Preface

The Danish Transport Council has engaged TetraPlan in a research project on ‘Traffic Effects of Metro in Copenhagen’. The project aims at describing changes in transport behaviour of the population in the Greater Copenhagen Area (GCA) due to opening of the Metro in autumn 2002.

The project is built as a before-and-after study in which data of different type will be completed in the period from year 2000 till 2005. The project has the following main phases:

Phase 1: Realisation of a literature study,

Phase 2: Completion of traffic counts, postcard surveys and personal interviews before and after opening of the Metro, and

Phase 3: Data analysis, which will lead to the description of changes in travel behaviour of the population in the GCA.

This report presents the results of the project’s phase 1.

A working group has been established to follow the project. The group includes:

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Professor Peter Jones, from the Westminster University in London, and Helena Sjöstrand from the Lund University are external advisors to the project.

The report is written by Goran Jovicic and Jane Ildensborg-Hansen, TetraPlan. Results and evaluations in this publication are the responsibility of the writers and are not necessarily shared by The Danish Transport Council.

The Danish Transport Council, May 2000

Contents

1. Introduction

1.1 Background

Transport infrastructure affects traffic, land-use, employment and labour market, tourism and consumer activities, environment and townscape in the area of its alignment and broader. Traffic effects of a new infrastructure can be defined as a difference between the traffic situations with and without that system, where all other circumstances are kept constant. These effects are difficult to measure because income, car ownership, road network and other things do change in the time of building of transport systems.

Traffic models can be applied in order to describe the theoretical difference between the two situations. If results of measuring the traffic effects before and after opening of a new system must be more accurate, other methods beside the application of traffic models must be applied.

Traffic effects of a new infrastructure in the form of a metro-system can be grouped under two major groups: changes in travel-patterns and changes in travel perceptions. Changes in travel-patterns include mode changes, route changes, destination changes, changes in frequency of travelling and changes in time of travelling.

Changes in travel perceptions among population describe how fast a new system adopts itself in the existing transport supply. A so-called 'inertia effect' often follows the introduction of a new infrastructure. This means that a number of people, who could apply the new infrastructure straight away, will tend to travel in the same way (e.g., the same mode and route) as they use to for a period of time after the introduction of a new system.

Traffic effects of a new infrastructure are measured by analysing data completed in before-and-after studies. In the vast majority of before-and-after studies from abroad these data originates from traffic counts and interviews, and to a smaller scale from postcard surveys.

One of the most often applied methods in the before-and-after studies is traffic-counts. Traffic counts can be used in order to identify traffic increase/decrease in an analysing area, changes in time-distribution of the traffic and changes in mode and route choices. Traffic counts can also be used in order to identify the period of stabilisation of a new infrastructure. Traffic counts must be carefully planned in time and space for a reason of not misunderstanding the obtained data. A number of traffic counts are required both before and after opening of a new infrastructure.

Personal interviews are completed in many before-and-after studies because they give the most detailed background information regarding respondents' travel behaviour. Socio-economic changes take usually place in the period between the before-studies and after-studies. In order to understand fully the effects of a new system over time these socio-economic changes must also be analysed. Travel diaries are important part of personal interviews.

Origin-destination (OD) surveys are typically done in form of postcard surveys. This kind of survey supplies traffic planners with information of how traffic effects of a new transport system are distributed over different trip purposes. Geographical spread of effects of a new system are also revealed in OD surveys. Postcard surveys can finally be used to recruit respondents for personal interviews.

1.2 Contents of the report

The report is built in a thematic orientated way. Two main subjects in the report are:

- Chapter 3: Methodologies applied in before-and-after studies, and
- Chapter 4: Traffic effects arising from the introduction of a new infrastructure.

Methodologies of interest in the literature study are:

- Definition of the analysing area in a study (chapter 3.1),
- Traffic counts (chapter 3.2),
- Panel data, interviews and postcard surveys (chapter 3.3), and
- Traffic modelling based on data from before-and-after studies (chapter 3.4).

Traffic effects described in the report relate to:

- Induced traffic (chapter 4.1),
- Changes in mode and route choices (chapter 4.2),
- Changes in time of travelling (chapter 4.3), and
- Changes in activities and in destination choice (chapter 4.4).

Chapters 3 and 4 begin with an introduction to the followed subjects. Further on, each of the sub-chapters begins with a short summary of the results from the followed case studies. Finally, in the third and most detailed level of the report are presented relevant case studies.

The summary of these two chapters is given in chapter 5. The most general overview of the literature study is therefore given in this chapter. For the readers who are not interested in details of the study it is proposed to read also the introductions in chapters 3 and 4.

Introductions to the sub-chapters will help those who are searching for specific subjects, e.g. changes in time of travelling. These introductions help also those who intend to read the whole report, as they give an overview of the specific subjects described in the followed case studies.

Each project included in this literature study defined a set of traffic effects to be investigated. According to that the analysing area, the type of data to be completed and the periods of data completion were also defined in the projects. The last three aspects of the projects can be called the *space*, *data* and *time* dimensions of the projects. Chapter 2 gives an overview of the included projects in the literature study in relation to the measured traffic effects and the project dimensions.

Process of searching of the literature took place in the end of 1999 and in the beginning of year 2000. The literature study refers to 30 reports and notes, which originate from Denmark, Sweden, England, Holland, France and Germany. The list of material included in the literature study is given in chapter 6. In some cases a number of reports refer to the same study, e.g. 7 reports from the Jubilee Line Extension project are included in the literature study. A list of studies included in the literature study is given in the beginning of chapter 2.

The literature study refers both to improvements in road/rail network and improvements of the public transport supply in a form of introduction or reorganisation of metro systems, light rail systems, tram systems and bus systems.

2. Project-dimensions and measured traffic-effects in the before-and-after studies up to date

Ten projects are included in the literature study:

1. Jubilee line extension,
2. VAL-system in Lille,
3. Supertram in Sheffield, local analysis in the West Street,
4. Supertram in Sheffield, general project,
5. Amsterdam-Almere tram system,
6. Bus system in Jönköping,
7. Ring road in Amsterdam,
8. The Great Belt railway project,
9. The Channel Tunnel, and
10. Metrolink in Manchester.

Jubilee line extension. The extended Jubilee underground line in London opened for operation in the end of 1999. The Jubilee underground line was extended into the east and south-east parts of London. This represents one of the major UK urban rail-investment for decades.

VAL-system in Lille, France. VAL in Lille is a fully automated metro system. The VAL system consists of two lines, where the first line was opened in 1983 and the second line was open in 1989. The VAL system runs with the headway of 1.12 minutes in the peak and 3.00 minutes out off peak, 20 hours per day.

Supertram in Sheffield. Supertram system in Sheffield consists of 2 lines, which are 29 km long in total. The system operates with 25 trams, where each vehicle consists of 3 sections, 35 meters long in total. Each vehicle can carry 250 passengers. The tram system in Sheffield was opened in a number of phases, the first in March 1994 and the last in October 1995.

Amsterdam-Almere tram system. Almere, Holland was a newly built town in 1987, situated some 25 km east from Amsterdam. A tram connection between Amsterdam and Almere was opened for operation in 1987.

Bus system in Jönköping. The bus network in Jönköping was reorganised in 1996. Instead of the bus network consisted of 12 ordinary bus lines, there was introduced a whole new system. This new bus network consists of a basic route network featuring high speeds and long distances between stops and a complemented bus network that have shorter distances between the stations.

Ring road in Amsterdam. The Amsterdam ring road was completed in September 1990 by opening the Ring North, which includes Zeeburger tunnel, and Ring East. The road extension provides extra road capacity for traffic crossing the North Sea Canal.

The Great Belt railway project. The fixed link over the Great Belt consists of a railway and a motorway connection. The railway connection opened on June, 1st 1997, while the motorway connection opened one year after on June, 14th 1998.

The Channel Tunnel. The Channel Tunnel between the United Kingdom and France was opened for traffic in 1994, seven years after the construction started. The link is defined to be one of the key elements in the present and future trans-European transport networks.

Metrolink in Manchester. Metro in Manchester, UK opened for operation in 1992. The system consists of two routes, one to Bury and the other to Altringham.

Each of the listed projects is completed taking into account the relationship between the effects to be measured (here is the focus on the traffic effects only) and the geographical, time and data dimensions of the studies.

Project-dimensions

A geographical dimension of a study refers to the size of the analysing area but also to the geographical-type of the applied analysis in the study. The analysing area in a study can be a very specific location as for example a single street (the case of the project in the West Street in Sheffield). In local projects that cover a small town or a single municipality (the case of the new bus system in Jönköping), the area of analysis is typically defined by the boarder of that area. Finally, in the case of large areas (e.g., the city of Lille or London) the geographical-type of the applied analysis is closely related to that part of the whole area, which is in one way or another influenced by the new infrastructure. For this kind of studies three types of analysis are most common: screen-line analysis, corridor analysis and catchment area analysis. The choice of the implemented type of analysis depends on the traffic effects to be investigated in the study.

Mode and route shares in the Great Belt project are measured on the screen-line, which is defined by the Great Belt and Kattegat. Defining a screen-line in the Great Belt project enabled an easier detection of the fixed link impact on the east-west traffic, due to fact that there is a limited number of ferry crossings between the two parts of the country. The Femer belt and the Øresund projects are also examples of the screen-line projects.

In a corridor analysis researchers are interested in measuring traffic effects of a new infrastructure (e.g., a new tram system or an introduction of a high-speed train between a pair of cities) in the area of alignment of the system. The Amsterdam-Almere tram-system project is an example of a corridor analysis project. The recently finished Copenhagen-Ringsted project is also a corridor analysis project. The project aims to describe the traffic effects of the improved railway infrastructure between the two cities, either as an extension of the existing capacity (i.e., an improved capacity of the railway line via Roskilde) or as a new corridor via Køge.

By a catchment area is defined a geographical area in which new transport systems have the biggest impact on the local population. Typical size of a metro system’s catchment area is in 1km radius around the stations. In catchment areas happen the biggest mode shift, induced traffic, changes in destination choice and changes in the time-of-day travel. Before-and-after studies in England following introductions of new public transport systems (e.g., extension of the Jubilee metro line in London, metro system in Manchester, tram system in Sheffield) are usually defined as catchment-area studies.

The time dimension divides the earlier listed 10 studies into those where the data is completed only in the after-surveys and those where the data is completed both in the before-study and in the after-study.

Finally, the data dimension classifies the studies among those where traffic-counts, postcard surveys and/or interviews are completed. In most cases more than one type of data is completed in a study. For the sake of simplicity it is not referred here to different types of interviews.

Types of effects of new infrastructure

New infrastructure influences the surrounding population in a number of ways. These effects can be summed up in the economical effects (e.g., increase in jobs), socio-economic effects (e.g., changes in car ownership), environmental effects and traffic effects. Most commonly analysed traffic effects in before-and-after studies are newly generated trips (induced traffic), changes in mode choice, changes in the choice of time-of-day travelling, changes in destination choice and changes in route choice.

Table 2.1 gives an overview of type of geographical, time and data dimensions included in the 10 studies. The same table also gives an overview of the measured traffic effects in the studies.

Dimensions and effects / Projects	Jubilee line extension	VAL-system in Lille	Supertram – local study	Supertram – general study	Amsterdam-Almere	Bus in Jönköping	Ring road in Amsterdam	Great Belt project	Channel Tunnel	Metrolink in Manchester
Geographical dimensions										
Analysis of the specific location										
Local analysis										
Screen-line analysis*										
Corridor analysis*										
Catchment area analysis*										
Time dimensions										
Only after-surveys										
Before and after surveys			( )					( )		
Data dimensions										
Traffic counts										
Postcard surveys										
Interviews										
Traffic effects										
Induced traffic										
Mode choice changes										
Time-of-day travelling changes										
Destination choice changes										
Route choice changes										

Table 2.1 – Project-dimensions and traffic-effects included in the analysed studies

*** This type of analysis is commonly applied in geographically large-scale projects**

Discussion

It can be observed from table 2.1 that calculation of induced traffic in a study is not dependent on the geographical dimension of the project. It is however important that data is completed at least once before and once after the introduction of a new infrastructure. Almost any type of data gives a possibility of measuring induced traffic as long as the data is completed in a consistent way. This means that both traffic counts and/or panel surveys give information about induced traffic.

Mode choice changes are analysed in all 10 projects. Any combination of the geographical, time and data dimensions in a study allows therefore a researcher to analyse modal changes in some scale. It is however important that data is completed both before opening and after opening of a new infrastructure.

Analysis of the choice of time-of-day travelling is not dependent on the geographical dimension of a study. Again, both traffic counts, interviews and postcard surveys (e.g., OD surveys) give a possibility of analysing this type of traffic effects in some scale.

Destination choice is vaguely described in the analysed literature. Only two studies (i.e., the local study in Sheffield and the railway Great Belt study) discuss this effect. Traffic counts can give an idea of changes in destination choices over time. Panel investigation gives however a much better starting point for analysing this type of traffic effects of a new infrastructure.

Route choice analysis is dependent on the geographical dimension of a study. Catchment-area studies cannot describe changes in route choices. Route choice changes can be properly described only in the screen-line type of analysis.

3. Methodologies

Under the term ‘methodologies’ are understood techniques for defining analysing areas, techniques for completing data and techniques for proceeding data.

Definition of an analysing area is rather essential for a successful before-and-after study. In the case of larger geographical areas three types of analyses are most relevant. These are corridor analyses, screen-line analyses and catchment area analyses. While the first two types of analyses have been applied in a number of Danish projects, catchment area studies are mostly applied abroad. A catchment area defines a geographical area around stations. Population in these areas is affected by a new infrastructure more strongly than population out of these areas (e.g., changes in mode choice, destination choice, frequency of travelling and time of travelling). Because of that panel surveys (e.g., household surveys) are usually organised among persons living and/or working in catchment areas. Extension of Jubilee metro line in London, metro system in Manchester and tram system in Sheffield projects are followed by before-and-after studies, defined as catchment-area studies.

Traffic counts, postcard surveys and interviews can be completed in many ways. Traffic counts can be done, for example, on a screen-line crossing the area of research. There are also examples where counts are done in a single street in order to measure only the local effects of a new infrastructure. Interviews can be completed in person, by telephone or by mail. There are interviews that are focused on a very specific subject (e.g., parking surveys) and there are interviews that are orientated towards a specific group of people (e.g., employer surveys).

Historically are data, which are completed in before-and-after studies, set up for purpose of monitoring changes rather than predicting changes. Accordingly, the vast majority of traffic models are based on the data completed prior to new infrastructure. In few cases some simple mode choice models are developed by applying data from both phases.

In each of the paragraphs below are first presented main results related to the subject and then results related to specific projects (i.e., case studies). The main subjects here are definition of an analysing area, traffic counts, interviews and postcard surveys, and traffic modelling based on data from before-and-after studies.

3.1 Definition of an analysing area

<u>Summary and discussion</u>

According to size of the area to be covered in a before-and-after study three categories of analysing areas can be defined:

- A very specific location as for example a single street,
- Smaller areas typically in a size of a municipality, and
- Large areas as for example the city of London.

The way of completing data in a study depends on the size of the analysing area. Corridor-type of analyses, screen-line analyses and catchment areas analyses can be completed in large analysing areas. A decision of which of the three types of analyses is to be implemented in a project depends on types of effects to be measured in the project. If economic effects (e.g., changes in employment, tourism) are important a catchment-area analysis should be implemented. The same type of analysis cannot, on the other side, describe changes in route choice. In that case a screen-line analysis should be implemented.

A screen-line analysis can however lead to a panel of respondents with a relatively large group of them who will not apply the new system in the future.

This can happen because they live or/and work far from the new system's stations. If researches want to obtain a panel of respondents to whom a new infrastructure has the largest potential impact a catchment-area analysis should be applied. The rest of this chapter presents how catchment areas are defined.

A catchment area defines a part of a larger area in which a new transport system has the biggest impact on the local population i.e., an area where effects are located and where effects originate. It is a general experience that catchment areas are defined on the corridors along the new systems or around the stations. Radius of impact of new systems (or in other words, the size of the area in which new systems have the biggest impact) depends on the type of infrastructure in question. The 'heavier' the new system is the greater area of impact of the system is. Tram systems have, as a rule, the weakest impact on the local population (typically about 400 meters around the stations) while metro systems have the strongest impact on the local population (typically about 1km around the stations). 600-800 meters radius around stations defines catchment areas for light-rail systems.

The precise size of catchment areas for different stations can be defined by applying traffic models for the area in question. Catchment areas must be analysed for the background data referring to age distribution, sex, family-size, income, employment and car-ownership distribution. The chosen panel must be a representative sample of the population in the catchment areas.

3.1.1 VAL-system in Lille [2]

Lille has approximately 1.1 million inhabitants. The population density is however low, which means that only some 110.000 people live in the area of 600 meters around the metro stations. The VAL system connects the city centre with the university campus, the major hospital complex in Lille and some housing areas.

Due to the low population density in Lille, the catchment area in the project was defined to be 600 meters (instead of 1000 meters) around the metro stations. The project results showed that the VAL system was a dominating mode of transport in the catchment area, where the mode shift to metro from other modes was as large as 50%. It took about one year for the VAL system to be fully integrated in the public transport system-network in Lille.

3.1.2 Jubilee line extension [9]

An extensive before-and-after study has been carried out from January 1997 by the Jubilee Line Extension (JLE) Impact Study Unit, from the University of Westminster in London. The study deals with a great number of metro impacts on the surrounding area. A number of various types of counts and interviews were undertaken in the project. For that reason a special attention was paid to the definition of the catchment area in the project.

The study shows that about 70% of underground passengers in London walk to and from a station between 10 min and 13 min. With a walk speed of 5 km/hr this equates to a distance between 800 meters and 1km. This is true for most underground stations in central London. Only Waterloo and London Bridge National Rail stations have a significant number of travellers walking to these stations between 1km and 2km.

On the basis of these evidences it was decided that 1km radius around 4 selected stations along the new Jubilee line defines the catchment area in the project regarding household panel surveys. The key stations in the area of JLE are defined by running the RAILPLAN traffic model.

The catchment area was afterwards analysed for a number of background data:

- Age distribution,
- Sex and family distribution,

- Income distribution,
- Employment, and
- Car ownership.

This analysis is important from the statistical point of view, i.e. the obtained interviewing sample should be distributed across the above mentioned characteristics similarly to the whole population in the catchment area.

3.1.3 Jubilee line extension [15]

The working paper 12 in the JLE before-and-after study refers to different definitions of catchment areas in some previous studies. The study of the metro system in Atlanta, USA defined the catchment area to be 800 meters around the stations (so called Transport Analysis Zones). The study of the Bay Area Rapid Transit (BART) in San Francisco, USA defined two types of the catchment areas, i.e. 400 meters radius of the Downtown stations and 800 meters radius of other stations.

3.1.4 Supertram in Sheffield – general study [17]

It was recognised in the report that the most likely users of Supertram were those people who live in the Supertram corridor or within 1km of tram stations. Data analysis of the population living in the tram catchment showed that people in the area were on average somewhat younger, came from larger households, were more likely to be full-time employed, belonged to higher socio-economic groups and owned cars more than people living outside this area.

3.2 Traffic counts

Summary and discussion

Traffic counts is the most spread method for observing changes in traffic over time in an analysing area. Modal changes, route choice changes, changes in time of travelling and changes in traffic volumes in an analysing area can be observed by completing traffic counts.

Counting of public-transport users is automatic nowadays. One way of doing public-transport counts is by monitoring the ticket system. The Copenhagen bus-company HT registers automatically the passengers both when entering and leaving the bus. In fully automatic systems, as the coming Metro in Copenhagen is, the traffic counts will be simply done by measuring the weight of the wagons at each station.

Car-traffic counts can be done automatically, but they can also be done manually. Pedestrian and bike counts are usually done manually.

It is important to note that traffic counts must be completed a number of times per year for the whole studying period. Multiply traffic counts increase the quality of completed data. Multiply counts also allow for observing changes in traffic patterns resulting from changes in supply (e.g., introduction of a new system or changes in pricing). Finally, time variations (day, week or seasonal variations) can also be monitored easier with the multiply traffic counts.

3.2.1 Supertram in Sheffield – local analysis [8]

Supertram system in Sheffield consists of two lines, which opened for operation in 1994 and in 1995. The report of the new tram system focused on a number of effects in a single street (i.e., West Street). The traffic counts applied in the project were completed in West Street, away from street crossings, in March 1989 and in November 1995. The counts were completed in period from 7am till 7pm.

3.2.2 Jubilee line extension [9], [10], [11], [12], [13], [14], [15]

A large number of traffic counts take place in the Jubilee Line Extension (JLE) before-and-after study in order to monitor the modal changes in the catchment areas. This includes regular counts for bus and underground passengers, entry/boarding counts, car traffic counts on the parallel routes to the JLE, parking counts and pedestrian counts.

Four different methods of pedestrian counting were exploited in the before opening study:

1. Full-time counts at each intercept location,
2. Full-time counts at selected intercept locations,
3. Interviewer administrated counts, and
4. Rotating counters.

Methods 1 and 2 are regarded to be a desired way of completing data but it is believed to be too costly for this type of data. Interviewer administrated counts completes counts the first 10 minutes of each hour. In the last method a rotating counter moved between a group of 3 interviewers and counted traffic for 10 minutes in each location, allowing 10 minutes to move between the locations. This was repeated each hour. Method three, i.e. interviewer administrated counts, were adopted for the future work regarding the pedestrian counts.

The public transport counts are completed automatically. The car-traffic counts are completed as full-time counts on the selected roads for the period of 12 hours.

3.3 Panel data, interviews and postcard surveys

<u>Summary and discussion</u>

By interviewing respondents from a panel in before-surveys and in after-surveys traffic planners can understand the traffic changes in the analysing area better as the socio-economic changes of the respondents are revealed in these surveys.

Household surveys are almost always done as panel surveys in before-and-after studies. Some of the critical points in relation to the household surveys are:

- Size of the panel,
- Period of completing the surveys in relation to the date of opening of the new infrastructure,
- Number of surveys with the panel, and
- Applied methods for interviewing the panel.

The size of panels varies from project to project in this literature study. The JLE study has a panel of 1647 households. The Amsterdam ring road project has a panel of 5000 household. In most cases the panel size is 2000-2500 respondents/households. The size of panels diminishes in after-surveys because some respondents change the address, die or refuse to participate in the after-survey because of other reasons. Experiences from two projects (i.e., Amsterdam-Almere tram-system and the bus system in Jönköping) show that the size of the panel decreased by about 25% in the after-survey.

In most cases are completed two household surveys, one in the before-study and the other in the after-study. Before-surveys are usually done just before opening of new infrastructure (i.e. 4 to 6 months before). If only one after-survey is planed, that is usually done 6 to 12 months after the opening date. It is assumed that short-term effects can be measured in those kinds of after-surveys. Long-term effects of a new infrastructure are typically measured 18 months after the system started with the operation. The group of researchers in the JLE project argues that 2 after-surveys should be done, i.e. one 6-9 months and the other 18 months after the opening of the new system. Bonsall [21] suggests that 2 after-surveys should be completed in the time period of 12 to 24 months after the introduction of a new system.

Household surveys can be completed on face-to-face basis, by telephone and as self-completed surveys. The quality of the completed data is highest in face-to-face surveys while it is lowest in self-completed surveys. Opposite to that, the costs bounded to the completion of surveys are highest in face-to-face surveys while they are lowest in self-completed surveys.

One of the most important information from household surveys is related to completion of travel diaries. In most cases respondents write travel diaries for one day only. Respondents in the JLE household surveys complete a three-day diary. The analysis of the completed data in the JLE project suggested that three-day diaries should generally be applied in household surveys because they measure intra-personal variability better than one-day travel diaries.

Design of questionnaires used in household surveys can be checked in pilot surveys. Pilot surveys also help in establishing/checking the validity of the analysing area.

Other surveys than household surveys need not to be connected to panels. These surveys are for example quality-surveys of any kind (e.g., surveys of bus passengers regarding a judgement of the present bus service), origin-destination surveys, on-street intercept surveys, employ/employee surveys and so on.

3.3.1 Timing of surveys [21]

Bonsall discussed timing of surveys in before-and-after studies primarily in order to detect induced traffic. In deciding when to carry out the surveys it is important to bear in mind that different responses take different lengths of time to become established and the ‘settling down’ period may be quite different from project to project.

In the case of shopping trips, changes in choice of time-of-travelling or choice of destination can occur quickly after the introduction of a new system. Besides that, some changes in behaviour might actually come about in advance of the ‘cause’, thus it is quite conceivable that land use changes might commence in anticipation of a network improvement and that new traffic thereby generated might arise before the new system itself is built.

Bonsall suggested that a pragmatic solution would be to conduct at least one before-survey and then at least two surveys after completion of the project. If only one before-survey is organised, it should be timed shortly before the new system opens for operation. If only one after-survey is to be organised it best to do it 9 to 18 months after implementation. If two after-surveys are to be organised they should be conducted in the period of 12 and 24 months after the start of the new system. Repeated surveys beyond three years or so would allow time for longer-term effects to become apparent but the data is likely to be clouded by exogenous factors.

3.3.2 Amsterdam-Almere tram system [4]

In order to monitor modal changes caused by the introduction of the Amsterdam-Almere tram system a panel of 2000 households was chosen. The respondents were interviewed the first time in 1987 prior to opening of the system. The after survey was done one year after with 1500 households. The interviews were done by a computer-telephone system (i.e., the system stores data automatically while interviewing respondents by telephone).

3.3.3 Supertram in Sheffield – local analysis [8]

The local traffic effects of the new tram system were investigated in the project by completing stop interviews, home interviews and interviews with the shop owners in West Street after the introduction of the new system. No before-surveys were completed in the project.

496 stop interviews were completed in July 1995. The period of interviewing was from 8 a.m. till 6 p.m.. Car users, pedestrians, bikers, bus and tram passengers were interviewed in the project.

74 home interviews were completed in the households in the area around West Street. Finally, 74 interviews were made with the shop owners and the personal working in the shops along the West Street.

3.3.4 Supertram in Sheffield – general study [17]

A large number of surveys were undertaken in the before-and-after study in Sheffield. The household panel in the study consisted of 3912 respondents. Some of the undertaken surveys in the study were:

- Household interview surveys (panel) – period: autumn 1993 and autumn 1995,
- Stated Preference surveys (household panel) - period: autumn 1993 and autumn 1995,
- Qualitative interviews (household panel) - period: autumn 1993 and autumn 1995,
- Surveys of bus passengers - period: autumn 1993 and autumn 1995,
- Surveys of Supertram passengers - period: autumn 1995, and
- Surveys investigating the importance of changes in bus and rail services - period: autumn 1993 and autumn 1995.

3.3.5 Jubilee line extension [9], [10], [11], [12], [13], [14], [15]

An extensive number of surveys take place in the Jubilee Line Extension (JLE) before-and-after study. A series of panel surveys take place with households, employers and employee. The before-surveys were done in the period between October 1998 and March 1999, i.e. 6 months before the metro line was opened. The first after-studies will be completed in October 2000. An extra household survey will be completed in 2001. The second survey is the main household after-survey in the study.

Interviews in the household panel are completed as a combination of face-to-face and self-completion questionnaires. The key variables in the household panel are:

- Personal and family socio-economic characteristics,
- Car ownership,
- Employment status,
- Skills and qualifications,
- Travel patterns, and
- Awareness of JLE and attitudes to transport.

In addition to the questionnaire each member of the family, which is 16 or more years of age, completed a three-day travel diary in the before-survey. In the pilot household survey were completed both one-day and three-day diaries. The analysis of the completed data suggested that three-day diaries should be applied in the main surveys because they measure intra-personal variability better than one-day travel diaries.

The sample in the household surveys is achieved by sending letters of introduction to households situated in the radius of 1km around 4 major stations along the JLE (i.e., the catchment area). The letters were either sent by mail or delivered personally to the selected households. The overall response rate for the household survey was 36%. 1647 households were included in the sample for the before survey. It is observed that there was no significant difference in the response rate between the two methods of delivering letters of introduction.

On-street intercept surveys are also planned in the project in order to determinate the impact of JLE on the local economic activities. Local employees, shoppers and tourists in the key areas along the JLE are included in the intercept surveys. They reveal the purpose for visiting the area and their activities whilst in the area. Employees complete a one-day travel diary in the intercept surveys.

Origin-destination surveys are also included in the study in order to localise the changes in travel patterns. A simple approach is adopted at the project, i.e. travellers do self-complete questionnaires regarding the origin and destinations. This approach can be described as a postcard survey.

It is important to underline that pilot surveys were done for the household, employ and employee surveys. The main purposes of the pilot surveys were to check the sampling methodologies, the definition of the catchment areas and design of the questionnaires.

3.3.6 Bus system in Jönköping [23], [26], [27]

Reorganised bus system in Jönköping is characterised by a high trip frequency and short travel time, new low-floor buses and included a high-technology information system announcing the arrival of the next bus.

There were completed a number of different analyses in the Jönköping project. One of the surveys aimed in investigating the changes in travel behaviour before and after the reorganisation of the bus system. This part was conducted as a travel diary survey following the practice of RiksRVU (National Travel Habits Survey). The interviews were conducted by telephone. The household panel in the before-study consisted of 3010 people in the age 15 or more living in the municipality of Jönköping. The panel was chosen from stratifications on age and area, which means that the number of persons in the different age groups and area groups corresponded to the share in the population. The same people were involved in the after-study but the after-panel consisted of 2309 people, which was the result of the fact that some people have moved away from the original addresses.

The before-and-after studies were carried out in March 1996 and in March 1998. The overall response rate for the household survey was 83% for the before-study and 90% for the after-study.

Besides the survey concerning travel behaviour the following surveys were undertaken:

- Quantitative interviews conducted on the bus concerning the passengers' assessment of the changes. Questionnaires were distributed to passengers on the buses and could be returned either on board the buses or sent by mail. The response frequency was around 75% and the study encompasses 4900 bus passengers.
- Qualitative interviews with a small number of bus-drivers and passengers after the reorganisation of the bus system.
- Stated Preference surveys, where the study began with contact-interviews at bus stops. About 420 names were recorded together with the person's

travelling time by bus on that particular day. It is estimated that 25% of the travellers did not want to participate in the study. In addition, individuals who arrived late at the bus stop were underrepresented in the sample. The SP-interviews were done by mail. No later than the day following the bus stop interviews, the letters with the SP-questionnaires were mailed. There were six types of SP-questionnaires. Only one questionnaire was sent to one respondent, which follows that about 70 individuals answered the same type of questionnaire. The response frequency varied between 71% and 90%.

3.3.7 Amsterdam ring road [18]

There was carried out a major before-and-after study in the city of Amsterdam in order to establish the short-term effect of the completion of the Amsterdam Ring Road in 1990. The before-survey was carried out four months before the new connection was opened and the after-survey was carried out two months after the opening date.

The study was based on a large household panel survey. A sample of 5000 households was drawn and interviewed by telephone. The questionnaire used was essentially the same in the before-study and in the after-study and it included questions about:

- The number of trips by destination,
- Mode used,
- Route followed, and
- Departure time.

The telephone interviewing method was chosen in the surveys. It was felt that the method was adequate because the questions were related to very specific trips with clearly defined origin, destination and purpose. This surveying method was used in the Netherlands several times before and tests indicated that the results of the method compared well with other, more expensive travel surveying methods.

3.4 Traffic modelling based on data from before-and-after studies

Summary and discussion

Panel surveys are in most cases completed for the purpose of monitoring changes. Information from after-surveys is usually applied in the existing traffic models for that area in order to re-calibrate the model for the new situation.

Experience from Holland shows that panel data from before-and-after studies can also be applied in, for instance, predicting mode choices. Multiply data from after-studies are necessary to determinate whether impacts of new systems grow, diminish or remain stable over time. Logit-type of models is often applied in this kind of modelling.

Time-series analyses are also applied in analysing data from before-and-after studies. This kind of analysis allows studying the extent to which specific factors (e.g., the ticket prices or the introduction of a new infrastructure) have influenced the changes in traffic.

Stated Preference (SP) data from before-and-after surveys are applied in the Jönköping project in order to estimate the value of different travelling-time components, bus frequency, interchanges, seat availability and the new information system.

3.4.1 Amsterdam-Almere tram system [4]

In order to describe the development in the modal changes in the Amsterdam-Almere project, a number of mode choice models were built. The models established a quantified relationship between changes in the level of services (e.g., travel time, travel costs, frequency of travelling) and changes in mode choice.

Models were built for the commuter segment only, which lowered the original panel of 2000 respondents to 475 respondents. The calculated in-mode time elasticity for train is –0.6. The train across-mode time elasticity is +1.2 for bus and only +0.2 for car. It can be therefore concluded from the obtained elasticities, that the new light rail system and the bus system are substitutes for the great majority of the commuters between the two cities, while car and light rail are not.

The experience from the before-and-after study in the project relates closely to the model results (see chapter 4.2.4 for details).

3.4.2 Amsterdam-Almere tram system - a practical comparison of modelling approaches for panel data [5]

The commuter panel data from the Amsterdam-Almere project was applied again, in total 475 respondents. Mode choice models of different kinds were built in the project. All models are of the logic type. The first two models applied only data from the after survey, because of what they were named ‘static’ models. The following 4 models applied all available data in different ways.

In the conclusion of the modelling work in the project it was underlined that panel data permits a wide variety of modelling approaches, which is not the case with the cross-sectional data (i.e., data from traffic counts). Panel data allows testing of various model specifications and derivation of various estimates of market shares and elasticities. It is suggested in the report that the panel data should be collected three or more times. Panel data from only two surveys (i.e., one before and one after survey) limits the possibility of estimating elasticities beyond a single period. Whether policies’ impacts grow, diminish or remain stable over time can easier be determined with multiply data from after studies.

3.4.3 Amsterdam ring road [18]

This before-and-after study measured the short-term effects of a major extension of the urban motorway system in the city of Amsterdam.

Conclusions from this study were that the most important effects of the new infrastructure are in the area of choice of time-of-travel and route choice. It is concluded that the model system must contain an explicit representation of time-of-travel choice in the case of existence of congested traffic conditions.

Given that congestion-effects are the driving factors behind the observed shifts in choice of time-of-travel and route choice (at least when existing bottlenecks are removed), the modelling procedure must be capable of reproducing these effects with high precision. That means that attention must be paid to estimating the travel time losses due to queuing and that a high level of detail must be retained during the model application process.

3.4.4 Bus system in Jönköping - time-series analysis [25], [26]

The reorganisation of the bus system in Jönköping was carried out in June 1996. A time-series analysis of travel statistics was conducted in the project on the basis of ticket sales month-by-month for the period 1990-1997. This kind of analysis allowed studying of the extent to which specific factors influenced the trend in numbers of passengers.

The analysis was made for the three most frequently used ticket-types, i.e. one-way tickets, monthly season tickets and prepaid tickets. ‘Pre-paid tickets’ was a special offer from the bus-operator, which included a possibility of buying a number of one-way tickets in shops instead of in busses. By doing that the passengers could save up 30% of the nominal price.

The bus traffic increased by 9% for those respondents using one-way tickets between 1990 and 1997. The corresponding increases for the other two types of tickets were 12% and 17%, respectively. It is important to note that the above increases are defined to be isolated from other effects (e.g., socio-economic changes) and that they, therefore, originate from the changes in the bus system only.

3.4.5 Bus system in Jönköping - Stated Preference analysis [27]

A Stated Preference study was carried out in Jönköping to form a part of the evaluation of the city's new bus system. The study showed that it is possible to do a Stated Preference study using questionnaires by mail and to get a high response rate, as well as reasonable and relatively certain evaluations.

Six different types of questionnaires existed in the project. In the sample of 420 respondents, each type of questionnaire was sent to a group of approximately 70 respondents.

The factors being analysed in the questionnaires were:

- Travelling time by bus,
- Walking time to bus stop,
- Bus frequency,
- Transfer time,
- Transfer compared to direct trip,
- Real time information at bus stop,
- Access to a seat, and
- Low floor bus compared to regular bus with small staircase.

Logit-type models were applied in the model-estimations.

4. Traffic effects

Changes in economical activities take usually place in the area along a new infrastructure. Some areas can suddenly be extremely interesting for both business and private housing due to improved accessibility arisen with a new infrastructure. Tourism can also grow rapidly due to a new transport infrastructure. Finally, a new infrastructure influences travel behaviour of people living, working and shopping in the area around that infrastructure.

The JLE before-and-after study focuses on all the above mentioned aspects of impacts of the improved metro system in the east and south-east parts of London. Most studies sampled in this literature study focus however on the traffic effects only. These effects are reflected in induced traffic, changes in mode and route choice, changes in time-of-day travel and changes in destination choice.

New public transport systems in form of metro attract first of all a large number of bus passengers. Magnitude of the mode shift to a new metro system is smaller for bikers and pedestrians, and smallest for car users. Many people change the route in order to include the new metro system in their travel. Changes in destination choice can occur due to the introduction of a new metro system because the new system can give a better accessibility to some areas. This is especially true for shopping trips.

Improved accessibility, followed from the introduction of a new system, often results in an increased number of trips, i.e. trips that otherwise would not be made. Trips that are solely caused by the existence of new infrastructure are understood in the literature study as induced traffic. Induced traffic is also formulated as ‘pure generated trips’ in the foreign literature.

In each of the paragraphs below are first presented main results related to the subject and then results related to specific projects (i.e., case studies). The main subjects in this part of the report are induced traffic, changes in mode and route choices, changes in time of travelling and changes in destination choice.

4.1 Induced traffic

<u>Summary and discussion</u>

Induced traffic is often a consequence of building a new infrastructure. A new infrastructure can give better accessibility to certain areas and travellers perceive that opportunity by increasing their travel. Shopping and other private trips usually count for the biggest part of induced traffic. New trips made purely as a consequence of a newly introduced system are understood in this study as induced traffic.

It is proved to be complicated to measure induced traffic. This is due to the fact that a new infrastructure is often not the only change made in the analysing area during a specific period. It is therefore difficult to separate the effects of the policy intervention and the effects of other changes.

A well-planned programme of traffic counts supplemented by different surveys (e.g., household surveys), both before and after opening of a new infrastructure, ensures necessary data for measuring induced traffic.

Introducing a new public transport system showed the following induced traffic volumes:

- 10%, one year after opening of the railway fixed link over the Great Belt,
- 12%, after introducing the Supertram system in Sheffield, and
- 13%, one year after reorganisation of the bus system in Jönköping.

4.1.1 Can induced traffic be measured by surveys? [21]

The article addressed the feasibility of measuring induced traffic by means of appropriately designed surveys. The author argued that measuring the induced traffic is not possible without a very ambitious programme of surveys involving a comprehensive schedule of traffic counts and household interviews over a wide geographical area. The expense of this, particularly the interview component is very considerable.

If a new infrastructure involves changes in land use then, in order to detect associated changes in the OD matrices, it would be useful to conduct trip-end interviews in the affected zones. Trip-end interviews need to be conducted from repeated waives of panel surveys.

If panel surveys are to be completed in a study it is important to make allowance for changes in the population between the before and after situations. A constant panel (i.e., the same panel of respondents in the before-study and in the after-study) will not pick up new residents who may have been attracted to the area as part of land use change initiated by the policy intervention.

In deciding when to make surveys to detect induced traffic it should be taken into consideration that different responses will take different lengths of time to become established. In relation to that one can measure short-term and long-term induced traffic.

4.1.2 Fixed link over the Great Belt [1], [29]

Transportrådets reports on the traffic effects of the railway fixed link over the Great Belt concluded that the daily number of personal trips between east and west parts of Denmark increased by 11% after opening of the railway connection. The daily traffic on the screen-line, defined by the Great Belt and Kattegat, increased from 55.080 passenger trips in the period June-October 1996 to 60.910 personal trips in the period June-October 1997.

The expected traffic increase on the screen line, under the assumption that the fixed link for railway has not been built was 1%. The rest of 10% related to the newly created trips, i.e. induced traffic, and/or to the trips, which have changed the destination. All new trips were carried by railway. Alternatively, these trips would either not be made or their destination would change.

The big increase in the train traffic was explained by the fact that the east-west trips became much shorter (i.e., travel time has decreased), which had a large impact on the business segment, cheap introduction prices and a large public interest for the fixed link.

4.1.3 VAL-system in Lille [2]

The VAL in Lille provides a very efficient public transport service. The system runs with a high frequency and the average availability is 0.998 (e.g., approximately 2 out of 1000 trips are delayed more than 4 minutes).

During the first 12 months of operation of the first VAL system, which is opened in 1983, the traffic rose from 35.000 daily trips to 74.000 trips. A portion of these trips came from the other modes (bus and car), but the biggest part of the observed increase was defined as induced traffic. This is connected to the fact that 47% of the newly observed traffic were not work-related trips.

4.1.4 Supertram in Sheffield – general study [17]

The Supertram system transported some 8 million passengers in 1996. 55% of the Supertram trips originated from bus, 21% from car traffic and 12% from other modes. Induced traffic counted for the rest of 12%.

4.1.5 Amsterdam ring road [18], [19]

The short term and long term effects of a major extension of the urban motorway system in the city of Amsterdam was analysed in the project. The results of the before-and-after study indicated that for inhabitants of North Holland (living north of the North Sea Canal), the opening of the Amsterdam ring road did not lead to a significant increase in the number of trips to Amsterdam in the short term (two months after the opening).

The traffic counts completed around the Amsterdam Ring Road showed that the opening of the Zeeburger tunnel led to 3% induced car traffic in the corridor in the short run. The main conclusion from a study carried out five years after the opening was that when correcting for autonomous growth, the increase in traffic turns out to be only a few percent higher than the short run effects. That made the authors conclude that most of the growth in car traffic, which was induced by the opening of the ring road occurred in the first year after opening.

4.1.6 Bus system in Jönköping [24], [26]

It was concluded in the report that 13% of the bus trips made one year after the reorganisation were newly created trips. This conclusion was drawn from the data completed in the quantitative interviews (see chapter 3.3.6 for details).

4.2 Changes in mode and route choices

Summary and discussion

New public transport systems have first of all a large modal effect on the existing public transport modes. Bikers and pedestrians are attracted by new public transport systems in a less scale than the public transport users. Finally, car drivers and passengers change to new public transport systems in a relatively small scale.

Larger effects in the car vs. public transport modal changes require introduction of restrictions on car travel, as for example, introduction of car-restricted areas, cutting down the number of parking places etc.

The following shifts in mode choice resulted from introductions of new public transport systems are observed in the literature:

- 3% of the total Danish east-west car traffic (observed on the Great Belt – Kattegat screen-line) shifted to rail 4 months after opening of the railway fixed link over the Great Belt.
- 6% of bus users in Jönköping travelled by car before the bus-system was reorganised in 1996.

Introducing an extension of the road capacity in Amsterdam had the consequence that 25% of all car drivers changed their route. The road extension did not have an effect on the mode choice except for a limited shift from passengers to drivers, i.e. a decrease in car occupancy.

4.2.1 Fixed link over the Great Belt [1], [29]

Table 4.2.1 shows the mode shares and increase in the Danish east-west traffic in personal trips per day, before and after opening of the railway fixed link.

The mode shift is rather small after the opening of the railway fixed link. As expected, the air traffic was influenced mostly by the new infrastructure. The air traffic to Odense decreased by 38%, while the air traffic to Billund decreased by 9%, from 1996 to 1997. The traffic to Aalborg increased by 2% in the same period of time.

6% of the car traffic changed to rail. From the route-choice point of view it was observed that car traffic over Kattegat is unchanged, while the car traffic over the Great Belt ferry routes decreased by 8%.

The large increase in train traffic is therefore primarily related to the newly created trips and the changes in destination choice. From the rail route-choice point of view it was observed that the train traffic over Kalundborg-Århus route decreased by 40% after opening of the railway fixed link.

	Car	Train	Air	Bus	Total
June-October 1996	30.590	13.370	6.660	4.460	55.080
June-October 1997	29.810	20.750	6.150	4.230	60.910
Changes from March-May 1996 till March-May 1997	3%	0%	+2%	-5%	+1%
Changes from June-October 1996 till June-October 1997	-3%	+55%	-8%	-5%	+11%

Table 4.2.1 – Danish east-west traffic by mode

4.2.2 VAL-system in Lille [2]

In the period of the first 12 months after the opening of the first metro line in Lille, in 1983, the metro traffic grew from 35.000 daily trips to 74.000 daily trips. The traffic surveys suggested that 50% of the latest traffic shifted from other modes (i.e., car, bus and tram). The rest was the newly created traffic.

4.2.3 Modal shares in some European cities [3]

The article in Transport Reviews Vol. 19 concluded that the introduction of new public-transport systems is not enough to persuade a larger number of car users to shift to public transport. The report focused therefore on the necessary actions for the European urban areas in order to decrease car traffic in inner cities after the improvements in the public transport supply have taken place.

	Car share	Public transport share	Share of non-motorised modes
Zurich	28	37	35
Basle	38	30	32
Amsterdam	31	23	46
Freiburg	42	18	40

Table 4.2.3 – Modal split for selected cities in Europe, 1990

Mode shares in the selected cities are presented in table 4.2.3. (Note that the modal shares before the public-transport improvements are not known.) These cities are chosen because apart from the improvements in the public transport service the city authorities restricted the car traffic by introducing car-restricted areas as well as by cutting the number of parking places in the inner cities. The extra available space on the streets were used in order to improve traffic conditions for bikers and pedestrians. The modal shares in the table refer to the inner-cities' in-going and out-going traffic.

4.2.4 Amsterdam-Almere tram system [4]

In 1987 the first phase of the light rail system was introduced between Amsterdam and Almere in Holland. A panel of 2000 households was interviewed the first time prior to the opening of the system. In the second wave, 12 months after, 1500 households were interviewed again.

The statistical analysis of the data showed no significant changes in the modal shares before and after opening of the railway connection. The data provided the following results:

- The commuter traffic had a slightly downward trend in before situation, while in the after situation that trend was stopped,
- Parts of Almere, less well served by the rail link continued to lose public transport travellers, and
- The new system did not change the modal share for education trips.

It is concluded in the report that improvements in public transport service between the two cities were not sufficient to cause significant changes in mode choices, at least when regarding the car users.

4.2.5 Metrolink in Manchester [6]

The before-and-after study following the introduction of metro in Manchester showed that the public transport on the corridors defined by the two lines, increased by 67%, from 7.6 million train passengers travelling in the previous railway system to 12.7 million metro passengers in 1994. Especially trips to the central Manchester increased sharply after the introduction of the Metrolink.

1.3 million car trips were removed from roads per annum as a result of the introduction of the Metrolink. Additional 3 million bus passengers per year changed to the Metrolink.

4.2.6 Supertram in Sheffield – local analysis [8]

The counted number of cars in West Street in 1989 was 9.664 while in 1995 6.797 cars were counted. The obtained data in the project showed that the sharp decrease in car traffic was caused by worsened conditions for car-users in the street, i.e. the introduction of the tram system in West Street slowed down the traffic flows and the number of parking places were reduced. The majority of the car users changed the route and the destination while only 14% of the car users shifted to the tram.

The public transport share (i.e., buses and trams) in West Street increased from 14% in 1989 to 22% in 1995.

64% of the tram passengers in West Street in 1995 were previously travelling by bus, 14% are old car user, 11% are previous pedestrians, and the rest of 11% originates from other modes, i.e. bike and motorbike.

4.2.7 Supertram in Sheffield – general study [17]

For the entire household sample (3912 respondents) over 50% of trips were made by car, 30% by foot, 14% by bus and only 1.3% by Supertram. Knowing that some 50% of the sample lives outside the catchment area (i.e., more than 1 km around the tram stations) it is not surprising that the total tram figure is so low. For those respondents living in the catchment area about 3% of all trips were made by tram.

Of trips by all modes made by those living in the catchment area about 23% were home-work trips whereas the Supertram carried only about 15% of these trips. Shopping trips counted for 23% of all trips whereas the Supertram carried 50% of these trips.

The data analysis showed that the most frequent users of Supertram were school children and elderly people. Students were responsible for 21% of tram trips and pensioners for about 26%.

The Supertram system transported some 8 million passengers in 1996, against the 22 millions predicted by the forecasting model made by MVA. 55% of the Supertram trips were shifted from bus, 21% from car and 12% from other modes. The remaining 12% of trips were newly made, i.e. induced traffic.

The mean travel time for Supertram trips was found to be 34 minutes, compared to 29 minutes by bus and 20 minutes for car trips. The qualitative analysis showed that comfort was the most important reason for using Supertram in relation to bus.

Respondents in the household surveys were asked if *'Supertram is a good thing for Sheffield'* or not. In the before survey only 1/3 of the respondents thought that Supertram is a good thing for the city while in the after survey nearly 50% of the respondents thought the same. The modal shares in the before-situation were not presented in the report.

4.2.8 Channel Tunnel [16]

The competition of the ferry companies was very hard in the first two-three years after the Channel Tunnel was opened. Most of the ferry companies increased the capacity as each operator sought to be the dominant operator to be left competing with the tunnel. The new supply (both the fixed link and the improved ferry traffic) attracted new trips, especially short-distance trips. This resulted in lowering the ferry prices, which in return caused the substantial traffic increase between the UK and the continent. It is noted that some of the traffic was induced but its size is not defined.

Table 4.2.8 shows the annual tunnel and ferry traffic between 1995 and 1998, in million of units. The percentages in brackets show the increase/decrease in traffic relative to 1995. It can be noticed that both the car, coach and train traffic via the fixed link increased substantially from 1994, while the ferry traffic started loosing its share in 1998, after a three-year period of traffic increase caused by the improved service and lower prices.

	1995	1996	1997	1998
Shuttle				
Cars	1.22	2.08 (+70%)	2.32 (+90%)	3.35 (+174%)
Coaches	0.23	0.58 (148%)	0.65 (+182%)	0.96 (+317%)
Train passengers	2.92	4.87 (67%)	6.00 (+105%)	6.30 (+115%)
Pass. ferry in Dover				
Cars	2.89	3.04 (+5%)	3.56 (+23%)	3.30 (+14%)
Coaches	0	0	0.17	0.15

Table 4.2.8 – Annual tunnel and ferry traffic figures in million units, 1995-1998

The report also described the changes in the modal shares for air and train traffic between London-Paris and London-Brussels, between 1994 and 1997. While in 1994 Le Shuttle transported only 3% of the annual magnitude of the air passengers between London and Paris, that proportion increased to 61% in 1997. In regard to London-Brussels, Le Shuttle transported 4% of the annual magnitude of the air travellers for this pair of cities in 1994 while in 1997 Le Shuttle transported 52% of the annual magnitude of the air travellers on the route.

4.2.9 Amsterdam ring road [18]

The road extension in Amsterdam provided extra road capacity for traffic crossing the North Sea Canal. As a consequence of that a number of car-passengers in the before-survey changed to be car-drivers in the after-survey, i.e. the extra road capacity resulted in decrease in car occupancy.

25% of all car drivers who crossed the North Sea Canal in the before-survey reported that they changed their route as a result of the opening of this new facility, the Zeeburger tunnel. Amongst commuters, this percentage was about 29% while amongst travellers with other journey purposes it was 15%.

The Zeeburger tunnel attracted, shortly after it was opened, a share of 19% of all car movements across the North Sea Canal. The most important shift in route was from the existing Coen-tunnel towards the Zeeburger tunnel (33% of total Zeeburger tunnel traffic came from the Coen-tunnel). It is worth noting that not only changes were observed towards the newly opened eastern part of the Ring Road, but that also ‘opposite shifts’ took place, back to the Coen-tunnel. This suggests that in the before situation the Coen-tunnel was being avoided by a number of road users, because of the high congestion levels in and around the tunnel. After the opening of the Zeeburger tunnel (which caused a reduction in congestion), these road users returned to their preferred route.

4.2.10 Bus system in Jönköping [23], [24], [26]

The survey investigating the travel behaviour in Jönköping showed that the total number of actually made trips by all modes decreased in the after-study, but that the bus share increased. The bus-share increased primarily among those under 25 and over 65 years of age. For those under 25 years the bus share increased from 22% to 27% and for those over 65 years the share increased from 8% to 11%. This information is based on trips made by people living throughout the municipality of Jönköping, and not only by those who live in the central urban area where the bus service was changed.

Bus passengers revealed in the on-board interviews how they travelled before the bus-network reorganisation. The replies showed that 11% used a different mode of transport, 6% previously travelled by car, either as driver (4%) or as passenger (2%). A certain changeover also occurred from pedestrian traffic and bike traffic (5%). 13% of the bus trips are newly created trips, i.e. they had not been made at all before the reorganisation.

When passengers were asked whether they changed their travel frequency by bus since the reorganisation 19% said that they travelled now more by bus, 10% travelled now less by bus and 71% did not change their bus travel frequency.

4.3 Changes in time of travelling

Summary and discussion

New infrastructure often influences the choice of time of travelling. Introducing a new public transport system has the following main effects:

- ‘Induced traffic’ effect occurs and a big part of the new traffic is not work-related. This has for a consequence that the increase in traffic occurs mainly outside the peak-periods (the cases of the new systems in Lille and Manchester).
- Shift of car traffic to the public transport modes reflects mostly in decreasing the peak-periods traffic (the metro system in Manchester).

Extensions of the road network in Amsterdam have the ‘return-to-the-peak’ effect on car drivers. This is caused by the fact that the road improvements related in less congestion and shorter travel times. As a result of that the travellers switched to a departure time better suited to their preferences. Proportion of the commuters who change the time-of-travel is larger than the proportion of the non-work related journeys.

4.3.1 VAL-system in Lille [2]

The VAL system in Lille influenced changes in time of travelling in the area along the system. VAL's high frequency combined with its high availability helped in changing the picture of the peak and out off peak traffic.

47% of the new metro traffic was not work-related. These trips were usually taken between the two peak-hours or later in the evening. A typical urban rail system bears between 15% and 20% of the daily traffic in the morning and afternoon peak hours (2x2 hours), each. One year after opening of the first metro line in Lille, VAL's morning peak traffic related to 12% of the total daily traffic, which suggest a rather large shift in the choice of time of travelling.

4.3.2 Metrolink in Manchester [6]

Metrolink in Manchester reduced car traffic in the city centre with 1.9% in peak hours and with 0.7% in the out of peak hours.

The increase in metro traffic was unevenly distributed over time. The off-peak metro traffic increased twice on the Bury corridor from 1991 to 1994, while the off-peak metro traffic increased 166% on the Altringham corridor in the same period. The peak traffic increased for 60% in average for the two corridors from 1991 to 1994. The changes in time of travelling suggested that the majority of the newly created trips by metro were not home-work trips.

4.3.3 Supertram in Sheffield – general study [17]

The Supertram system in Sheffield failed in attracting the commuters until now. The project results showed that only 15% of the tram users were commuters. On the other side were children and elderly people who applied the tram much more often than the commuters. The shopping-trips and education-trips made far the biggest part of the tram trips.

The large importance of the non-commuting trips meant that the morning and afternoon-peak traffic for the tram system in Sheffield was much smaller than in a typical urban rail system.

4.3.4 Amsterdam ring road [18]

29% of all car users in the project who crossed the North Sea Canal reported that they had changed their departure time. Changes took place in both directions, i.e. there were earlier as well as later departures. Many of these changes concern relatively small shifts in departure within the peak period itself. Table 4.3.4 shows the net increases/decreases in the trips for all purposes and for commuter trips after opening the new ring road, relative to the before-situation.

Passing time	% change all purposes	% change commuter trips
0-7 am	- 8%	- 6%
7-9 am	+ 16%	+ 19%
9-12 am	- 11%	- 11%

Table 4.3.4 – Observed changes in river crossings in the North-South direction

The table shows that the so-called 'return-to-the-peak' effect seems to have occurred amongst car drivers after the ring road was opened. Before the opening of the new facility, these travellers presumably chose departure times, which were different from their desired departure times. The road improvements related in less congestion and shorter travel times. As a result of that the travellers switched to a departure time better suited to their preferences.

The share of car-commuters in the panel, which changed the departure time in the two surveys, was 31%, while the share of the car non-commuters, which changed the departure time between the two surveys, was 21%.

4.4 Changes in activities and in destination choice

Summary and discussion

Improved accessibility influences the travel behaviour and the undertaken activities of people living, working and shopping in the area around a new infrastructure. Better accessibility to some areas provided by a new infrastructure causes also destination changes. That is first of all reflected in shopping and other private trips.

The fixed link over the Great Belt has already changed the living style of the people who live and work in the region surrounding the fixed link. It is expected further on that the number of commuters passing the Great Belt will continue to increase in the future. The number of short and longer business trips will also increase and finally the number of private trips will change, as people living on one side of the Great Belt began to attempt the cultural activities on the other side of the Great Belt.

The tram system in Sheffield caused indirectly a decrease in shopping activities in the main shopping street in the city, the West Street. The tram system slowed down the car traffic, as less space is now available for the drivers. In addition to that a number of available parking places were drastically reduced after the opening of the new system.

4.4.1 Fixed link over the Great Belt [1], [29]

Transportrådets reports on the traffic effects of the railway fixed link over the Great Belt postulated that the fixed link changed the way of living in the areas close to the fixed link. Importance of the railway connection is of different magnitude for different trip purposes. It is expected that the destination choice has changed for a number of commuters because of the possibility to live and work on the opposite sides of the Belt. The number of private trips (activities) have also increased, as people easier choose to buy summerhouses on the other side of the Belt. The cultural activities have also found no barriers in the length of travelling after the fixed link was opened.

The greatly improved accessibility between the two parts of the country influenced also the number of activities on longer distances. A large number of new business trips were observed by train between Copenhagen and Århus after opening of the railway fixed link because business people can now travel between the two cities in the same day and additionally work while travelling.

4.4.2 Supertram in Sheffield – local analysis [8]

West Street in Sheffield is one of the major shopping streets in the city. The lowered speed for car traffic in West Street resulted from the introduction of the tram and the reduction of parking places caused a decrease in the shopping activities in the street. The analysis of the data completed from interviews with the travellers and the shop owners/assistants in West Street showed that the number of activities slowly decreased with the time after opening of the tram system.

5. Summary of the applied methodologies and analysed traffic effects in before-and-after studies up to date

The largest traffic impact of a new public transport system occurs among people living and/or working in a 400-1000 meter radius around stations. These areas are called catchment areas and they can be more precisely defined with the help of traffic models. Catchment areas must be analysed for the background socio-economic data because the chosen panel for the household and other surveys should statistically correctly represent the population in these areas. Corridor and screen-line analyses are also frequently applied in before-and-after studies, which follow the introduction of new public transport systems.

Changes in traffic volumes, modal changes, route choice changes and changes of time of travelling can be observed by completing traffic counts. Traffic counts are usually completed a number of times per year for the whole studying period. One reason for that is that the accuracy of the obtained data becomes better with multiply counts. Time variations can also be observed in the case of multiply counts. Finally, changes in traffic patterns arising from price changes (e.g., increase in petrol price) or changes in the infrastructure (e.g., an introduction of a new metro system) can be better monitored with multiply counts.

In order to understand the traffic effects of a new infrastructure better traffic planners must analyse changes in the socio-economic characteristics of the chosen panel or travellers along the time. Household surveys reveal in details the background information of respondents' travel behaviour. An average panel size of the projects included in the literature study consists of 2000 households. The before household surveys are usually completed 4 to 6 months before opening date of a new system. European researches recommend completion of 2 after-surveys for measuring short-tem effects (6 to 12 months after the opening date) and long-term effects (about 18 months after the opening date) of a new infrastructure. Face-to-face surveys deliver the highest quality of the obtained data but they are at the same time the most costly way of completing the data. The opposite is true for self-completed surveys.

Introduction of a new infrastructure is often followed by induced traffic in the area defined by that infrastructure. Especially shopping trips increase with the improved accessibility to certain areas. It is rather difficult to measure the magnitude of induced traffic because the traffic effects of a new infrastructure are mixed with the other changes (e.g., socio-economical changes) in the analysing area along the time. It has been therefore proposed in the analysed literature that a number of traffic counts and surveys of other kinds (especially the household panel survey) should be completed in before-and-after studies.

The largest shift to new public transport systems comes from other public transport modes. Bikers and pedestrians shift to new public transport modes in a smaller scale. Introduction of new public transport systems is often not enough to persuade many car users to shift to public transport.

A large increase of the non-work related trips, which is caused by new public transport systems, lowers the magnitude of the peak-hours traffic and increases the magnitude of the out of peak traffic. Finally, a new infrastructure often causes changes in the destination choice. The reason for that is that some areas get a substantially better accessibility with the introduction of a new infrastructure.

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