Evaluation of the Delft Bicycle Network Plan

Final summary report

Ministry of Transport and Public Works,

Transportation and Traffic Engineering Division.

The Hague, Netherlands

july 1987

FOREWORD

In 1979 Delft Municipality developed a bicycle network scheme for the entire town. The Ministry of Transport and Public Works gave a subsidy for this plan. At this moment the bicycle network plan has been implemented to a large extent. The implementation was monitored by an extensive evaluation study. Specific studies were carried out into two new large-scale facilities, Plantage Bridge and Station Tunnel.
The majority of the evaluation studies refer to the part of the bicycle network within districts 13 and 14 (Delft North-West). The district Wippolder was chosen as the control area. The bicycle route between Tanthof and Delft city centre was selected as a representative major corridor between a residential district and the city centre.

The before-study, carried out in 1983 and 1984, was reported on extensively in individual reports. In addition, a summary report contains the results in a brief and coherent manner. Spring 1987 all after-studies were completed, except the investigation into safety aspects. Again, several extensive reports on these studies were published. This report presents an integral evaluation of the Delft bicycle network plan.

From the evaluation study extensive new insights were gained with respect to the performance of urban bicycle networks. The effects measured in districts 13 and 14 (Delft North-West) give indications about the effect of a complete network. Furthermore, this research showed that the circumstances in Delft are such that the findings of this evaluation may be transferred to other Dutch medium-sized towns (population 50,000 - 200,000). The findings and recommendations therefore provide many useful elements and ideas with respect to the role of the bicycle for a comprehensive transport policy of medium-sized cities.

This integral final report offers a condensed description of the objectives and set up of the evaluation study and summarizes briefly the main results of the various investigations. Conclusions are drawn with respect to the effects of the Delft bicycle network and the significance of the findings to urban transport policy concerning the slow modes.

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SUMMARY

The implementation of the Delft bicycle network plan, consisting of a variety of measures, has been evaluated. This evaluation was carried out as a before-and-after study into the effects of the plan on bicycle use, traffic safety and perceived cycling conditions. Separate investigations were made into general mobility, modal choice, origin and destination pattern, route choice and traffic flows. In addition to cyclists' travel behaviour, other modes of travel, in particular car drivers, were analysed. This integral summary report summarizes the findings of the various investigations and gives consistent estimates of the plan's effects. It integrates the findings using a common theoretical framework that enables an explanation of the behavioural responses.

It was found that the bicycle network plan resulted in a significant increase in bicycle use and in improved cycling conditions. Car use did not increase in the study period.

CONTENTS

1 INTRODUCTION

In Dutch transport policy, as formulated in the 'Structuurschema's Verkeer en Vervoer' and the Multi-Year Programmes for Personal Transport, high priority is given to the encouragement of bicycle use and to the improvement of traffic safety by means of providing facilities for cyclists. It was thought that thus car traffic and its negative impacts could be reduced.

To this end, the second Multi-Year Programme for Personal Transport 1980-1984 included several actions such as constructing urban bicycle networks. The Ministry of Transport and Public Works has several instruments to realize the abovementioned goal. In addition to its subsidy schemes for financing specific projects, giving information is an important task too. In the view of the Ministry it is its task to gather the necessary insights and to develop instruments that may be used by local authorities for their transport planning.

In 1980 the Minister of Traffic and Public Works chose the plan put forward by Delft Municipality as the project for evaluation. The before-study was started in 1982. All the component studies have been carried out and the reports completed.

The study should provide answers to 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 traffic 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 essential assumption of this plan is that a comprehensive bicycle network in an urban environment affects bicycle use and its quality much more than a number of individual bicycle routes.This hypothesis is based on the findings obtained from the earlier 'demonstration projects' in Tilburg, The Hague, Rijswijk and Eindhoven.

The evaluation study consists of a before-study held in 1982 and an after-study that was carried out in 1985, after a large number of measures were taken. At this moment all parts of the evaluation study have been completed, except the investigation into safety effects (See the list of publications in the back of this report).

This summary report briefly discusses the main results and conclusions of the evaluation study. The next chapter outlines the principles of the bicycle network plan. Chapter three offers a unified theoretical framework for the explanation of the observed changes in travel behaviour. Then the set-up of the investigations is presented, followed by condensed summaries of the individual parts of the evaluation.
Chapter six integrates the results of these separate studies into coherent and consistent estimates of the plan's effects. Using the theoretical framework these effects will be explained as results of changes in behaviour. The final chapter eight summarizes the findings and conclusions.

2 THE DELFT BICYCLE NETWORK PLAN

The objective of the Delft bicycle network plan is to encourage the use of the bicycle and to make cycling safer, quicker and more comfortable, especially for those who rely on the bicycle, such as pupils and students. It is hoped that cartraffic is reduced.

Characteristic of this network, of which 75% existed already, is its hierarchy. It consists of three sub-networks, each having its own functional and design characteristics: the city level, the district level and the subdistrict level network (for details see appendix 1).

The city level network consists of a grid of corridors at ca.500m apart, which traverse the entire town and connect to the regional bicycle system. This sub-network with its main purpose to serve heavy traffic volumes links important urban activities in the city: the centre, secondary schools, university, railway stations, work areas, sports centres and recreational areas.

This sub-network serves external and through bicycle trips in addition to internal trips within Delft. Most gaps at this level are caused by physical barriers like canals, railways and main roads. In order to avoid detours and at-grade crossings expensive large-scale improvements have been made (bridges, tunnels etc.).

The district level network has two major functions. It connects various facilities within the district like schools, shops etc. and collects and distributes bicycle traffic to and from the urban network. The links at this level are spaced 200 to 300 m apart. It is assumed that the bicycle traffic flows on this sub-network are less heavy and that bicycle trips will use it only for shorter distances. Unlike at the city level, capacity is less important at the district level compared to well-chosen location and its fine grain. Its main purpose is to provide access.

The necessary facilities at this level are relatively simple and of a varied nature: separated bicycle paths, bicycle lanes, small bridges, improved junction lay-out, etc.

The subdistrict level network provides access to premises and serves bicycle trips within the neighbourhood. In most cases these trips are short and often made by children. The subdistrict level network is a fine-grained system with links at 100 m intervals. The provisions are very simple and consists of little paths and small bridges, woonerfs, short-cuts etc.. Facilities may often be used by pedestrians as well.

The entire bicycle network plan includes a multitude and diversity of measures, not only referring to the infrastructure but also regarding traffic control and traffic regulations. The implementation of the plan started 1982 and will take approx. 10 years. The measures already implemented 1982 - 1985 are listed in appendix 2.

In the study period the following main provisions have been made:
- two large bicycle underpasses (Tanthof)
- three bicycle bridges (Delft North-West)
- new bicycle paths totalling 3.3 km
- exemption of cyclist from one-way traffic on 2.6 km
- new bicycle tracks or segregated bicycle paths along 8.5 km of road
- resurfacing 10km of bicycle path.

As will be shown later, the main effect of these measures is not a distance reduction, except to very short trips, but rather a coherent and functionally designed system offering many new route alternatives.

3 THEORETICAL FRAMEWORK

3.1 Approach

Aggregate changes in travel patterns result from changes at the micro-level of individual travel behaviour on the one hand, and from changes in the size of various classes of travellers, due to external factors like demography, labour market etc.. Aggregate or macro-level indicators of travel are traffic volumes, modal shares, etc., whereas micro-level behaviour refers to modal choice, route choice, etc..
Individual travel behaviour may be affected by measures of the bicycle network plan, as well as by other factors like car ownership decisions. The diagram below illustrates the interrelationship between these elements.

```
        BICYCLE                       other
      NETWORK PLAN                   factors
           |                            |
           v  <- - - - - - - - - - - - -|
                                        v
     micro - level                macro - level
   travel behaviour  =======>    travel pattern

    travel choices    ------>    traffic flows
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Changes in individual travel behaviour to be investigated refer to:
- trip frequency
- modal transfer (to and from the bicycle)
- destination choice
- route choice
- perceived cycling conditions.

It is necessary to determine the alterations in the bicycle system that made people to travel differently and why they did so. Understanding this causal relationship is necessary to formulate adequate traffic policies for the unmotorized transport modes. This insight indicates measures that have to be taken in order to achieve certain modifications in travel behaviour.

In this section only direct short term reactions of individuals are dealt with: choice of a different time of departure, of a different mode, of a different route, etc.. In view of the evaluation study design the outcomes of the investigations only enable these reactions to be determined. It should be realized, however, that these changes constitute only a part of the total behavioural response to the plan. Long-term responses are difficult to estimate at this moment. The importance of the long-term effects should not be underestimated, given the rapid change in the area's population characteristics and its activity pattern (on average every seven year a person changes address, job or school).

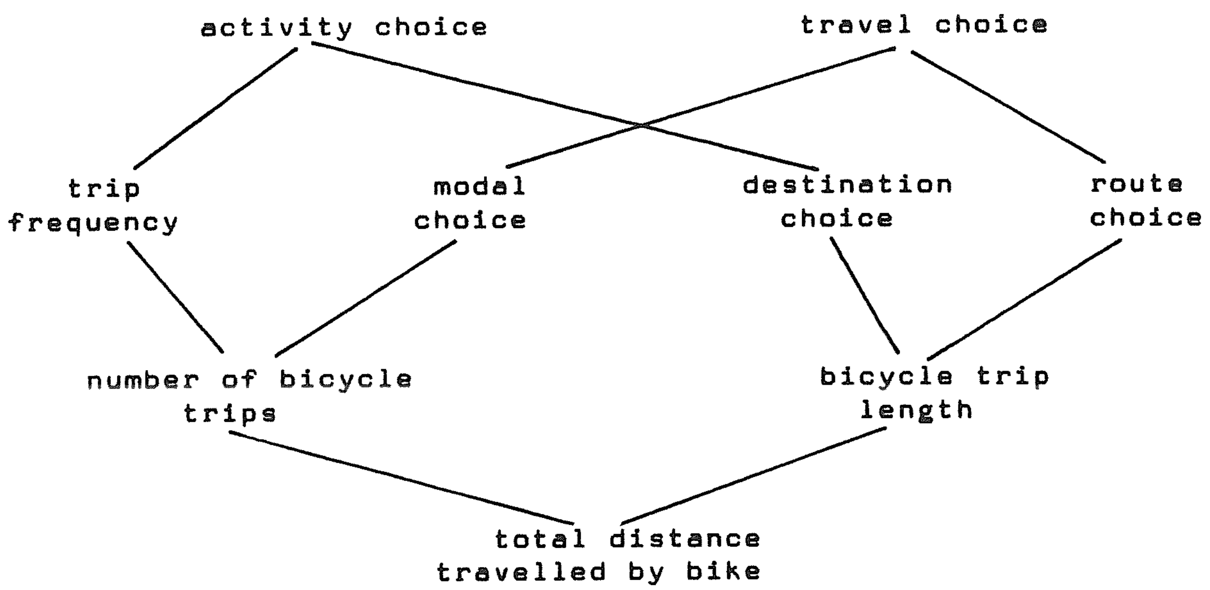
3.2 Choice theory

Activity and travel choices

The travel pattern is a derivative of the individual's activity pattern. This means that if the activity pattern changes, e.g.in terms of frequencies, points of times, duration, sequence and location, the individual's travel choices will necessarily be adapted. The choice of activities may be affected by the bicycle network plan.
A modification of the activity pattern thus results in a different trip frequency, different mode, different distance travelled, etc.. Changes in the activity pattern can be derived from the distribution of trips by trip purpose.

Travel behaviour encompasses all choices related to trip timing and mode used. Four dimensions of individual travel behaviour will be dealt with in view of possible effects of the bicycle network plan:
- choice to make a trip (trip frequency)
- destination choice
- mode choice and
- route choice.

It is assumed that trip frequency and destination choice are indirect decisions which depend upon the activity pattern, whereas mode and route decisions are made directly and enable an immediate response to improvements of the bicycle network. The diagram below illustrates the way these four choice dimensions affect total distance travelled by bicycle.

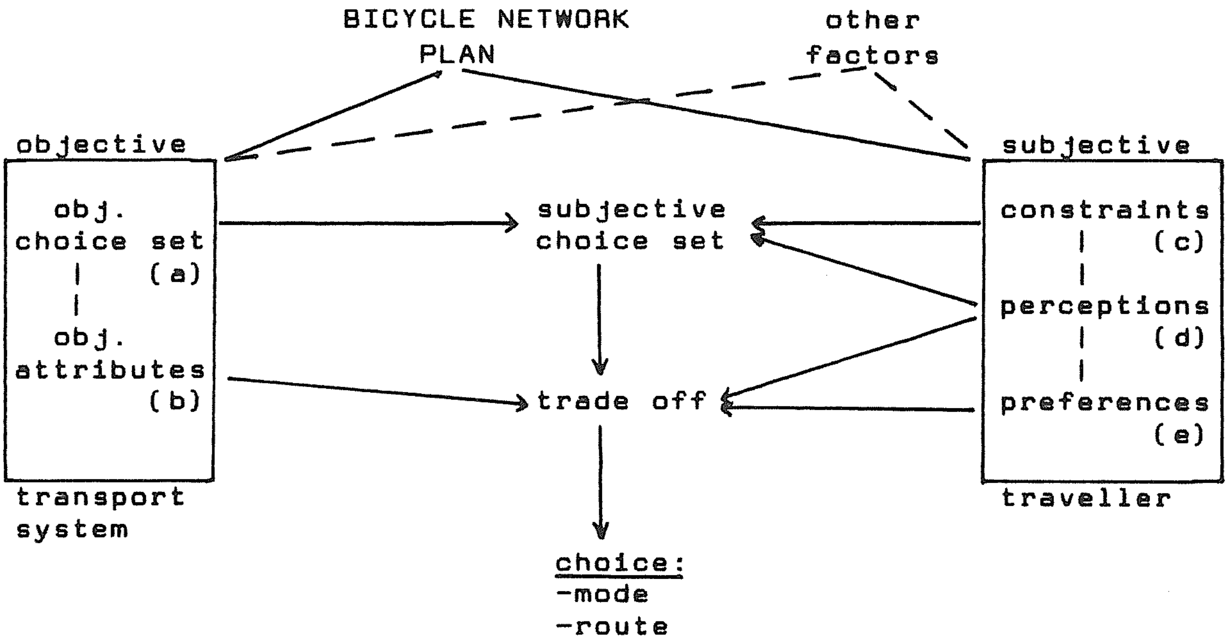


Elements of the choice process

Activities carried out and trips made can be viewed as outcomes of choice processes. Individuals choose more or less rationally from various options available to them, based on their personal taste and preferences.

A traveller has available a number of alternatives (e.g. modes, routes), each having a variety of attributes. It is on the basis on these attributes that the individual traveller evaluates the attractiveness of the alternatives. Examples of such attributes are travel time, comfort, safety. Both these elements define the objective choice situation.
On the other hand personal and subjective characteristics of the traveller play an important role in travel choice processes. Due to his personal circumstances not all existing alternatives are feasible to him for the trip to be made. These constraints are both of a more objective nature (e.g. bicycle ownership, car availability, physical handicaps) and of a subjective type (e.g. personal perception of travel times and distances, lack of knowledge about existing alternatives).
Choice restraints result in a much more limited subjective choice situation, having less alternatives and attributes perceived differently. The traveller will evaluate the advantages and disadvantages of these alternatives. Given his personal preferences and taste with respect to travel time, safety, convenience etc., he will trade off the relevant attributes. It is assumed that he tries to maximize his utility which means that he selects the alternative that is most attractive to him. Utility or attractiveness is a weighted combination of all relevant attributes.

The next scheme illustrates the essential elements of the choice process. The bicycle network plan may in principle affect objective (impersonal) as well as subjective (personal) aspects. The way these choice elements (alternatives, attributes, constraints, perceptions, and preferences) might have been affected by this plan will be discussed later.



Certain effects, in particular those on the perception of alternatives and attributes, grow to their full extent only after a longer period, during which travellers get acquainted with the enhanced bicycle network.

4 SET-UP OF THE EVALUATION STUDY

The objectives of the investigations, initiated by the Central Gouvernement (Ministry of Transport and Public Works), are:

. to determine the effectiveness of the bicycle network scheme with respect to the encouragement of the bicycle use and the improvement of the comfort and safety of bicycle trips;
. to test the underlying traffic-related hypotheses of the scheme;
. to measure the changes in travel behaviour of cyclists and non-cyclists induced by the plan in order to gain an understanding of this behaviour that is generally applicable in planning.

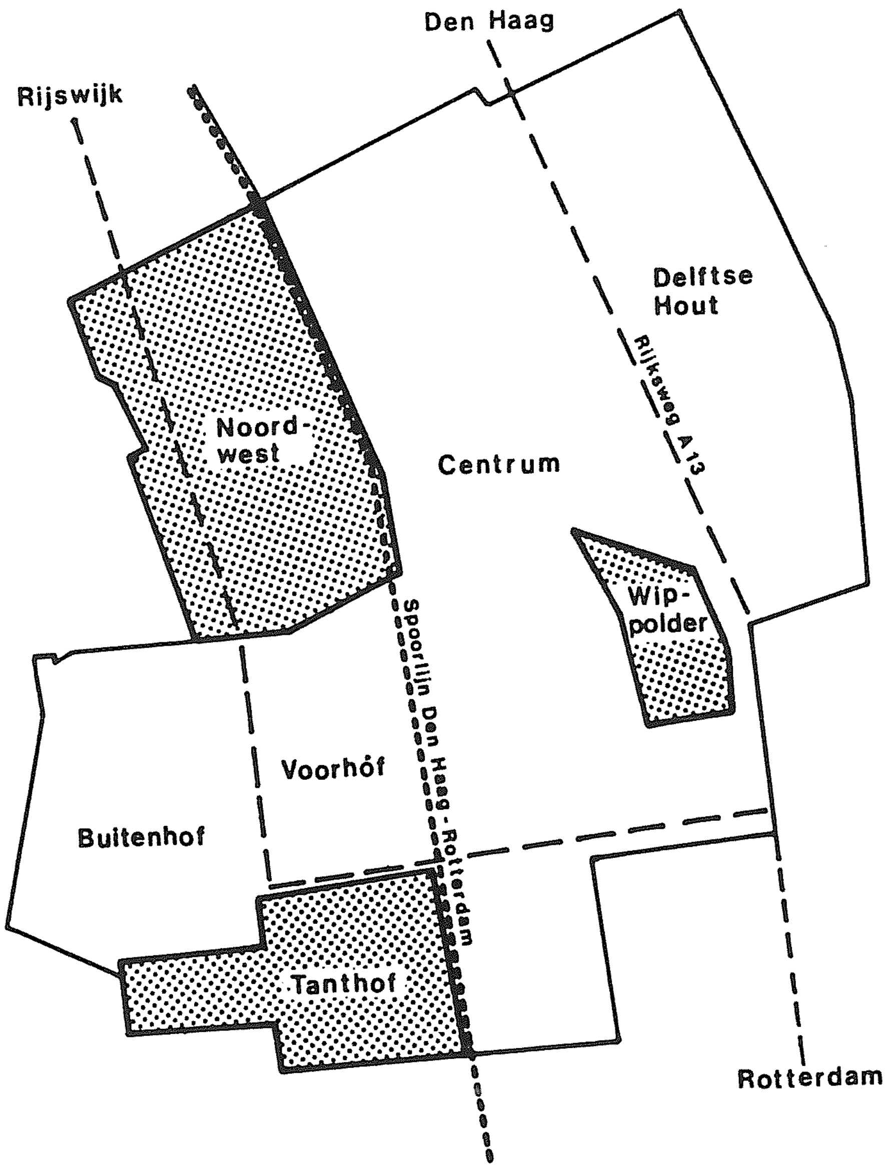
The evaluation study consists of a main study dealing with the entire bicycle network plan and a number of project evaluations. The latter monitor the effects of some large and expensive infrastructural projects that were built. Examples are the Plantage Bridge and the Station Tunnel. This summary report confines itself to the main study.

The evaluation study has been designed as a before-and-after study with a study area and a control area. The before-study was carried out in September and October 1982 prior to the implementation of the plan. The after-study took place in September and October 1985 after a large part of the improvements were carried out.

Districts 13 and 14 (North-West Delft) were selected as the study area, where all planned improvements were made within the study period. District Wippolder is the control area, where no improvements were made. In addition to the study area that was monitored by almost all investigations, some of these also deal with the Tanthof district, since some special facilities were built to improve the connection of this new residential area to the town centre. Figure 1 shows the three subareas (for details see appendix 3).

The next chapter describes the design and results of the various evaluation parts which make up the main study. Subsequently, the findings are integrated into coherent answers to the policy questions mentioned above.

Figure 1: The city of Delft and three sub-areas.



5 RESULTS AND CONCLUSIONS OF THE STUDY PARTS

5.1 Overview of the individual studies

The entire evaluation study into the plan's effects consists of a number of study parts which were carried out more-or-less independently:

a. Analysis of changes in mobility of Delft inhabitants with emphasis on mode-choice and the mode-choice situation. This investigation is based on home interviews and in-depth interviews. It was carried out by the Institute of Applied Sociology (ITS) at Nijmegen University.

b. Analysis of changes in the origin-destination pattern of bicycle trips. This investigation was based on mail back roadside surveys among cyclists. It was carried out by the Traffic and Transport Group of TNO (VVG-TNO) in Delft.

c. Analysis of changes in cyclists' route choice and network use. This analysis is based on observations of routes followed by cyclists in the Delft network. This investigation has been done by the Research Insititute of Urban Planning and Architecture at Delft University of Technology (OSPA-TU Delft).

d. Analysis of changes in car and bicycle traffic volumes. This investigation compares counts held during the before and the after study. It was performend by the Stichting voor Mobiliteits- en Transportresearch in Delft (SMT).

e. Analysis of changes in traffic safety. This analysis uses traffic accident data of the period 1980-1988 as recorded in a centralized manner by Dutch Government. The investigation is being carried out by OSPA- TU Delft and will be completed in 1988.

f. Analysis of the effects of the newly built Plantage Bridge. Two seperate evaluations of this project have been made. The first one, carried out by ITS, deals with the effects on the travel pattern of inhabitants of an adjacent residential district. The second investigation, by OSPA-TU Delft, determines the effects on bicycle traffic crossing the canal.

g. Analysis of the effects of the Station Tunnel on bicycle traffic and train use. This investigation by OSPA-TU Delft will be completed in 1988.

h. Comparison of the Delft travel pattern with that of other Dutch medium-sized towns. The objective of this study is to determine whether the findings of the evaluation study are transferable to other towns. It is carried out by OSPA-TU Delft, using existing data (National Mobility Survey, Survey on Labour Force).

To a certain extent these investigations are linked through the common use of observations and data. All investigations, except h., were before-and-after studies.

In this report only the investigations mentioned at a. through d. are dealt with.

Table 1: Overview of investigations

CONTRACTOR	PRIMARY OBJECTIVE	OBSERVATIONS	PUBLICATIONS Before study	Final report
a. ITS/Nijmegen	general mobility;	home interviews	[1]	
	mode choice;		[9]	[12]
	choice constraints; perceptions	in-depth interviews	[3]	
b. VVG/TNO	bicycle trip pattern	road side surveys	[8]	[13]
c. OSPA/TU Delft	route choice and network use of cyclists	route surveys	[2]	[10] [11]
d. SMT/Delft	traffic volumes	counts	--	[14]
f. ITS/Nijmegen	Plantage Bridge travel pattern	in-depth interviews	[7]	[16]
f. OSPA/TU Delft	Plantage Bridge crossing bicycle trips	road side surveys	[6]	[15]
g. OSPA/TU Delft	Station Tunnel bicycle use	platform surveys	[5]	to appear
h. OSPA/TU Delft	transferrability	statistics	--	[17]
e. OSPA/TU Delft	traffic safety	accident data	--	to appear

5.2 Travel behaviour and choice constraints

5.2.1 Objectives and set-up of the study

This study part evaluates the Delft bicycle network plan from the perspective of actual and potential use of the bicycle. By investigating actual bicycle use the achieved increase in cycling will be determined in a quantitative sense, also in relation to other modes of transport. Encouragement of bicycle use is also assessed from a more qualitative point of view, e.g. removing choice constraints, improving the conditions for cycling as perceived by people.

In keeping with the distinction made above, the study has been divided into two parts:
- a descriptive study of the population's work-day travel behaviour; emphasis is on the proportion of trips made by bicycle, before and after implementation of the bicycle network;
- a subsequent in-depth study, offering an explanation for the level of bicycle use found, and furthermore providing insight into changes which occured in the perception of conditions for cycling.

Data for the descriptive study were collected by means of a postal home interview survey. The more qualitative information was gathered by in-depth interviews.
Both approaches were used both before (1982/1983) and after (1985/1986) the actual implementation of the infrastructural measures. The study investigates the population of Delft. The survey was limited to two study areas and one control area. The main study area was North-West, where a large mumber of measures varying in scale and type were made at numerous locations. The minor study area was Tanthof, a new peripheral residential district which was linked to the city centre by major new bicycle links.
The Wippolder district is a control area where no measures were implemented during the study period.

The in-depth interviews and related analyses were done according to the situational approach model, developed by the German research institute Sozialforschung Broeg. This method especially provides good insight into existing choice constraints. Gaining experience with this approach was one of the objectives of this study.

5.2.2 Results

<u>Mobility in general</u>
The residents of Delft showed a stable level of mobility between 1982 and 1985. The number of mobile people remained the same (88 per cent of the total), as did the number of trips made by the mobile group. This stability can be explained in view of the already high level of mobility in Delft; data from the National Mobility Survey shows that it is higher than in other comparable medium-sized towns in the Netherlands [17].

Modal split

The modal split has changed between the two moments of measurement. The change in the control area is different from that in both 'experimental' districts.
In the control area an increase in car mobility was found. In terms of absolute numbers of car trips per person per day, as well as in terms of the proportion of trips made by car, car mobility increased by more than 10 per cent. The increase refers to both driver and passenger trips. This coincided with a reduction of public transport mobility. This reduction is an expression of the falling trend in public transport mobility since 1979, observed in all medium-sized Dutch towns [17].
The modal choice of the residents of Tanthof changed in a completely different sense. Although they also made less use of public transport, though to a limited degree, no increase was found in car mobility. On the contrary, car mobility clearly dropped and was compensated by an increase in bicycle mobility. The proportion of bicycles in the total number of trips grew from 38 per cent to 39 per cent.
In North-West a similar shift was observed, but somewhat less pronounced with respect to cycling. There the proportion of bicycle trips grew from 40 per cent to 43 per cent. In contrast to the control area, car use did not increase.

The increase found in bicycle mobility cannot be ascribed to a growth of travel mobility: there was no change in total mobility between 1982 and 1985. The increase observed is consistent with comparisons based on volume counts: in the study area and even more so in Tanthof bicycle volumes increased [14].

Sources of increased bicycle use

The growth of the bicycle share does not originate from one other mode of transport in particular, but from former trips on foot as well as former car-trips and, though to a lesser extent, former public-transport-trips. The contribution of former trips-on foot and former motorized privat-trips is more or less equal. In general, a rather limited degree of mode change was found, insofar as a person's activity pattern remained the same. For both bicycle and car trips, a stability level of approximately 95 per cent.
was found.

The increase of bicycle mobility cannot be ascribed to a larger number of people using the bicycle, but is the result of a larger number of bicycle trips per cyclist per day. This finding is consistent with the finding from the before-study, based on the situational approach, that many non-cyclists are captive users of other modes (car, public transport) and do not have freedom of choice [3].
Bicycle use by men increased more than that by women. This finding is also consistent with that of the other studies in Delft. Moreover, the increase in the test areas is concentrated especially in work and school trips.

The average bicycle trip length has increased, in contrast to the average trip duration. This means that cycling has become faster compared to 1982. To illustrate: in 1985 bicycle trips by Tanthof residents were approx. 6 per cent longer, while the average duration of a trip even decreased. In general, this suggests a positive effect of the improved continuity of the bicycle network, which extends its influence throughout Delft.

Choice constraints partly removed

Various constraints may limit the use of the bicycle. Compared to 1982, some constraints appear to occur less often. Particularly, the amount of time needed for travelling by bicycle is raised as an objection less often; this reduction may have to do with the improved accessibility. In figures, in 1982 for 27 per cent of trips by car and public transport, too much time was argued to be an objection to using the bicycle; in 1985 this objection was reported for 18 per cent of the non-bicycle-trips. General considerations of safety and comfort also form less frequently a restriction: previously for 17 per cent, now 8 per cent of the non-bicycle-trips. Specific road and traffic situations do not prevent people from cycling, neither in 1985 nor in 1982. This in itself indicates that improving only individual junctions and links hardly encourages the use of the bicycle. In other words: isolated infrastructural measures clearly offer less prospects for increased bicycle use than systematic, mutually interdependent measures, as were implemented within the framework of the Delft bicycle network plan.

The measures taken near Tanthof proved to be effective, as indicated by the growth in cycling observed for Tanthof residents; the increase here is larger than in the district North-West. The new bicycle tunnels and routes not only improved comfort and safety, the improved connection with the town centre also implies a shorter route and a reduction in travel time. The importance of these improvements in the corridor involved has been clearly demonstrated by the reported perceptions of Tanthof residents.

The perception of cycling

The bicycle climate has evidently improved in Delft. The conditions for cycling are now perceived clearly more positively in comparison with three years ago. In Tanthof this improvement was found to apply to slightly more than half of the respondents, with respect to comfort, continuity and safety. It applies to less people in North-West, and involved more frequently comfort and continuity (less detours, shorter waiting times) than safety.

On balance, a small minority of less than 10 per cent still perceives the bicycle system in Delft as negative in terms of comfort and continuity. The conditions for driving a car are experienced as being notably worse.

A wide range of effects can be ascribed to the bicycle plan: positive effects are noticable for a considerable part of bicycle trips being made now. This is the case for over a quarter of

these trips made by residents of the district North-West and furthermore for approx. 45 per cent of the bicycle trips by Tanthof residents.
The positive effect of the bicycle plan can also be derived from the notable reduction of the number of bicycle trips which experience problems en route. The proportion of 'problem trips' fell from one half to one third. All this is the combined result of removed bottlenecks as well as route shifts which have become possible.

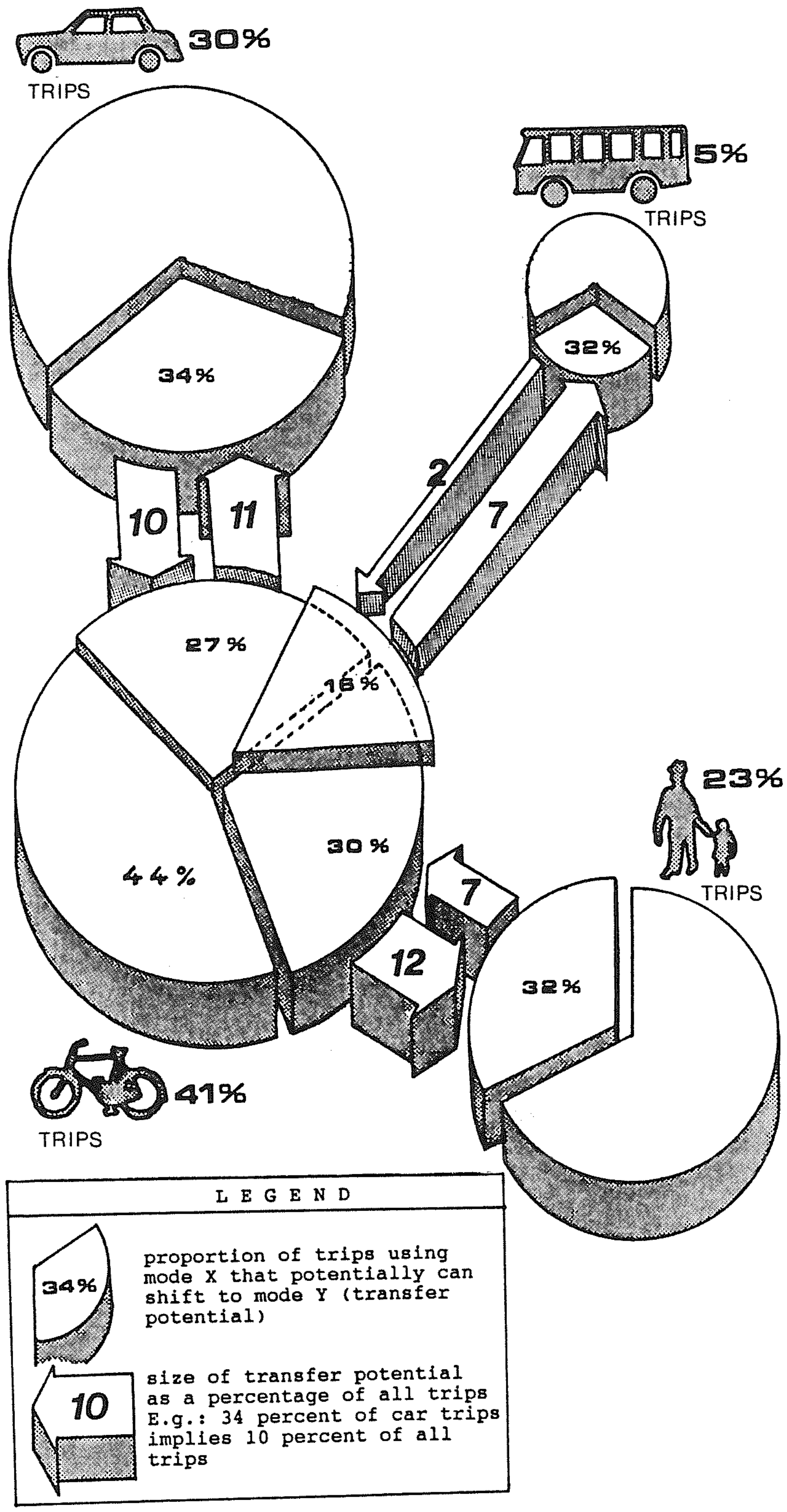
Transfer potentials

Besides the use of transport modes actually found, an assessment was made of the extent to which the market position of the bicycle, relative to the other modes, had improved. The position of the bicycle was not very strong in 1982; the potential losses were bigger than the potential increase.
The study has determined changes in transfer potentials between different modes of transport. A transfer potential to a certain mode is assumed to exist if there are no constraints that prevent that mode from being chosen. After the measures were implemented, the potential use of the bicycle grew considerably. This increase is largest for people who travel by car or on foot; the increase is much smaller for travellers using public transport. Tanthof residents show the largest increase. Although causality cannot be demonstrated, the conclusion is that the measures for encourageing cycling to a certain degree have increased the cycling potential by removing constraints. Besides the measures taken, other factors related to objective constraints have also extended this potential.

Besides the increased number of trips by car, public transport or on foot that could be made by bicycle without any difficulty, there is also a reversed transfer potential from the bicycle to the car, to public transport or to walking. The potential which could shift from the bicycle to the other modes has also grown since 1982 , but less than the possible inflowing potential. In other words: the possible gain of the bicycle has grown more than the potential loss.

In absolute numbers of trips the mutual tranfer potentials between the bicycle and the car are balanced. This is not the case between the bicycle and walking, since cycling may loose more than gain (see figure 2).

Figure 2: Choice potentials regarding the bike, and of cyclists regarding other modes (after situation)



This clearly shows the competitiveness of the bicycle compared to the other modes of transport. It is interesting to conclude that its competitiveness has improved since 1982, especially because of the improved position relative to the car. Nevertheless the bicycle still remains somewhat at a disadvantage.

Assessment of the results

The foregoing indicates that quantitative as well as qualitative improvements were made to the bicycle mode between 1982 and 1985. In view of the transfers found in the use of modes of transport, it is likely that the implementation of the bicycle network has prevented a further growth of car use and has strengthened the position of the bicycle.

The question is how to assess this result. It could be argued that the observed growth of bicycle use is only marginal. In evaluating these figures, the following should be taken into account:

- The increase in bicycle use occurred in a situation in which the chances of a reduction were greater than the chances of growth [3]. In view of the existing choice restrictions, in 1982 more trips by bicycle could have been made by any other mode without any difficulty than the number of non-bicycle trips which could have been made by bicycle without problems.
- The bicycle is not a feasible transport mode for a large number of trips in view of existing constraints, either of a more objective nature, or of a more subjective one. The situational analysis has shown that only a limited proportion of people have real freedom of choice.
- Generating new bicycle traffic is certainly not the only aim of bicycle stimulating measures. Another objective is to improve the conditions for cycling in terms of comfort, safety etc; furthermore it should be realized that such a policy is necessary in order to prevent a reduction of bicycle use in the long run.
- In 1982, the proportion of trips made by bicycle was already quite high in Delft (approx. 40 per cent), although in some Dutch towns it is even higher. Therefore,a higher proportion is difficult to obtain. In this respect it is relevant to note that an increase in car use -as was the case in the control area- did not occur in North-West and that car use even was reduced in Tanthof.
- The increase in bicycle use can not be completely ascribed to the bicycle network. For years now, bicycle use is growing in most medium sized Dutch town's [17].

The effect of the bicycle plan can be traced even more clearly in a qualitative sense than in a quantitative one. The nature of the qualitative changes found are directly linked to the implemented measures:

- to the extent that the bicycle is not used (yet), certain types of constraints (trip time needed and considerations of comfort) apply less frequently than before; this partly results in more freedom of choice;

- a considerable improvement in the conditions for cycling was reported; first, less concrete problems during a cycling trip were reported. Second, people who experience cycling as being positive have increased in number.

Another qualitative result is a better balance between the car and the bicycle with respect to mutual transfer potentials.

The results obtained lead to the conclusion that the bicycle network has had a positive influence on actual bicycle use as well as on the modal choice situation. Especially the last, more qualitative result is important in the long run.

5.2.3 Conclusions of this study

From this study the following conclusions can be drawn:

a. The Delft bicycle plan has succeeded in realizing an increase, though be it limited, in bicycle use of the inhabitants of Delft. Even more important is the fact that the measures for stimulating bicycle use prevented a growth of car use. In Tanthof the measures even coincided with a reduction in car travel.

b. The bicycle plan also has merits in a qualitative sense in the form of clearly improved perceived conditions for cycling with respect to safety, comfort and continuity. This improves the stability of the bicycle system in the long term.

c. Moreover, a qualitative result was obtained by establishing a balance between the position of the bicycle and other modes of transport, although at the moment the chances of a reduction in the use of bicycle are still slightly larger than the chances of an increase. In particular, the position of the bicycle compared to that of the car has become stronger.

d. The design philosophy of the bicycle network proves to provide solutions to the problems perceived in reality by cyclists and to their preferences. Since bicycle trips have a widely distributed pattern in a spatial sense and since the problems encountered en route (detours, unsafe and uncomfortable locations) are scattered, a policy accounting for these characteristics has favourable prospects.

e. Measures aimed at improving continuity in a corridor have a positive effect if heavy flows are involved; an example is the relationship between Tanthof and the town centre of Delft.

f. The situational approach proved to be a valuable method to investigate the bicycle potential and mutual transfer likelihood of modes. The method takes objectve and subjective choice constraints into account which results in a realistic estimate of the existing freedom of choice and probability of behavioral changes. Through this, the method possesses predictive value.

5.3 **Origin-destination pattern of bicycle trips**

5.3.1 Goal and set-up of the investigation

The aim of this investigation part was to answer the following questions:
- What changes occured in the origin-destination pattern and in the bicycle flows?
- Do these changes differ for certain categories of cyclists?
- To what extent do the changes result from the measures taken as part of the bicycle network plan?

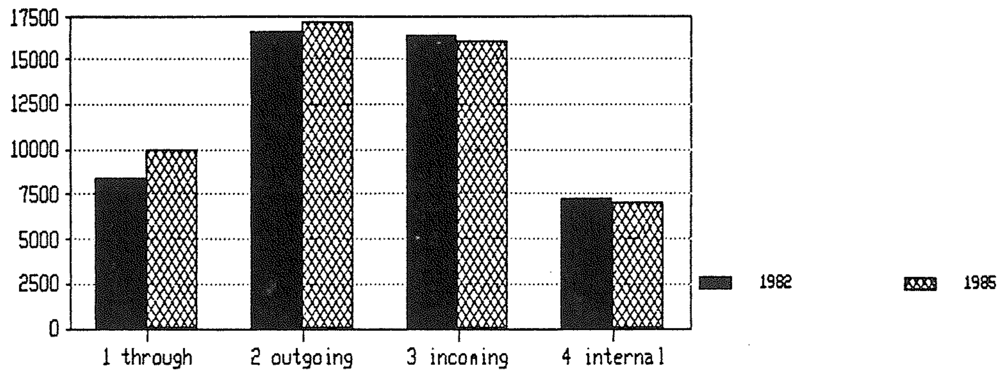
Changes in the origin-destination pattern were studied by comparing the situation before and after. For this purpose information was gathered, both in September 1982, just before the implementation of the measures started, and in September 1985 after most of the measures had been implemented.
The investigation focused on work-day bicycle trips which make use of the (bicycle) infrastructure of North-West Delft (the study area). This therefore involved trips of the area's inhabitants, as was the case in the home interview survey, but also trips of inhabitants from other parts of Delft or other municipalities. For the purpose of analysing the origin-destination pattern, the results of the investigation were mainly drawn from the following sources:
- verbal and mail-back self-completed roadside interviews among cyclists who left the study area;
- complete count of cyclists who passed the cordon line around the study area (continous counts);
- partial count of cyclists at a large number of locations inside the study area (short-duration counts).

In the origin-destination study changes in bicycle use were expressed in numbers of trips or bicycle flows.

5.3.2 Results

<u>Changes in the origin-destination pattern</u>.
During the period investigated the number of bicycle trips in and through the study area (approx. 50,000 per day) clearly increased by approx. 1800 trips, or nearly 4 per cent. The increase mainly concerns trips with origin and destination outside the study area. These through cyclists have a share of over 17 per cent in the total bicycle travel in the study area. The number of through trips increased by 1700 (20 per cent) compared with 1982. The total number of other trips has barely altered (internal, incoming and outgoing cycle traffic). There are small differences in the situation before and after as regards the type of trip (fig. 3).
The increase in through trips can be seen on virtually all interchanges. The increase is the largest between the areas:
- South-West Delft - Delft Centre (in both directions)
- South-West Delft - municipalities outside Delft (in both directions).

Figure 3: Number of trips in and through the study area in 1982 and 1985



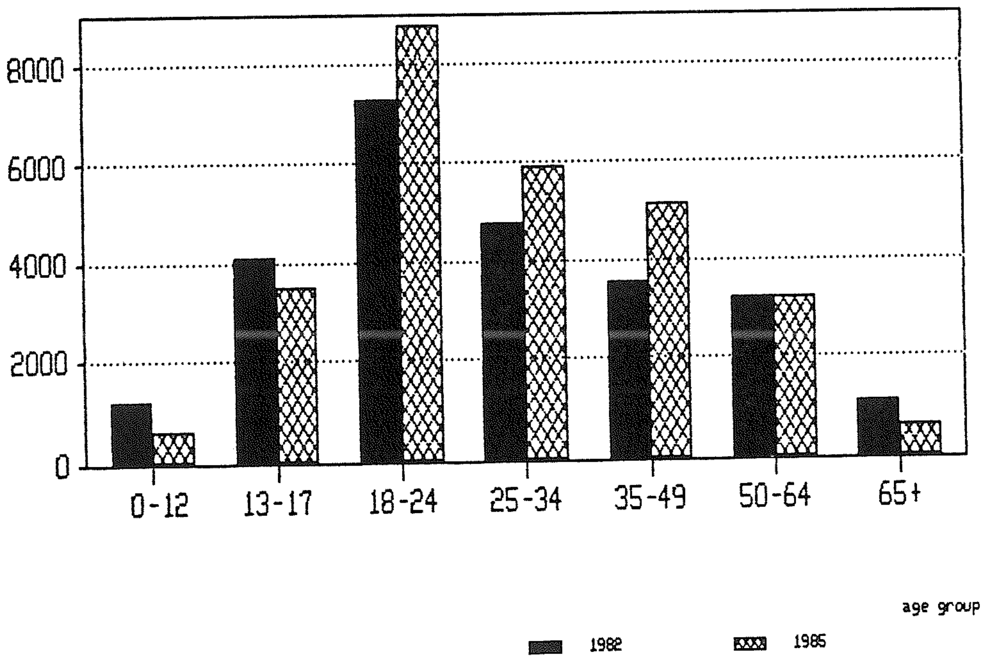
Changes by cyclist category

With respect to bicycle travel leaving the study area, changes for various categories can be derived.

Age and sex

The increase in the number of trips occurred in the age categories between 18 and 50 years (26 per cent). It was largest in the 35 to 50 age group (40 per cent). Even after correcting for the population trend per age category, the increase in the 35 to 50 age group was the largest (34 per cent). The increase in the 18 to 35 age group, too, was still over 22 per cent after correction. The increase is higher amongst men than amongst women.

Figure 4: Number of trips by age category (before and after)



Purpose and time

The growth in bicycle travel partly concerns trips which are made according to a fixed daily pattern at more or less fixed times (purpose work, about 26 per cent of all trips) and partly concerns trips which are made less regularly and are less time related (purpose shopping, about 16 per cent of all trips). The increase in shopping travel (28 per cent) is higher than in work travel (9 per cent). The increase in the number of trips is therefore fairly evenly distributed over the day.

Residence

More bicycle trips (through the study area) are mainly made by inhabitants of the districts in South-West Delft and inhabitants of municipalities outside Delft. The total number of trips by inhabitants of the study area barely altered. However, if this figure is corrected for the downward trend in the population of the study area, there is a small increase. This closely matches the results of the home interview survey. Even after correcting for the population trend in South-West Delft and the municipalities outside Delft, the increase for these areas remains considerable (13 - 19 per cent).

Bicycle flow pattern

The flows at the cordon line of cyclists leaving or entering the study area (about 54,000) rose by about 7 per cent. The increase in bicycle traffic can be found at all parts of the cordon line around the study area. However, the increase is largest at the cordon section between the study area and the municipal boundary between Delft and Rijswijk (northern side) and Delft and Den Hoorn (western side).
Within the study area the increase in bicycle flows is highest in the southern part of the study area.
As regards the cordon line around the study area, the through traffic mainly increased at locations which were already busy in the before situation. Cyclists departing within the study area are the main beneficiaries of the new connections (bicycle crossing at Molen de Roos, Locomotiefpad and the Buitenwatersloot-Westlandseweg bicycle bridge). These connections, therefore, are particularly important for trips beginning or ending in the vicinity of these facilities.

Effect of the bicycle network plan

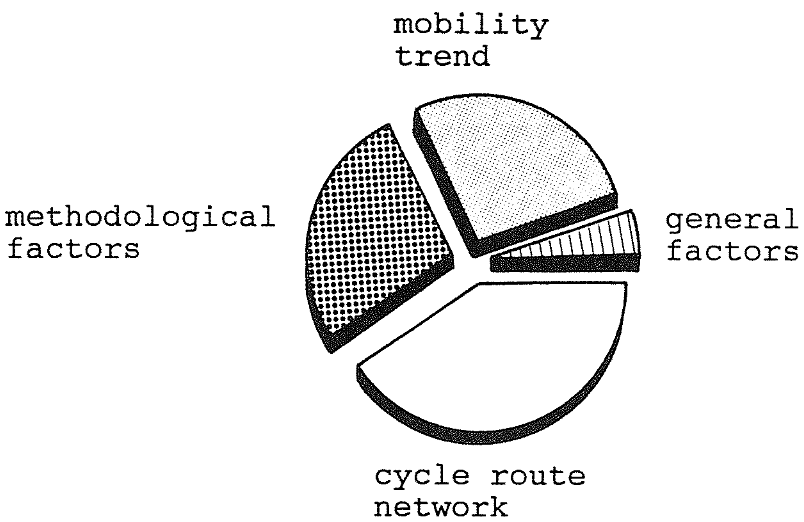
In addition to a possible effect of the bicycle plan, the differences between the before and after investigations may also be caused by several other factors. The main general factors include:
- the population trend;
- the general mobility trend;
- the weather conditions;
- methodological factors.

Several factors related to the specific situation in Delft (and the surrounding area) may also be important in explaining the differences:

- the number of jobs and the size of the working population;
- the number of secondary school pupils and students at the University of Technology; the relocation of a secondary school to a location within the study area plays a major role here;
- the extent and nature of shopping facilities and sports centres;
- the number of travellers arriving at and departing from Delft Railway Station.

Using a predictive model, an estimation was made of the effects of the above factors on the cycle trips leaving the study area. It was found that 40 per cent of the increase in the number of trips may be due to the measures of the bicycle plan. Considering the calculation method used, this estimate of the effect can be regarded as a lower limit for the effect of the bicycle network. In other words, a minimum of 40 per cent of the differences found can be attributed to the enhancements of the bicycle network (figure 5).

Figure 5: The effects of the main background factors



The measures mainly aimed at offering a comprehensive network structure and at increasing the possibilities of travelling through the study area. This is thought to explain the sharp increase in the through traffic. Part of this increase is probably due to trips which in the before situation made no use of the bicycle infrastructure inside the study area. This emerges amongst other things from the fall in the volume of traffic on stretches of road just outside the study area (Westvest,Zuidwal), which was noted in the investigation on route choice behaviour and network use [10].
The small changes in the number of trips originating inside the study area and ending outside it are mainly due to the relocation of a secondary school and the increase in the number of students at the Technical University. The starting and end time of lessons at the relocated secondary school also affects the spread of the increase in traffic over the day.

5.3.3 Conclusions of this study

The main conclusions are as follows:
- bicycle travel in North- West Delft has increased as a result of the measures taken as part of the bicycle network;
- these measures, which were mainly aimed at offering a comprehensive network structure and improving the possibilities of crossing through North-West Delft, have led, as expected, to inhabitants from mainly outside the area making more use of the bicycle infrastructure in North-West Delft.
- the age categories between 18 and 50 are the main beneficiaries of the measures. As far as the purpose for the journey is concerned, the increase was highest among shopping traffic.

5.4 **Route choice and network use**

5.4.1 Objectives and method

This part of the evaluation study, carried out by the Research Institute for Urban Planning and Architecture (OSPA) of the Delft University of Technology deals with changes in cyclists route choice and network use between the before and after situation.

The aim of this partial evaluation is:
- to determine whether the measures taken have had the intended effect on cyclists' route choice;
- to test the appropriateness of the bicycle network's design principles, e.g. hierarchy, spacings;
- to gain a better understanding of cyclists' route choice behaviour.

This study part analyses the route characteristics of the bicycle trips crossing the cordon around the study area in the outward direction, irrespective of the traveller's place of residence: trips made by inhabitants of Delft (all districts) and those made by others are included.
Among these cyclists roadside-mailback surveys were held with respect to trip and route information. The analysis deals with the information on the routes followed obtained from both surveys, whereas the other trip data were used by VVG-TNO to determine changes in origin-destination patterns.
The observed routes help in detecting changes in route choice, trip length and network use with respect to road types between the before and after situation.

5.4.2 Findings

<u>Network changes</u>
In the study period (1982-1985) a large number of measures have been taken in the study area: new bridges, bicycle paths or lanes and short-cuts were built. Furthermore, many one-way streets were opened to bicycle traffic in both directions. A number of existing bicycle paths and lanes were resurfaced.
In total the bicycle network length increased by 3.3 km (+1.4 per cent). It is not so much the additional system length that matters, but rather the degree to which these additions transform the existing network into a comprehensive and interconnected system. Given the high density of the existing network, it is not surprising that on average in Delft a decrease of bicycle distances of only -1 per cent results from the additions. Only for very short bicycle trips of less than 1 km length a larger decrease of -3 per cent is found.

It should be emphasised that in a more qualitative way the bicycle network has been improved substantially by building separate bicycle paths and bicycle lanes on existing connections. Also replacing brick and tile paving with asphalt added much to improvement of the comfort.

Changes in the trip pattern
The number of bicycle trips leaving the cordon around the study area increased sharply from 25,000 to 28,000 (+10 per cent). Partly, this increase can be explained by changes in the demographic composition of the Delft population. After correcting for this factor an increase of about +8 per cent remains. More than 90 per cent of this increase stems from the growth of the number of through trips. About 65 per cent of the growth is accounted for by inhabitants of Delft living outside the study area. Inhabitants of the study area on the other hand make less bicycle trips.

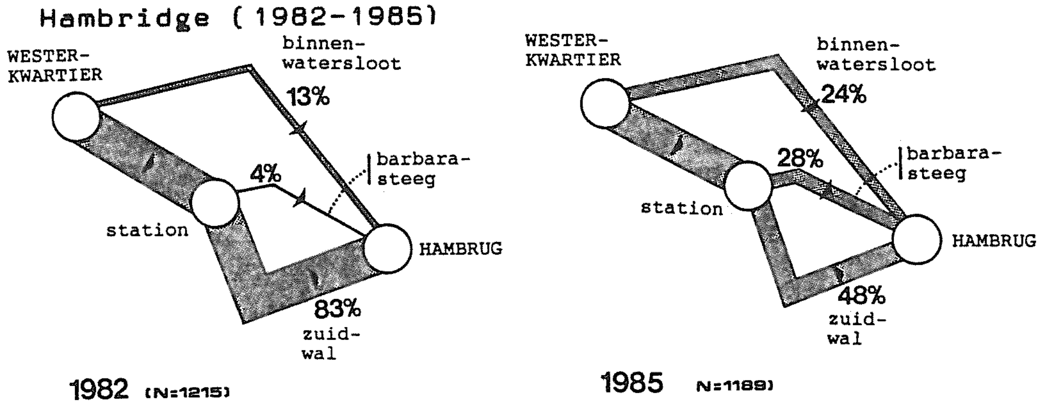
In the after-situation clearly less short trips and more long bicycle trips were made. As a result the average trip length increased by 6.5 per cent from 3.7 to 3.9 km. This implies a clear improvement of the cyclist's mobility.

The larger number of trips and the larger average trip length resulted in a sharply increased total distance travelled, which went up by 17 per cent (if corrected for demographic changes the increase is +15 per cent). The growth of total distance travelled can be seen with all trip purposes, especially with shopping trips.

From this study, as well as from the other investigations, it can be concluded that demographic changes as well as general national mobility developments only explain a part of the observed increase of bicycle travel. We therefore conclude that the measures taken as part of the bicycle network clearly stimulated the use of the bicycle in Delft.

Changes in route choice
Cyclists' route choice appears to be very sensitive to distance and travel time. More than 20 per cent uses a route with a travel time equal to the shortest possible time. Half of the cyclists succeeds in finding a path that is, on average, only half-a-minute longer than the shortest time. Apart from travel time and distance, also surface quality matters as a route choice factor, whereas facility type appears to be less important.
The route pattern of the cyclists in the after-situation differs significantly from that in the before-situation. This change resulted directly from the measures of the bicycle network plan carried out. In particular, newly built bicycle facilities attract much bicycle traffic, that is diverted from existing routes. In this way, heavily loaded links and intersections have been relieved according to the planners' intentions. Examples are: Westvest, Zuidwal.

Figure 6: Distribution of bicycle trips among main route alternatives between Westerkwartier, Railway Station, and Hambridge (1982-1985)



As an example figure 6 shows the Barbararoad. After opening of this footpath to cyclists in both directions, this lane attracts 28 per cent of all travel between the Westerkwartier-area and the University campus, thereby largely relieving the overloaded Westvest-Zuidwal-street (decrease in flowshare from 83 to 48 per cent)

Exempting cyclists from one-way traffic only led to local changes in routes followed. Dependent upon the exact location of these measures, they stimulated the use of new connections.

It was found that the main cause of the changes in route choice is not so much the reduction of travel distance or time due to new or improved bicycle facilities. New facilities are used because they constitute a new and additional route alternative, which is not necessarily shorter than the existing facilities. Moreover, other characteristics like comfort, surface quality, protection from the wind, visual quality, safety etc. determine the choice among equally long routes.

Changes in network use

The Delft bicycle network provides facilities at three functional levels: urban, district and connections. This functional hierarchy proved to be a successful concept. The network is used as designed: facilities at different levels appear to be used differently in terms of number and type of bicycle trips.
Almost 60 per cent of the total distance travelled by cyclists is performed on urban level facilities which comprise less than one-third of the network length (see table 2). Measures taken as part of the network plan have increased this concentration. The largest increase of average flow was observed at this urban level. This is not surprising given the fact that most network improvements were at this level. The objective of the plan to enhance the traffic function of the high-order links and the access function of the low-order ones has been achieved.

This study showed that cyclists travel less on streets where they mix with car traffic. Nevertheless, still 40 per cent of the total distance travelled takes place on these roads after implementation of the plan in the study area.

The newly built separate bicycle paths attract a disproportionately larger amount of traffic, resulting in 35 per cent share of total distance travelled. As a consequence bicycle traffic volumes on streets with mixed traffic and on bicycle lanes went down. These shifts suggest a positive effect on subjective and objective safety of cyclists.

Table 2: Changes in cyclists' network use

functional class	road length [km]	growth 82-85 [%]	distance travelled [km]	growth 82-85 [%]	kilometrage/ km road index	growth 82-85 index
subdistrict level	73.8	-.7%	3794	24%	26	+ 6
district level	84.7	1.9%	24261	15%	143	+18
city level	74.7	2.9%	35245	18%	236	+35
total network	233.2	1.4%	63300	17%	136	+21
facility type						
mixed traffic .	159.6	-5.3%	28372	4%	89	+ 9
bicycle lane	18.6	17.7%	16165	17%	441	- 5
separate path	27.5	10.9%	13706	34%	249	+55
independent path	23.5	23.8%	4790	48%	99	+23

5.4.3 Conclusions of this study part

This study on route choice and network use shows that, despite the high quality of the existing bicycle system, it was possible to improve the structure and connectivity of the network by means of various projects of varying scale. In Delft, small-scale improvements proved to induce significant changes in route choice, thereby relieving busy and dangerous situations.

It is recommended to design bicycle networks according to the principle of a functional hierarchy. By expressing the functional level into the design of the facilities the cyclist will perceive and recognize the network structure as a clear and logical system. Better cognition and perception of this structure will enable the cyclist to estimate distances and travel times more correctly, which will stimulate bicycle use. It was found that cyclists increased their trip length, which may be considered as an improvement of mobility.

New bicycle paths will always be used. A heavy use, however, will only be obtained if such facilities offer a gain in travel time to the cyclists. Expensive separate bicycle paths are of no use for attracting bicycle traffic if they offer no shorter alternative to existing routes. Compared to travel time and directness, the type of facility as such is an unimportant route choice factor.

5.5 **Changes in traffic volume patterns**

5.5.1 Objective and set-up

In addition to the studies on individual travel behaviour reported on earlier, the collective result of these individual choices were investigated too. This study, which was carried out by Stichting voor Mobiliteits- en Transport Research (SMT) in Delft, deals with changes in bicycle and car traffic volumes in the Delft bicycle network. Furthermore, it establishes the contribution of the Delft bicycle network to these changes.

For this purpose, many counts of bicycle and car traffic were held both in the before and in the after situation. Counts of bicycle traffic were carried out on ca. 250 road sections in both directions: they were located in various districts of Delft and distributed among various functional classes and facility types. Within and around the study area North-West the density of counts was much higher in order to adequately trace possible changes in network use by cyclists.

Car traffic was counted bidirectionally on ca. 130 road sections throughout Delft. This number of counts does not allow area-specific conclusions on car traffic volume changes to be made.

5.5.2 Findings

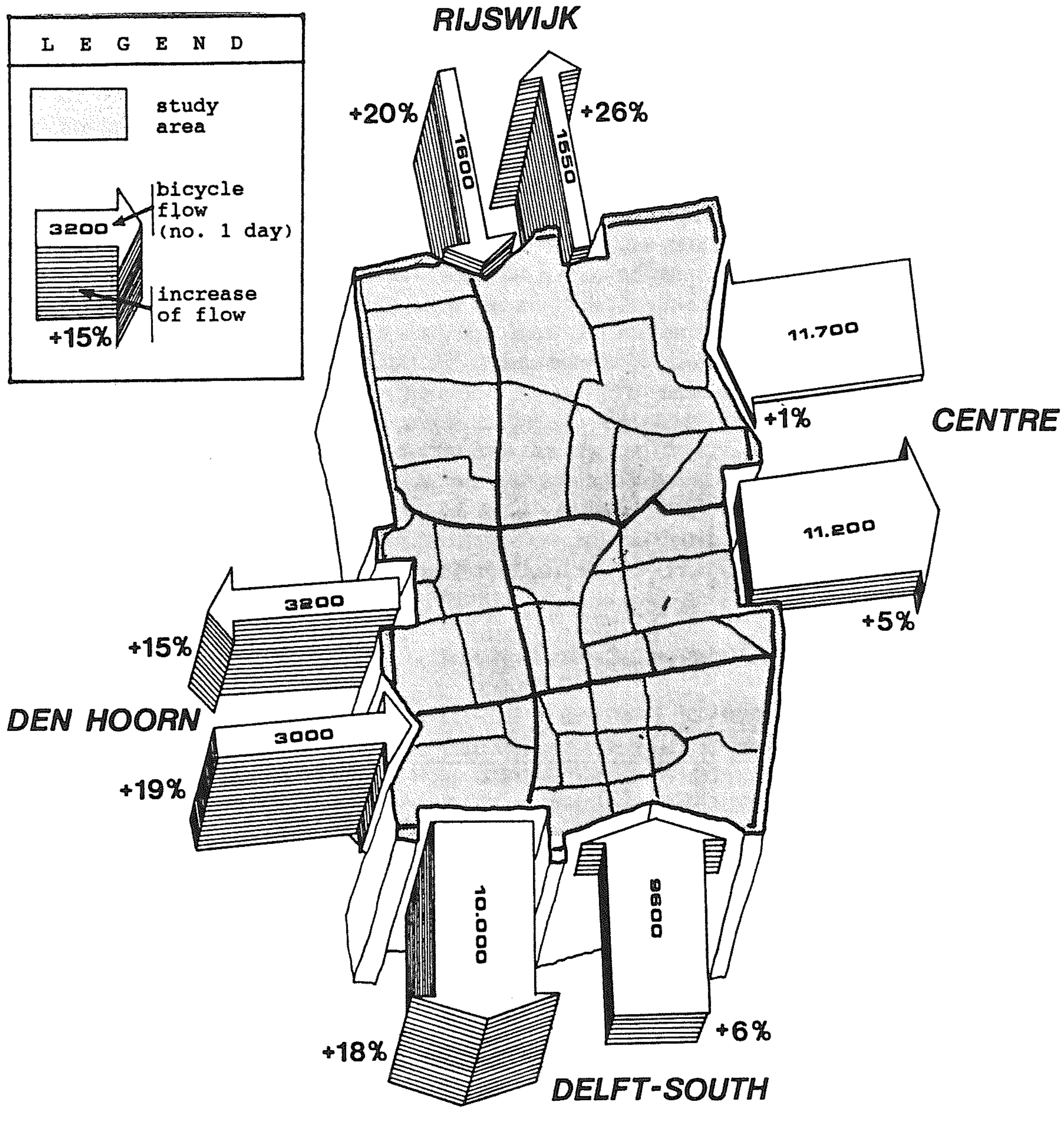
Between 1982 and 1985 bicycle traffic volumes in Delft increased on average by ca. 15 per cent. Car volumes remained stable. The increase in bicycle traffic varies considerably between areas, locations and types of facility.

In the study area Delft North-West, bicycle traffic volumes increased by ca. 14 per cent, whereas they remained constant in the control area Wippolder. It is plausible that this difference is to a considerable degree caused by the new provisions made as part of the bicycle network plan.

Bicycle traffic showed a large increase of about 24 per cent in Delft-South too. Partly this growth stems from the population increase in the district Tanthof, although a large contribution is due to the new bicycle links connecting this district to the rest of Delft. For example, two tunnels for cyclists have been built.

Detailed analyses of bicycle traffic volumes within and around the study area showed that growth varies strongly between directions (see Figure 7). Traffic to and from the city centre only increases marginally (+3 per cent), whereas the flows to and from Delft-South (+12 per cent) and in particular to and from adjacent communities (Rijswijk +23 per cent, Den Hoorn +17 per cent) rose significantly. Put differently: external bicycle traffic increased much more than the internal traffic within Delft.

Figure 7: Inrease in bicycle traffic volumes on screenlines around study area



Within the study area, north-south bicycle traffic growed with almost 25 per cent, whereas that in east-west direction increased by only 8 per cent. Partly this difference can be explained by the specific measures taken which enable the study area to be traversed in particular from south to north and vice versa more easily. Examples of these measures are the new bridges on the Buitenwatersloot, and the conversion of one-way cycle paths into two-way ones along the Provincial road.

Apart from the general increase in bicycle traffic volumes, large local changes in flows were found. The underlying pattern of these variations suggests that cyclists transferred their routes as a result of the attractiveness of the new links.
Rather large shifts occured within the bicycle network: urban level links showed a volume increase above average (41 per cent), whereas the district network links even carry less bicycle volumes (-3 per cent). Since most urban level links are separated cycle paths, bicycle traffic volume on this type of facility showed the largest increase of 41 per cent. Transfer of bicycle traffic from the district level facilities to the city level links is caused by the fact that most of the new provisions were made at the latter level, resulting in a larger coherence of the city level network.
Since separated cycle paths are considered more safe, these shifts imply an improvement of the cyclists' safety.

Table 3: Changes in bicycle volumes by functional class and roadway type

functional	BEFORE (1982)		AFTER (1985)		1982 - 1985		same per
class	counts	volume	counts	volume	difference	%-growth	location
city level	81	71184	93	89640	18456	26%	10%
district level	59	38065	61	36867	-1198	-3%	-6%
subdistrict level	49	9293	51	10860	1567	17%	12%
facility type							
mixed traffic	111	41495	113	40838	-657	-2%	-3%
bicycle lane	26	26939	28	25640	-1299	-5%	-12%
independent path	52	50108	64	70889	20781	41%	15%
total network	189	118542	205	137367	18825	16%	7%

Largest bicycle volume changes were found in the vicinity of the new provisions like the Tanthof underpasses, the Barbarasteeg, the Polderpad Bridge, etc. On the other hand, exemption of cyclists from one-way traffic appeared to result in clear volume changes; generally a more even distribution of traffic load was obtained.

Car traffic volumes remained more-or-less stable in the period investigated (1982-1985). An explanation can not be given since data did not allow for detailed analysis.

The increase in bicycle traffic volume may have many causes, including ones not related with the bicycle network plan. In addition to the comparison between the development in the study and the control area, another method for estimating the effect of these other factors was developed and applied. It indicates that more than half of the average growth stems from demographic and general mobility trends among the Delft inhabitants. It can also be shown that 50 to 60 percent of the local bicycle volume shifts can be attributed to the implementation of the Delft bicycle network plan in the study area.
This total effect can be roughly divided into the following partial effects of the measures:
- general increase in average volume: 7 per cent;
- shifts of travelled routes towards new facilities: 36 per cent;
- shifts in routes between existing facilities: 15 per cent.

5.5.3 Conclusions

From this it can be concluded that the measures taken between 1982 and 1985 had a clear effect on the bicycle volume pattern. They resulted in a clear growth of bicycle traffic and in even larger shifts of these volumes due to changes in route choice. Car traffic remained constant in this period.

These conclusions based on the analysis of bicycle and car traffic volumes are similar to those from the other evaluation studies such as the one dealing with changes in modal choice (ITS).

6 EFFECTS OF THE DELFT BICYCLE NETWORK PLAN

6.1 Introduction

Approach

In the sequel, the results about effects found in the various study parts will be integrated: scattered results about the same issue will be brought together; quantitative figures will be standardized; and results not reported elsewhere will be added if neccessary. Starting point is the objective of the Delft bicycle network plan, being the encouragement of the bicycle use thereby reducing car use in Delft; in addition the plan has to improve the cyclist's comfort, convenienence and safety.

By comparing changes in bicycle use in the study area with those in the control area the existence of other factors not related to the bicyce network plan can be determined. In addition to this interarea comparison the contribution of these factors to the overall changes in bicycle use is established, using national data on travel elasticities to changes in various factors like public transport fares, etc..
From this the increase in bicycle use that would have occurred if no bicycle network plan were implemented, can be assessed.

If the modal shifts in the study area are larger than may be expected from these other factors, it may be assumed that the bicycle network plan has a positive effect. This net increase is the true and unconfounded effect of the bicycle improvements made in the study area.

Definitions

The effect will be mainly measured by means of the total distance travelled by bike or car, sometimes called total kilometers travelled. This total distance equals the product of the number of trips and the average trip length. A change in the total distance travelled may be caused by a change in both these factors.

Effects are expressed as percentage changes in the level of bicycle or car use, measured by total distance travelled, volumes, number of trips, etc. between 1982 and 1985.

Changes in bicycle or car use between 1982 and 1985 can be measured correctly only if demographic changes are accounted for. Therefore bicycle or car use per capita is used a variable in most cases, e.g. trips per day per capita, total distance travelled per day per capita.

The components of the bicycle network plan, the effects of which are to be determined, are located in the study area (Delft North-West). Both residents of this area and other travellers may benefit from these improvements. When determining the plan's affect both bicycle use by residents of the study area and total distan-

ce travelled by bicycle in this area are relevant indicators. The latter distance stems from internal, external and through trips of the study area, made by residents and non-residents as well.

6.2 Effects of bicycle plan on level of bicycle use

Central issue of the evaluation study is whether the measures taken result in an increased bicycle use. This intended effect can be determined by comparing the development of bicycle use in the study area and the control area. Table 4 summarizes the changes in trip frequencies, total distance travelled by bike per day per capita and total distance travelled in the two areas. For details see [19].

Table 4: Changes in bicycle use in study and control area between 1982 and 1985

indicator	study area North-West	control area Wippolder
no. of bicycle trips by inhabitants, per capita/day	+ 4 %	0 %
total distance travelled by bicycle by inhabitants per capita per day	+ 8 %	0 %
total distance travelled by bicycle, all trips	+ 11 %	-1 %

The results show that bicycle use clearly increased in the study area. Per capita total distance travelled by bike by inhabitants in the after-situation was 8 per cent higher. Bicycle trip frequencies of inhabitants increased by 4 per cent.The increase in bicycle use differs between trip categories (see sec. 5.3 and [10,13]). No increase was found in the control area.

The observed bicycle traffic volumes show a similar difference in change in both areas. After seasonal adjustment volumes rose by 11 per cent in the study area and fell by 1 per cent in the control area.

The differences found between study area and control area suggest a clear effect of the bicycle network plan. To further corroborate this finding a different way of estimating effects has been applied. The part of the measured changes is due to background factors not related to the cycle plan has been calculated. This splitting up of effects has been done for the trips leaving the study area using the so called 'Mobility Explorer', which is a model designed to make short term predictions [13].

Total growth in number of bicycle trips leaving the study area (consisting of trips of both inhabitants and non-inhabitants of the area) amounts to 8.6 per cent.
The analysis shows that background factors cause an increase in bicycle use of about 2.7 per cent in the same period. Decomposed by specific factors partial effects are:

- public transport fares	+2.1 %
- employment	+0.5 %
- demography	-1.1 %
- other factors	+0.8 %
total effect	+2.7 %

Changes in public transport fares and employment appear to have a large positive effect and demographic changes affect bicycle use negatively.

The true effect of the bicycle network plan can be established after measurement errors and daily variations are accounted for. The analysis by TNO indicates that the 90 per cent confidence limits of the measured bicycle travel increase are 2.4 per cent. This figure may be used to establish minimum and maximum values (90 per cent confidence limit) for measured and calculated effects.
Table 5 shows the components of total growth in number of trips. The expected value of the true effect of the bicycle network on bicycle travel is therefore about + 6 per cent (i.e. 8.6 - 2.7 per cent), which is about two thirds of the total increase. Taking account of measurement errors and daily variations the estimated effect ranges between 3 and 9 per cent.

Table 5: The estimates of the bicycle network plan's true effect on bicycle travel

COMPONENT	average	minimum	maximum
total growth	9 %	6 %	11 %
background effect	3 %	2 %	3 %
true effect of plan	6 %	3 %	9 %

These figures indicate that this category of trips shows a significant increase of 6 per cent caused by the bicycle plan measures. The contribution of background factors to measured growth is relatively small. It can be concluded that the bicycle network scheme has succesfully attained the objective of encourageing bicycle usage or at least of stopping a decrease in use.

6.3 Effects of bicycle plan on level of car use

An objective of the bicycle network plan is to reduce car travel by encouraging bicycle use. In the evaluation study, only limited attention has been paid to car travel. The investigation by ITS has established car mobility per capita by residents of both the study and the control area in the before and in the after situation. Furthermore SMT compared car traffic counts throughout Delft at both points of time. The effect of the bicycle network scheme can therefore only be established by comparing car travel per capita of the two areas.

Table 6 indicates that the study area inhabitants had a constant per capita car trip frequency, whereas the total kilometrage driven by car rose. It can be seen that the stability of car trip frequency is the net result of an increase in external trips and a decrease in internal trips. This shift results in a growth in total distance travelled by car since, on average, external trips are longer than internal trips.
Car use did not increase in the study period, despite an increase in car ownership.

Table 6: Changes in per capita car travel (passenger trips included) between 1982 and 1985 in percentages [12].

mobility indicator	inhabitants study area	inhabitants control area
car trip frequency	0 %	+15 %
internal trips Delft	-6 %	+25 %
external trips	+9 %	- 1 %
total distance travelled by car	+10 %	+13 %

In the control area on the other hand, both car trip frequency and car kilometrage of the inhabitants rose. In particular, internal car trips in Delft increased. Even when statistical uncertainties are taken into account, largely different changes in car travel can be noticed between the study and control area.
Below it will be shown that mode transfers from car to bicycle mainly stem from car passengers, as a result of which the reduction of car traffic in terms of vehicle volumes, due to the increased bicycle use, will be limited.
Counts showed a constant level of car traffic as far as entire Delft is concerned.
The differences between study and control area, combined with stagnating car traffic volumes, indicate that the bicycle enhancement plan has contributed to restraining (an increase in) car travel.

6.4 Modal transfers of study area residents

The effect of the bicycle network plan on travel behaviour has also been determined by comparing the mode choice of the same individuals before and after the plan was implemented. This analysis was limited to individuals whose personal circumstances were unchanged during the study period (the so-called panel) [12]. Modal transfer is said to occur if for a similar trip at both points of time different modes were used.

Stability in mode use

Table 7 shows for each mode the proportion of trips that changed mode. The first column presents for each mode the share of trips using the same mode in 1985 as in 1982 ('stayers'). These figures indicate the choice stability of each mode. Column two containes the reciproke values, being the proportion lost to other modes ('switchers').
In the third column for each mode the share of the 1985 trips that used the same mode in 1982, is given. The complement measures the attractive force of each mode (column four).

Table 7: Stability, gains and losses of the mode choices of the panel trips in 1985 compared to 1982

transport mode	1985 (1982=100%)		1982 (1985=100%)	
	kept	lost	kept	gained
walking	89,0%	11,0%	97,5%	2,5%
BICYCLE	97,5%	2,5%	91,2%	8,8%
car (driver or passenger)	92,0%	8,0%	94,8%	5,2%
public transport	83,0%	17,0%	80,0%	20,0%
all modes	92,8%	7,2%	92,8%	7,2%

From this table it can be seen that:
- on average 93 per cent of the trips included in the panel did not change mode. Modal transfers appear to occur very infrequently. Partly, this finding has to do with the bias of the panel, i.e. it is a selected group of individuals and trips having the same characteristics in 1985 compared to 1982.
- the bicycle mode looses only a very limited proportion of users (2.5 per cent). Despite changes in personal circumstances (ageing, car ownership, income etc.) cyclists adhere to their mode. This may be due to the bicycle network plan.
- the bicycle mode succeeds to increase its share by 9 per cent by attracting trips from other modes.
- public transport users appear to be a rather changeable group. It looses 17 per cent of its 1982 ridership and at the same time attract 20 per cent of new trips from other modes. It should be remembered that because of its small modal share (6 per cent) only small flows are involved.
- the car and walking mode attract only limited numbers of switchers.

Modal transfers

To which modes does the bicycle mode loose trips and from which modes does it gain travellers? Table 8 illustrates the loss of the bicycle mode specified by 'destination' mode as well as its gain by 'origin' mode; only study area residents were involved in this analysis.(The diagonal cells of the table show the percentages of trips with the same mode; the row and column totals comprise the modal split in 1985 and 1982 respectively).

following can be derived form this table:

- Losses from the bike to other modes are insignificant; they can not be interpreted as structural. Half of this loss is to 'walking'
- The bicycle mode gained 8.8 per cent new trips:
  * half of this gain (4.4%) originates from 'walking'
  * nearly a quarter (1.9%) from 'car passenger'
  * a fifth (1.4%) are former car drivers

  Apparently an important mutual transition exists between cycling and walking.
- About 20 per cent of car passenger trips switched to the bicycle mode; the slight reduction in car driver trips may be due to a related decline of escort trips. This means that although the number of person trips made by car declined, the number of car trips remained nearly constant. Only car occupancy decreased as a result.
- The transfer of trips between cycling and public transport is rather limited.

The net gain of the bicycle mode (+6 %) mainly comes form walking and the car, both drivers and passengers. The size of this figure also implies that the increase in bicycle use by study area residents largely results from modal transfers. Other analyses demonstrated that the increased use mainly stems from travellers that used the bike for certain trips previously. Travellers not using the bike at all in 1982 were not attracted [12].

Table 8: Modal transfers (in percentages) of all panel member trips

TRANSPORT MODE (study area) in 1985	in 1982 walking	BICYCLE	car driver	car pass.	public transp.	all modes
walking	23.1	.5			.1	23.7
BICYCLE	1.9	39.3	.6	.8	.3	43.1
car driver	.1	.2	20.0		.5	20.9
car passenger		.1	.1	3.5	.2	3.9
public transport	.4	.2	.2	.3	5.2	6.5
all modes (incl.other)	25.9	40.3	21.0	4.6	6.3	100.0

6.5 Effects on mode choice constraints

Choice of mode decision by a traveller for a specific trip has been analysed in the evaluation study in terms of so called choice constraints, which prevent travellers from choosing certain modes. These choice constraints may be very different and vary from objective restrictions, e.g. no bicycle is available, to very subjective reasons, e.g. traveller hates cycling. The bicycle traffic infrastructure may also cause choice constraints.

It is important to know to what extent the bicycle network plan succeeded in removing constraints that prevent travellers from choosing the bike and thereby enlarging the class of travellers having a choice (unconstrained travellers). The class of trips for which the bicycle might be chosen is called 'cycling potential'. Three questions were dealt with in this respect:

a) Did the constraints with respect to bicycle use diminish between 1982 and 1985 ?
b) How did the bicycle network plan remove constraints?
c) Did competition between bicycle and the other modes change?

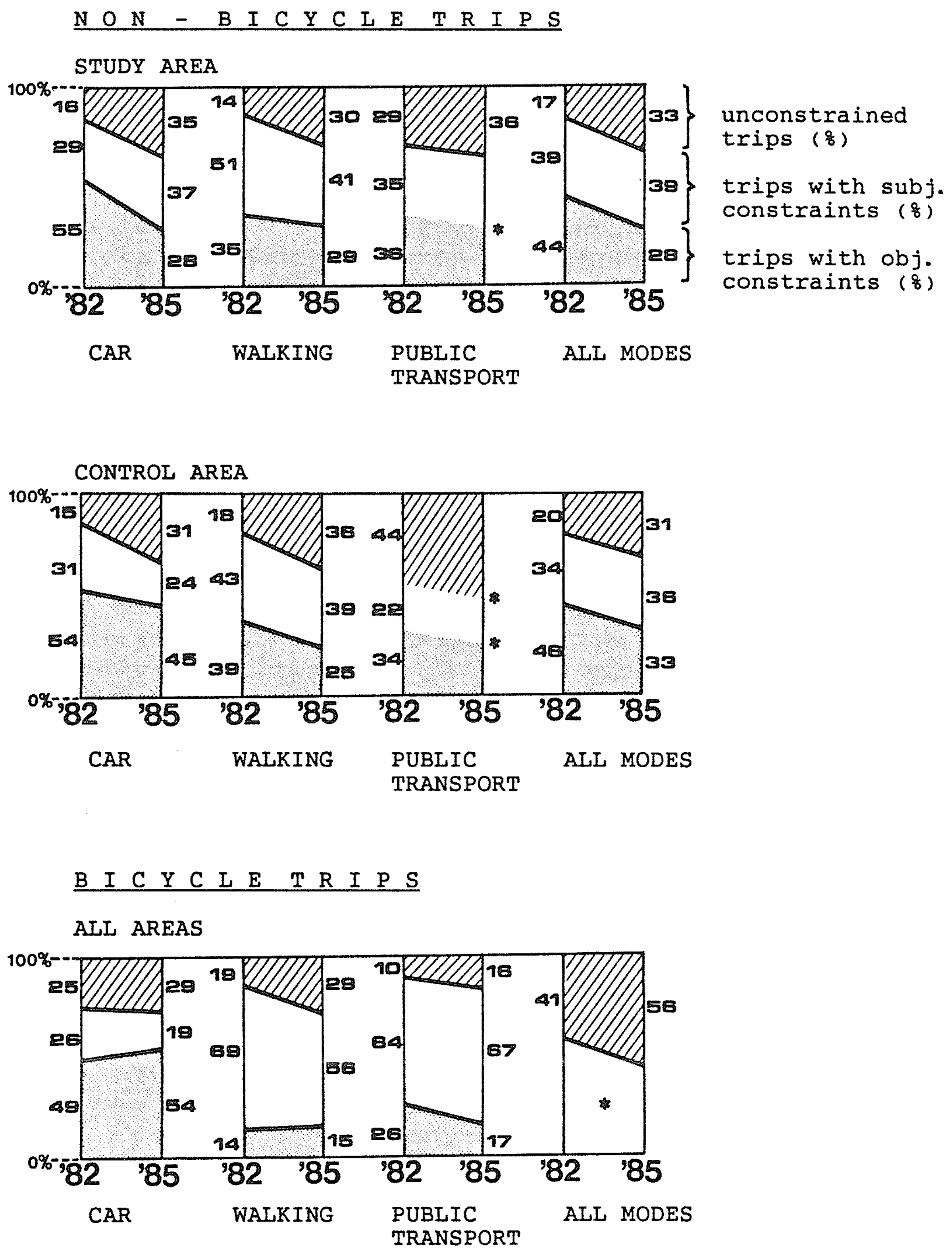
<u>a. Decrease in constraints</u>
Figure 8 (a,b) shows the proportions of unconstrained non-bicycle trips in 1982 and 1985 for both the study and the control area. The shares of non-bicycle trips having objective and subjective choice constraints respectively are indicated too. From the figure it can be seen that in both areas constraints against cycling clearly diminished. The group of unconstrained trips with respect to bicycle use, i.e. the bike could have been used for these trips, almost doubled its size to ca. 32 per cent.
A striking result is that this large increase is mainly caused by a reduction in the objective restrictions. This type includes two specific constraints. The first one is "no objective possibility of choosing the bike", referring to reasons like 'do not own a bike' or 'can not cycle'. The second constraint is called 'compelling reasons', including luggage, health reasons, car needed during work, etc.. The occurrence of the second type of constraint fell most from 30 per cent to 22 per cent.
This finding applies equally to both car and walking trips, although these modes serve rather distinct travel market segments.

<u>b. Effect of bicycle network plan on choice constraints</u>
The contribution of the bicycle network plan on the increase of the unconstrained travellers with respect to bicycle use has been established by:
1. comparing the study area and control area results,
2. analysing in detail the occurrence of specific constraints.

Figure 8(a,b) indicates that the proportion of choice travellers

among non-bicycle trips ('cycling potential') is almost identical in the study and control area. This similarity was found both for 1982 as for 1985, implying equal changes in both areas.

Figure 8: Changes in choice constraints in study and control area between 1982 and 1985



(* no data available)

As was mentioned earlier the removal of objective constraints was the main cause of the growth of the share of choice travellers. No measures taken as part of the bicycle network plan can have contributed to these changes, since the objective constraints deal with bicycle ownership, health, long trip distances, luggage etc. [12].

For both areas and both points of time, table 9 gives the possibility of choosing the bicycle for non-bicycle trips, as well as the limiting effect of six types of constraints. The table starts with 100 per cent unconstrained trips and successively subtracts the percentage of trips that is bound to the used mode because of a particular constraint. In the case of trips of study area inhabitants in 1982 (first column), 12.4 per cent of the non-bike trips do not have an objective possibility of using the bicycle. Of the remaining 87.6 per cent of these trips, 31.5 per cent have compelling reasons against bike use. Thus, only 56.1 per cent remains unconstrained at that stage; and so forth.

The striking resemblance of the contributions of each constraint between study and control area is maintained after the implementation of the plan. This leads to the conclusion that the comparison of both areas with respect to frequencies and changes in the occurrence of constraints does not provide evidence of a significant effect of the bicycle network plan.

Table 9: Choice restraints of non-bicycle trips, all modes [3,12]

	BEFORE - SITUATION		AFTER - SITUATION		
DIMENSION	study area (N=1948)	control area (N=586)	study area (N=1101)	control area (N=398)	
bicycle is	100%	100%	100%	100%	
an objective choice alternative	no 12,4%	no 16,0%	no 6%	no 10%	
	87,6%	84,0%	94%	90%	
compelling reasons against bicycle use	yes 31,5%	yes 29,9%	yes 22%	yes 23%	OBJECTIVE CONSTRAINTS
	56,1%	54,1%	72%	67%	
perception of travel time	28,7%	28,4%	28%	30%	
	27,4%	25,7%	44%	37%	
perception of road and traffic condition	0,4%	0%	0%	0%	
	27,0%	25,7%	44%	37%	
perception of comfort	4,6%	3,0%	4%	4%	SUBJECTIVE CONSTRAINTS
	22,4%	22,7%	40%	33%	
subjective attitude	5,6%	2,5%	7%	2%	
UNCONSTRAINED TRIPS:	16,8%	20,2%	33%	31%	

e. Changed competition between the bicycle and other modes

This conclusion is also supported by the occurrence of the subjective constraints which would have been affected by the plan. The 'perceived road and traffic conditions' appears to be an insignificant restriction. 'Perceived travel time' is an important subjective constraint but its occurrence remains unchanged.
The final conclusion of this analysis is therefore that the group of travellers that may choose the bicycle has increased, but that the bicycle network measures did not have any influence.

The previous section showed that the proportion of non-bicycle trips that may choose the bike nearly doubled. This large increase in bicycle potential stems from the car and walking modes, because of their large modal shares.
Conversely, an important question is whether bicycle trips may choose other modes to a larger extent. It is assumed that the bicycle network plan does not affect this choice possibility. Therefore, ITS has investigated this aspect for all areas combined.

Figure 8(C) shows that the share of unconstrained bicycle trips also increased between 1982 and 1985. This class of cyclists, who may choose other modes, increased from 41 to 56 per cent. It is remarkable that this growth is caused by an increased possibility of cyclists to choose walking. This may be explained by the fact that a number of travellers that walked in 1982, cycled in 1985. These cyclists may easily switch back to the walk mode.

The general finding is that all categories of travellers have got more choice options. This enlargement of the choice set means an advantage and at the same time a disadvantage to the bicycle mode. Competition has become tougher. It offers the possibility of attracting more travellers to the bicycle mode by improving this mode substantially.

6.6 **Effects on bicycle travel experience**

An objective of the bicycle network plan is to enhance perceived comfort and safety of cycling. Panel members were asked therefore about their subjective experience with cycling after the measures were taken. Respondents' answers were classified into three aspects; comfort en route, continuity and safety.
Generally it is found that cyclists' opinion on the measures introduced does not differ between those living in the study area and control are respectively. Only 20 per cent of the cyclists perceived a marked improvement between 1982 and 1985. The remaining 80 per cent experienced a slight ar no improvement to cycling conditions. Aspects like 'surface quality' and 'directness' proved to improve most as perceived by the cyclists: 30 per cent of them noticed a significant improvement. These appeared to be the most important factors of cyclists' route choice as well [10]! Traffic safety on the other hand was hardly perceived as being improved.
From the equal and stable scores in both areas, it is concluded that the measures taken affected the experienced conditions only marginally.

In contrast with these results 40 per cent of the people living in Tanthof perceived a significant improvement in cycling comfort. This is to be understood in view of the large-scale facilities that were built there, i.e. two bicycle tunnels, long separate bicycle routes with asphalt paving, new direct links to the town centre, etc.

The conclusion from these findings is that only significant improvements in the cyclists' perception of comfort and safety will be achieved if radical and large-scale measures are taken.

6.7 Effects on route choice and network use of cyclists

Route shifts

The analysis of route choices showed clear changes in routes followed by cyclists in the study area. This analysis was carried out by comparing routes chosen in choice situations where the measures taken have changed choice alternatives. The route shifts found were supported by the investigation of volume changes on screenlines and on links near new facilities [14].
The observed route shifts were mainly caused by newly built links like Barbara Street, Molen de Roos, and Polderpad Bridge. These new links attract bicycle trips from existing facilities mainly because they constitute an additional route alternative and not in the first place because they result in significantly shorter routes [10].

Exemption of cyclists from one-way traffic also results in noticeable route shifts [10,14]; these shifts are smaller however and confined to the immediate vicinity of the streets involved.

A clear finding is that the implementation of the bicycle network plan did not result in significant reductions in travel distance and travel time at the level of the total network. The total distance travelled by bike on all trips was reduced by less than 1 per cent. Significant distance reduction was only obtained at the shorter trip distances, but few bicycle trips take advantage of this improvements

Network use

An important objective of the bicycle network plan is to improve comfort and safety of cycling . The analysis of network use by OSPA shows significant changes in this respect.
Table 10 indicates a shift from cycling in mixed traffic to the use of separate or independent bicycle paths which are safer and more comfortable. The proportion of mixed traffic links in total distance travelled by bicycle fell from 45 to 40 per cent, whereas the share of separate and independent bicycle paths rose from 30 to 35 per cent. New facilities prove to be very effective since the total distance cycled on them increased twice as much as their link length, 38 per cent versus 17 per cent. Almost three-quarter of the additional total distance cycled in 1985 compared with 1982 is accounted for by these new high-quality facilities [10].

It may therefore be concluded that the shifts induced made cycling more comfortable and presumably safer. This improvement is a clear and direct consequence of the bicycle network plan.
It is interesting to note that the ITS-investigation into cycling experiences showed about 20 per cent of the cyclists perceived a marked increase in cycling comfort [12].

Table 10: Total distance travelled by bicycle by facility type [10]

type of facility	total distance travelled by bicycle BEFORE-SITUATION [kmx1000]	%	AFTER-SITUATION [kmx1000]	%
mixed traffic link	28,4	45	29,5	40
bicycle lane	16,2	26	19,0	26
separate/independant bicycle path	18,5	30	25,5	35
other	0,3	0	0,3	0
total network	63,3	100	74,2	100

True effect of bicycle network plan on volume changes

Changes in bicycle traffic volumes may be caused by various factors, including ones not related to the bicycle network plan. From an analyses of these influences it was deduced that some 50 to 60 per cent of the observed volume changes between 1982 and 1985 stem from the measures taken as part of this plan [14]. Partial effects of these measures may be decomposed according to type of volume shift as follows:

- overall increase of volumes 7%
- route shifts to new links 36%
- route shifts between existing links 15%

7 EXPLANATION OF CHANGES IN TRAVEL BEHAVIOUR

7.1 Introduction

The investigations have shown that the implementation of the bicycle network plan has resulted in various effects, both at the level of individual decisions (e.g. mode choice) and at the macro level (e.g. bicycle traffic volumes). In view of future transport policies it is worthwile to understand the mechanisms how the network changes may have caused a changed travel behaviour. On the basis of the theoretical framework given in chapter three some attention will be given to this question. To this end, we will first examine how the measures taken may have affected the major choice elements; these insights are used subsequently to examine the most important travel choices.

7.2 Effects of measures on choice elements

a. Objective alternatives

A direct change of objective choice options due to the bicycle network plan only occurs in the case of route choice. The construction of new links like bridges and underpasses offer route alternatives that did not exist formerly. An analysis of extensions of route choice sets can be found elsewhere [10,11].
Newly added route alternatives will always attract trips from existing alternatives, even when they do not constitute better options in terms of the relevant attributes like travel time, comfort, etc..

b. Objective attributes of alternatives

It is clear that the measures introduced generally resulted in an improvement of the objective characteristics of the bicycle network: resurfacing and separate bicycle paths lead to better comfort, bridging gaps cause distances to be reduced, safety may be enhanced through separate bicycle paths and improved traffic control at junctions, etc.. The effect of the bicycle network on such network attributes like distance, travel time, surface type, facility type, may be found elsewhere [10].

It may be concluded that the impedance to travel by bicycle has been reduced. It has become easier to get to many destinations by bike, also compared to other means of transport. As a result travellers, whose only feasible mode is using the bicycle, will make more trips; individuals having a real choice will opt for the bike more often.

c. Subjective choice constraints

The distance reductions realized are in general insufficient to remove constraints with respect to activity and mode choice, except perhaps in the case of Tanthof district.
The analysis of changes in subjective mode choice constraints showed that the bicycle network plan hardly affected this choice element (cf. section 6.5). The reason for this is that con-

straints related to road infrastructure hardly existed before the plan was implemented. Consequently, it was not possible to further reduce these choice restrictions.

d. Perceptions

Individual travel choices are not made on the basis of the objective choice situation, but on perceived alternatives and attributes. Did the bicycle network plan encourage bicycle use through improved perceptions?
The Delft bicycle network is designed as a hierarchical network with three levels, each having its own spacing and design characteristics. From urban geography it is known that such a network leads to a better 'mental map', at least if the differences in structure and design are clearly recognizable to the users. Cyclists are able to estimate distances and travel times more precizely. They have a better understanding of the network structure and thereby a better sense of direction. Available links and routes are better known (see [10] for a detailed discussion).
All this may encourage people to travel by bicycle more frequently. Route choice will be clearly affected: the cyclist is inclined to use high-order facilities more since he knows them better and they help him to navigate in the network.

The analysis of routes followed by cyclists showed that the network is used according to the built-in functional hierarchy [10].

e. Preferences

The importance the traveller attaches to various attributes plays a substantial role in the evaluation of alternatives. It is assumed that these preferences are very personal and that they are related to his character and social context. Therefore, preferences are very stable and will not be affected by implementation of the bicycle network plan in the short run.

7.3 Modal transfers

To change modal choice is the central objective of the bicycle network plan. The analyses of effects showed that the bicycle share in the modal split actually rose from 40 to 43 per cent.
In order to determine to what extent this change is due to modal transfers a panel of persons making similar trips in 1982 and 1985 was surveyed. In this group modal transfers occurred: 8 per cent of the 1985 bicycle trips were made by a different mode in 1982. In the same period the bicycle lost 2 per cent of its trips to other modes. As was discussed in section 6.4 the bicycle mode attracts trips from all other modes, but predominantly from 'walking' and 'car passenger'.

In order to explain the observed transfers all choice elements are checked on potential changes due to the plan:

- an extension of the objective choice set (new modes) is very unlikely;
- the improvement of the objective accessibility of destinations by bicycle, relative to other modes was an important factor. Although distance and travel time reductions were limited, comfort and safety have been improved substantially. This enhancement stems from the amelioration of existing routes (resurfacing, separate cycle paths) as well as from the construction of new routes.
- choice constraints on bicycle use have diminished strongly between the before and after situation. As was explained in section 6.5 only a small part of this reduction can be ascribed to the measures taken. It implies however that the group of unconstrained trips, i.e. trips that could be made by bike, grew considerably. If the bicycle mode is made more attractive than the competing modes, it will be effectively used for these trips.
- it is plausible that the perception of the bicycle travel alternatives and its related attributes has been improved because of the implementation of the plan.

Modal transfers are the chief cause of the increase in the number of bicycle trips per capita. As total trip frequency per capita remained constant [12], the transfers also result in a larger modal share of the bicycle.
These modal transfers to the bicycle are partly the result of the growth of the class of unconstrained trips, and partly due to the increased attractiveness of the bicycle mode. In the latter case travellers with a choice will more often opt for the bike.

It should be realized that the panel trips for which modal transfers could be analysed, relate only to half of the total trips made in 1985. The other half are 'new' trips, made e.g. by residents that moved into the study area during the study period. From the aggregate figures it may be concluded that new residents choose more often the bike than residents who left the area in the same period.

7.4 Trip frequency

It is relevant to determine whether bicycle trip frequencies also increased through an increased number of activities carried out. It is very unlikely that the bicycle network plan caused an autonomous growth of bicycle mobility. Total trip frequency, irrespective of mode, remained constant in the study period. The distributions of trips by purpose at both points of time do not suggest any change in activity pattern. Expectedly, the improvements to the bicycle network are not large enough to induce such changes in the short term.

7.5 Destination choice

Impedance to distance was reduced for the bicycle mode. Cognition and perception of travel alternatives by bicycle improved. This may lead cyclists to choose destinations at larger distances, especially for discretionary trips like shopping and leisure journeys.
Indirectly, the investigations suggest shifts of this kind. A large increase in the number of shopping trips from Delft-South to the centre of Delft was observed. These trips traverse the study area. The increase of the average length of bicycle trips (+6 per cent) may also be due to this effect.

7.6 Cyclists' route choice

The most direct and presumably the largest effect of the bicycle network plan occurred through cyclists' route choice. Attributes gouverning cyclists' route choice have been affected most by the measures taken. They frequently use different routes than before due to many new links and improved facilities. At some locations massive route shifts took place (e.g. Barbara Street).
Route shifts are mainly the result of the extension of the choice set with new but not necessarely superior alternatives. Improvements of existing links doe not induce different route choice that much, since distance reduction and comfort enhancement are relatively limited.
It was shown that about 58 per cent of the observed changes in bicycle volumes are caused by route shifts [14].

8 SUMMARY AND CONCLUSIONS

8.1 The Delft Bicycle Network Plan

In Delft a bicycle network enhancement plan has been launched aimed at encouraging bicycle use and improving cycling conditions.
As part of this plan new links for bicycle traffic have been built in Delft in order to bridge existing gaps. These new facilities are high-quality and large-scale provisions like bridges, tunnels and separate bicycle paths, as well as small-scale measures. The result is a coherent fine-grained network of bicycle links.

Other measures taken have enhanced existing facilities in many ways aimed at increasing convenience, comfort and safety. Examples are resurfacing, cycle lanes, improved junction lay-out, etc.

The improvements and provisions are located and designed in such a way that a hierarchical bicycle network was created consisting of a coarse subnetwork of high quality city-level routes and a fine system of local provisions.

8.2 Evaluation study

Implementation of the provisions made in the period 1982 - 1985 has been monitored by means of a before-and after-study in a study and a control area. In both years home interview and road-side surveys have been conducted and traffic volumes were counted.
Effects of the plan have been determined by eliminating the effects of other factors causing changes in bicycle use like demographic shifts, public transport fares, etc. as far as possible. National trends in mobility have been taken into account too.

8.3 Effects observed

With respect to the effects that are related to important objectives of the bicycle network plan, the main findings are:

a. Bicycle use

The primary goal of the plan is to encourage cycling. It was found that due to the measures taken bicycle use per capita increased in terms of number of trips as well as in average trip length. As a result, the network plan caused total distance travelled by bicycle to increase by about 6 to 8 per cent depending on the type of trip. This figure does not include growth caused by other factors not related to the bicycle network plan. Various

separate investigations that used different types of information like home interview survey results, traffic volume counts and simulation outcomes, came up with similar results on this point.

This increase in bicycle use can be explained by two changes that took place simultaneously. First, the proportion of travellers for whom the bike is a feasible alternative grew substantially. This reduction of constraints to bicycle use is not related to the bicycle network plan. Second, the attractiveness of cycling relative to competing modes was improved as a result of the plan. This means that the enlarged group of travellers having a real choice to use the bike will use the bicycle more often.

The increased bicycle use is caused by modal changes, especially by transfers from former walk and car passenger trips. There is no significant loss of public transport trips to the bicycle mode.

b. Route choice and network use

The bicycle network plan had a large effect on cyclists' route choice in that they shifted their routes to a large extent to new and improved facilities. This shift to high-quality links caused at the same time a reduction of bicycle traffic at minor links of less comfort. As a consequence, some previously overloaded locations have been clearly relieved.
The proportion of the separate and independent bicycle paths in total distance travelled by bicycle rose form 30 to 35 per cent, whereas cycling in mixed traffic fell form 45 to 40 per cent. It may be expected therefore that safety has been improved. This has to be shown by future investigations.

c. comfort and safety

Cycling comfort and safety clearly improved as a result of the implementation of the bicycle network plan. Analysis of the network use by cyclists showed that the distance travelled by bike on separate and independent cycle paths increased twice as much as the total distance cycled in the network.
Bicycle volumes on links with mixed traffic decreased. This improvement was also reflected by the results of the interviews into the perception of cycling conditions.

d. Car use

A secondary objective of the bicycle network plan is to reduce car traffic by encouraging cycling. In the study area, where the provisions were made in the study period, the number of car trips did not increase. A striking finding is that in internal travel within Delft the number of car trips even fell. This is the segment of the travel market in which the bicycle is the most competitive compared to the car.

Although the evaluation study does not allow to determine the true effect of the bicycle network plan, part of this decline may be attributed to the measures taken with certainty.

e. Competition between modes

All these changes taken together resulted in a shift of the modal split: the share of the bicycle rose from 40 per cent to 43 per cent. The car and walking mode both remained stable at 26 per cent. Public transport share declined form 6 to 4 per cent. It should be noted, however, that these figures refer to trips made by residents of the study area. The total ridership of local public transport may at the same time increase due to trips by other travellers living outside Delft.
The market position the bike compared to the competing modes clearly improved also in a more qualitative sense. Cycling conditions were enhanced. In addition, choice constraints preventing travellers from choosing the bicycle, diminished in such a way that a balance was achieved between potential loss to and potential gain from other modes. In particular, competitiveness of the bicycle relative to the car was improved.

f. Long-term effects

The effects measured in 1985 by means of the after-study must for various reasons be regarded as underestimates of the effects that are expected to occur in the long-term. By the end of 1985 the bicycle network scheme was not fully implemented; a number of major projects, essential to the coherence of the network, were not completed. Examples are: Plantage Bridge, Railway Station Tunnel. Furthermore, it is well known that travellers need some time to get informed about new routes and their properties. Learning processes take place before a new equilibrium in the transport system is reached. In view of the design of the evaluation study, only direct and short-term responses related to travel decisions can be established. Individuals modify their behaviour also in an indirect manner on the long-term, but only after certain changes in their personal circumstances took place. Expectations are therefore that in the long term effects of the bicycle network plan will be larger than those that were found in this study.

8.4 **Transferability of results**

Bicycle use appeared to vary markedly between Dutch medium-sized towns (population 50,000 - 200,000). The proportion of trips made by bicycle varies from 20 to 50 per cent. Assuming 55 per cent to be its maximum attainable share of the internal trips, in many cities there are a lot of possibilities to increase bicycle use.

Comparison of Delft with other Dutch medium-sized towns with respect to demographic, socio-economic and mobility characteristics justifies the assumption that the findings of the evaluation

study are transferrable to other cities. Similar effects on bicycle use may be expected if similar measures were taken. No reasons could be found that would restrict transferrability of the Delft findings.

8.5 Recommendations

The evaluation study leads to a number of recommendations with respect to policy measures that encourage bicycle use and improve cycling conditions.
The implementation of a dense, consistent and coherent network of bicycle facilities promotes cycling. A dense structure and continuity is necessary for a number of reasons. Relative to the size of the city the bicycle is used fo a variety of trips as to their length: both very short and long trips are make by bike. In addition, bicycle trips have a widely scattered pattern of origins and destinations that is better served by a fine network. Finally, it has been shown that cyclists do not use circuitous routes even if they are much safer and more comfortable. A fine-grained network largely avoids such detours.

It is further recommended to apply a clear functional hierarchy to the network by means of different design features and spacings at each of the functional levels. By providing the most expensive high-quality facilities only at wider spacing costs can be restricted and traffic flows concentrated in such a way that a maximum number of cyclists will benefit from the investments made. Maximum comfort and safety is offered where most of the distance is travelled.
A hierarchical functional design also encourages the use of the bicycle network. A logical structure visualized by means of a clear design improves cognition and perception of bicycle travel possibilities, distances, etc. and enables easy navigation. As a result the bicyle will be preferred to other modes more frequently.

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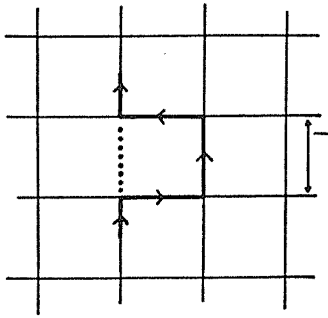
CITY LEVEL NETWORK (CORRIDORS)

DISTRICT LEVEL NETWORK

THE NETWORK PRINCIPLE AT THREE FUNCTIONAL LEVELS.

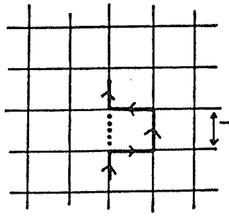
The effect of gaps on trip length.
For sake of illustration only a rectangular pattern is assumed.

CITY LEVEL NETWORK



spacing
ca. 400-600m

DISTRICT LEVEL NETWORK



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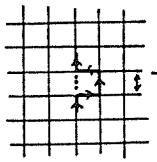
ca. 200-300m

SUBDISTRICT LEVEL NETWORK



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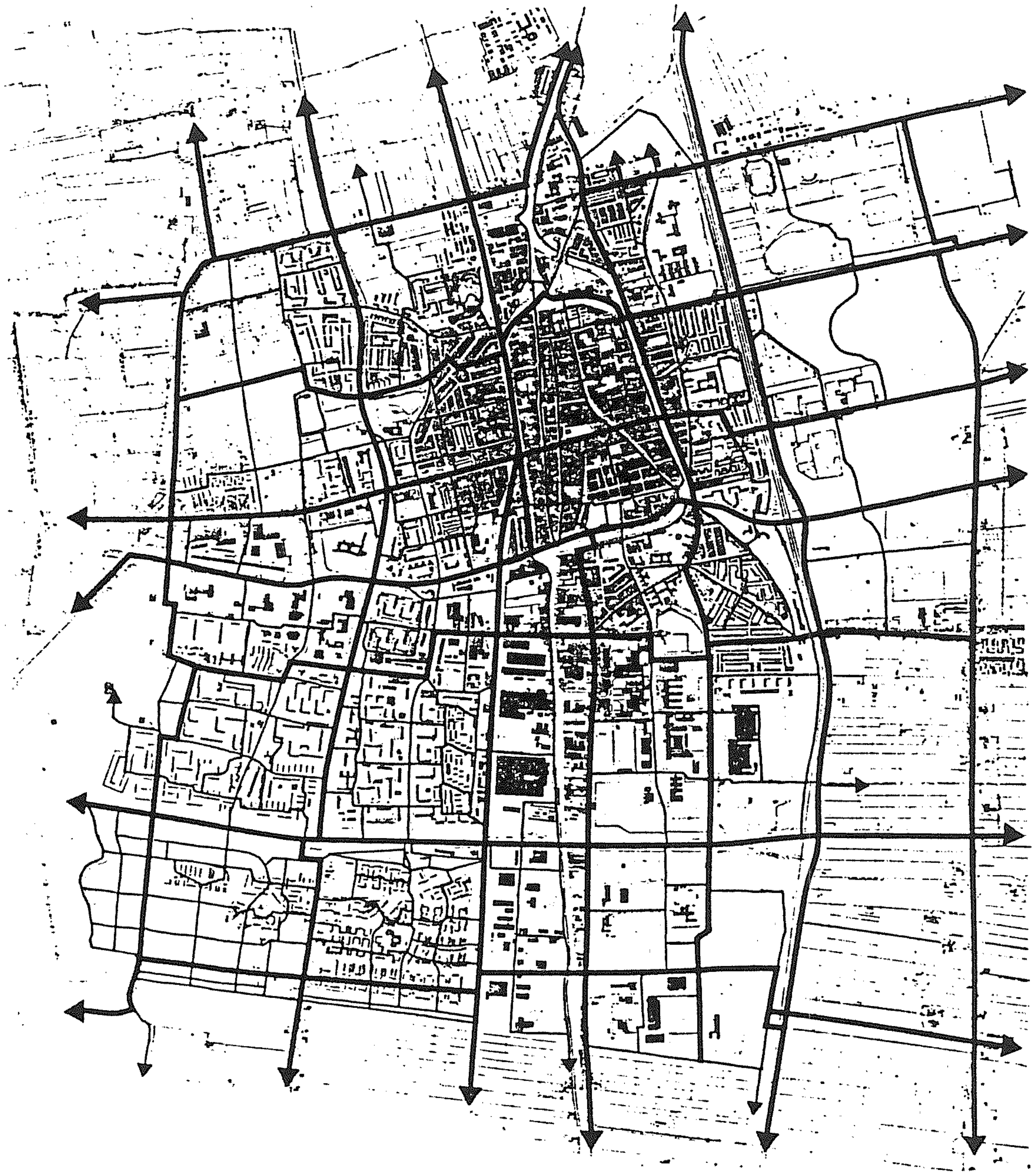
ca. 100-150m



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Delft bicycle network plan

APPENDIX 1

PROJECTS IMPLEMENTED DURING STUDY PERIOD

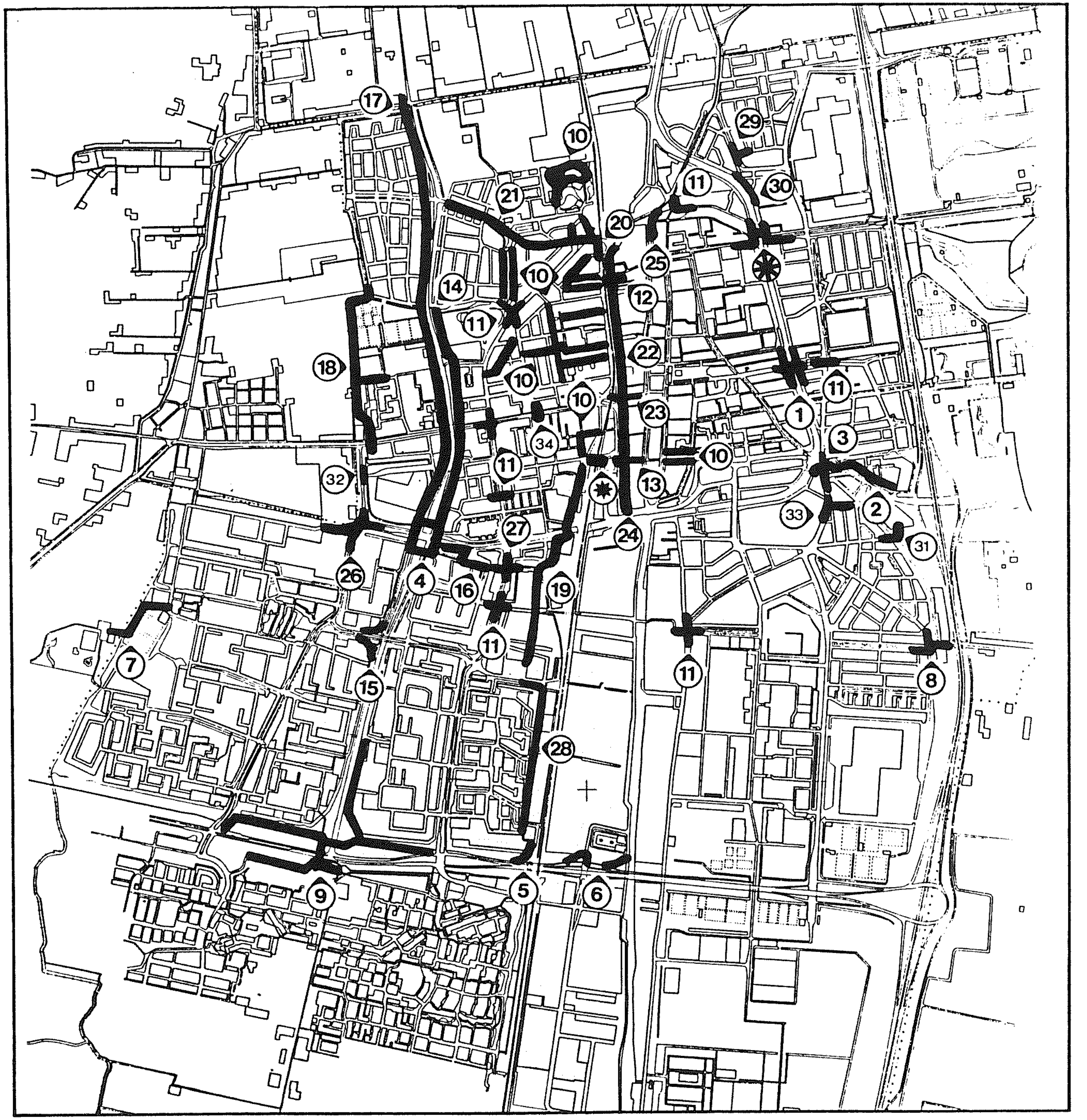
nr	projekt	omschrijving
1	Koepoortbrug-Maria Duystlaan	opheffen eenrichtingsverkeer, aanpassen verkeersregelinst.
2	Weideweg	nieuw fietspad
3	Oostplein	aansluit. fietspad, maken 2 ri. aansluiting, wijz. verkeersreg.
4	Westlandseweg-SW15	vergroten opstelvak+2 ri. maken
5	M.Emantspad-Kruithuisweg	nieuwe aanluiting op SW15
6	Schiekade-station Z.	nieuwe fietspaden
7	Kerkpolderpad	nieuwe fietsverbinding
8	doorsteek Pauwmolen	nieuwe fietsdoorsteek
9	fietstunnels Tanthof	twee tunnels met aansl. routes
10	opheffen eenrichting	in 18 straten opheffen van eenrichtingverkeer
11	offossen en rechts-af-vrij (vli)	maatregelen op 7 kruispunten
12	fietsoversteek Molen de Roos	met verkeerslichten beveiligde oversteek
13	Barbarasteeg	nieuw fietspad met beveiliging en rekonstruktie aansl. krp.
14	fietspaden SW15	verbreden fietspaden tbv. tweerichtingen bereiden, aansluitingen en aanpassen vli's
15	Componistenpad-M. Nijhofflaan	twee nieuwe aansluitingen
16	fietspad SW15-Troelstralaan	nieuw fietspad
17	't Haantje (kr)	nieuwe brug en wijzigen vli.
18	v.d. Dussenweg-Buitenwatersloot	nieuw fietspad met brug en vli.
19	pad ten westen van het spoor	nieuw fietspad met viadukt (viadukt was pas gereed na de onderzoeksperiode)
20	oversteek Spoorsingel	rekonstruktie kruispunt met aanbrengen vli.
21	eilanden Ruys de Beerenbrouckstraat	verbeteren oversteekbaarheid door middeneilanden
22	fietsstrook Phoenixstraat	aanbrengen fietsstrook en aanpassen kruispunt met vli.
23	aanpassen Bolwerk	gedeeltelijke rekonstruktie en aanpassing vli.
24	fietsstroken Westvest	herindeling en aanbrengen stroken tbv. fietsverkeer
25	Hoordeinde-Wateringsevest	fietsdoorsteek en aanpassen vli.
26	Reinier de Graafweg-Westlandseweg	reconstruktie kruispunt (fietsaandeel)
27	oversteek Papsouwselaan	aanpassing kruispunt met aanbrengen verkeersregeling
28	pad Vulcanusweg	nieuw vrijliggend fietspad
29	Insulindeweg	doorsteek naar Arubastraat
30	Oostsingel	profielverbreding

PROJECTS IMPLEMENTED AFTER STUDY PERIOD

31	fietsbrug Simonsstraat	nieuwe brug + pad voor verbinding Simonsstraat-Staalweg
32	eiland Westlandseweg	aanbrengen tussensteunpunt ter verbetering van de oversteekbaarheid
33	fietsoversteek Lipkensstraat	nieuwe oversteek over Julianalaan voor fietsers en voetg.
34	fietsbrug Buitenwatersloot	aanleg fietsbrug thv. de Heinsiusstraat

PROJECTS EVALUATED IN SEPERATE STUDIES

Plantagebrug	nieuwe fietsbrug over Rijn-Schiekanaal met aansluitende routes
Stationstunnel	uitbouwen best. voetg. tunnel met aansluitende voorzieningen



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LOCATION OF PROJECTS

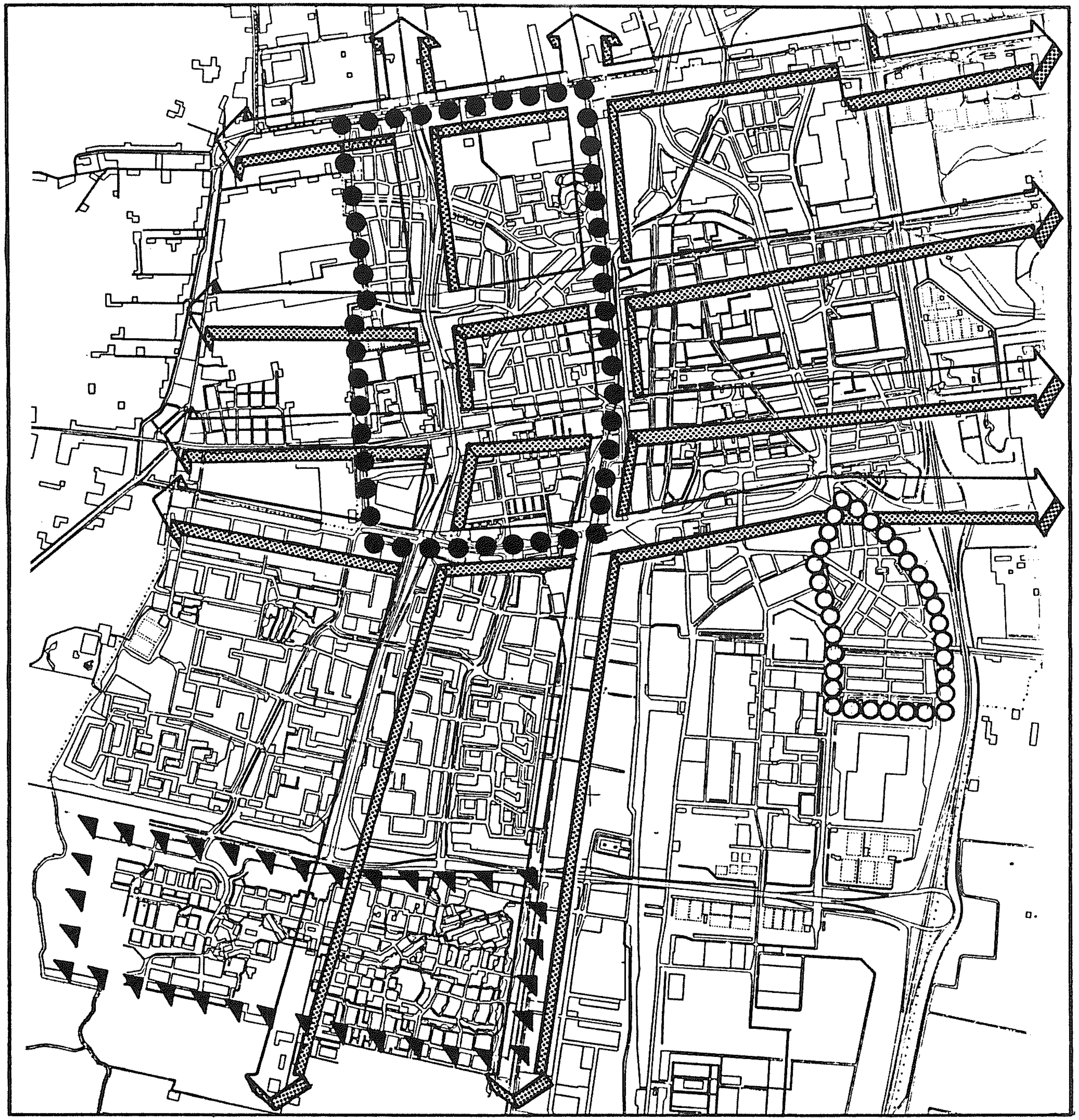
APPENDIX 2

DISTRICT 13,14 (NORTH-WEST): TEST AREA WITH CONCENTRATION OF MEASURES

DISTRICT WIPPOLDER: CONTROL AREA, NO MEASURES

TANTHOF DISTRICT, STRONG IMPROVEMENTS IN CORRIDORS TO CITY CENTRE

CORRIDORS TO STUDY AREAS



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Three sub-areas with connecting corridors

APPENDIX 3