastructure: bicycle parking facilities, bicycle related services, good transfer facilities to accommodate cycling as a feeder mode to the rail system, showing cyclists on advertisements for very diverse products (showing the normality of cycling), the relative absence of 'dressed up' cyclists in lycra, etc. Yet the 'Dutch school' road design is clearly a substantial part of the Dutch 'cycling-inclusive' traffic culture. The provision of good quality bicycle infrastructure is partly because bicycle use is high, *and* bicycle use is high because there is a good cycling infrastructure.

2. Investments in bicycle infrastructure have generally a larger impact on the qualitative perception than on measurable quantities.

This conclusion is valid for both safety and bicycle use. Generally, the perceived improvement of safety was significant but was not (fully) reflected by the observed decrease in accidents and casualties. Correspondingly, the general appreciation of improved infrastructure is substantial (not in the least because of the improved perceived safety), while the observed increases of bicycle use are moderate.

The main reason why the studies never show a large increase in bicycle use is that the investments brought about improvements of infrastructure that was already adequate. The improvements occur gradually, even in the case of a city-wide project like the Delft bicycle network. Additionally, habitual behaviour may hamper behavioural changes, at least in the short run. It is generally thought that habituated travel behaviour is reconsidered only after a significant change in a person's relevant conditions, and that gradual improvements in bicycling conditions individually might be not reach the "shock" threshold needed to change habitual behaviour.

3. Involvement of citizens and interest groups in an early phase of a project creates civic support and enlarges the probability of successful implementation.

The demonstration projects in Tilburg and The Hague had to be completed in a short time frame due to political reasons and there was limited time for informing and consulting citizens and interest groups. Insufficient citizen involvement was an important reason why the planned bicycle route in The Hague was never completed and even completed parts of the route later were abolished. In the Delft project, a good example of early involvement, the project had a wide support and large a number of measures could be implemented without severe opposition.

4. Travel time is the most important explanatory variable for route choice.

Cyclists are strongly motivated to minimize travel times (for utilitarian trips). Travel time has a significantly larger impact on route choice than does travel distance.

Consequently, cyclists will take a longer route if the travel time is (expected) to be shorted.

5. There is a positive relationship between the continuity and recognisability of bicycle facilities and the appreciation of these facilities by cyclists.

With regard to the demonstration bicycle routes in The Hague and Tilburg, the elements underlining recognisability and route continuity (like the red coloured pavement) were mentioned spontaneously by cyclists as ‘being a very good idea’.

6. Cyclists have a clear preference for undisturbed and convenient cycling conditions.

Also the possibility of safe and undisturbed cycling (by providing segregated facilities) was mentioned spontaneously by many respondents as a big advantage of the routes in The Hague and Tilburg.

7. Two sided one-directional bicycle tracks are on average experienced as more safe than one sided two-directional cycle tracks.

Cyclists on two directional tracks cycling closest to head on car traffic felt significantly less safe than cyclists cycling near the sidewalk. In addition, at intersections car drivers tend to overlook cyclists coming from the ‘wrong’, i.e. unexpected, direction.

8.2 Recommendations

A number of recommendations can be given to other countries.

1. The promotion of bicycle use is only credible and successful if cycling is a practical, relatively fast and convenient mode of transport. We recommend the five main requirements for planning and designing bicycle infrastructure that are generally adopted by the Dutch professionals: coherence, directness, attractiveness, safety, and comfort.

2. Promotion of the bicycle should include improving the perception of the conditions by (potential) cyclists. Improving the perception of conditions results in increased bicycle use beyond the increases associated with improving the actual conditions.

3. Minimizing travel times between origins and destinations is important in designing bicycle infrastructure. First, the detours compared to crow-fly distances should be small, implying a high density of the cycle network. Second, the average speed that cyclists can achieve should be high and delays at traffic lights and other bottlenecks should be minimized, for instance by bicycle-friendly phasing of traffic lights and giving right of way to cyclists at intersections.

4. Urban bicycle routes should preferably be traced through traffic-restrained areas because cyclists prefer cycling conditions involving less traffic stress and interaction.

5. The Dutch studies give information about when segregation of cycling facilities is preferable and when not. There is an ongoing international debate on the usefulness and need of segregated facilities. It is well known that a certain type of (often masculine) assertive cyclist activists, mainly in Anglo Saxon countries, challenge the need of segregation, often with road safety arguments. The lessons from the Dutch studies on this point are:
    - Generally, segregation is preferred if there are large differences between the speeds of the different road users and traffic volumes are fairly high. In particular, segregated bicycle paths are highly desirable for busy main roads, both for safety reasons and undisturbed travelling. The bicycle paths should be comfortable and have sufficient capacity for uncongested cycling. In urban conditions, two sided one directional cycle tracks are generally preferred to one sided two directional tracks. Only when one sided two directional tracks substantially reduce the need to cross busy roads, should this be considered the best solution.
    - In the urban context bicycle and motorized modes can be mixed on condition that traffic volume is not too high and speeds are harmonized (i.e. car speeds are limited to the speed of the bicycles). Bicycle streets and shared space solutions are good examples of mixed facilities that meet the quality requirements for cycling.

6. Good design of intersections is essential. Intersections are the most important cause for delays, and most cycling accidents happen at intersections. Specific design elements such as table crossings are recommended to accommodate safely the right of way for cyclists. The ramps of these crossings should be about 5 m before the edge of the cycle track so as to promote a proper interaction between car drivers and cyclists.

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