TRANSPORT TELEMATICS IN URBAN SYSTEMS—A BACKCASTING DELPHI STUDY

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Abstract—This paper includes a presentation of the results from a scenario study on transport telematics in urban passenger transport. An international Delphi panel of 100 experts from 20 countries replied to questions on the feasibility and impact of a restricted number of different technical scenarios. The results show that most experts see substantial potential for limiting certain transport problems if there is broad implementation of transport telematics as described in this study. The majority of experts favoured a scenario based on extended public transport information. In that scenario, environmental gains were in practice paid for in terms of less comfortable trips and longer travel times. © 1998 Elsevier Science Ltd. All rights reserved

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1. INTRODUCTION

The future development of transport telematics has the power to change the conditions for people’s movements. It is important to be aware that this development involves opportunities as well as risks. The results of the change are not predestined.

The field of transport telematics is developing very quickly. This development is driven by industry. It focuses on finding markets for new functions and on solving specific tasks in the traffic system, e.g. route guidance, public transport information or parking reservations. The motivation for the research has been to find competitive IT products and functions for sale to the car industry and car owners. It is quite possible that spontaneous development along this path will not lead to the transport system most desired by society as a whole. There are two main reasons for this. The first reason is that by developing a transport system based on functions demanded by users, the interests of non-users are not represented in the development, although many non-users are definitely affected by it. The second reason is that a transport system cannot solely be described by the functions that are included in it. A transport system also includes, for example, vehicle operators and organisations. The functioning of these elements and their interrelation are just as important for the description of the system (Gudmundsson and Höjer, 1996). Obviously, a system that is built on the separate functions that are demanded runs the risk of not being the preferred system if a wider perspective had been used.

The aim of this study is to provide information that can be used when long-term public policy for the development of transport telematics is being formulated. Today’s transport system violates sustainable development (Gudmundsson and Höjer, 1996), and current trends point towards continued expansion in traffic volumes and growing problems (for example, related to congestion, energy use, environmental degradation, safety and barrier effects). It is therefore important to investigate how such a powerful tool as transport telematics can be used to overcome these and other problems.

By presenting the functions in scenario settings, a holistic, problem-oriented view is accomplished, which is not common in the transport telematics literature. The aim has been to generate scenarios that facilitate change towards a transport system in accordance with the principles of...
sustainable development. Using scenarios will make it possible to present IT functions in a societal environment, thus revealing the advantages and shortcomings of separate parts of a system.

In this study a combination of backcasting, Delphi assessment and other scenario techniques has been used to reduce the problem with the non-users’ lack of influence. The backcasting approach mitigates the risk that only potential customers are taken into account by the focus on reaching targets rather than on fulfilling demands. The use of a Delphi expert panel can help by pointing out parts of the scenario descriptions that have a negative effect on non-users. The scenario descriptions in themselves facilitate for non-users to take part in the debate, since they display a number of separate alternatives. Therefore, it is quite plausible that the interests of non-users are given higher priority with this approach than when development is purely demand driven.

In the next section, ‘Backcasting Delphi’, the method used in the survey is explained. The section following that, ‘The Survey’, includes a rather concrete description of how the survey was carried out, whereas ‘Validation of the Method’ is an attempt to validate the method by looking at response rates, potential biases, and the stability of responses.

The section headed ‘Scenario Specific Results’ is the first section including actual results. It presents the experts’ judgements of the three individual scenarios, with one subsection per scenario. These subsections also include the scenario descriptions that were generated in the study. The scenario descriptions are important outputs from the study and may be read separately. In ‘Comparison of scenarios’, the results from a comparison of the three scenarios are given. The article ends with a concluding discussion.

2. BACKCASTING DELPHI

A method suited to the process of formulating long-term public policies has been developed, here called Backcasting Delphi: a structured scenario technique, which is a variant of technology assessment, designed as a combination of a backcasting, scenario and Delphi study.

Backcasting is a scenario technique which focuses on presenting solutions to problems that do not seem to be solved, according to conventional scenarios, trends and forecasts. By concentrating on solving certain problems, the idea is that solutions that do not show up in ordinary analysis may become visible. When an image of the future has been identified which seems to solve the problem in question, the task is to depict a path between that image and today. On the other hand, if an image does not seem to solve the problem, the path will not be explored. Instead, the image will be redeveloped and adjusted. A more comprehensive description of backcasting can be found in Dreborg (1996).

Delphi surveys are a way of questioning experts on their opinion regarding certain aspects of development. The questions are repeated at least once in order to let the experts react to responses to previous questions. The questions are often quantifiable: e.g. “Within how many years will something specific happen?” or “How many percent of the population will have access to something specific within 20 years?”. In the past, this method has been used primarily within the field of technological forecasting. However, as we will see, it can also be used as a complement to backcasting. In order to create interesting scenario descriptions or images of the future, solid understanding of the performance of state-of-the-art technology is a prerequisite. This understanding can be hard to build since there might not be consensus as to what is state-of-the-art, and because the experts on one scenario description might come from several disciplines.

The Delphi technique used in the 1960's and 1970's has been criticised by, among others, Asplund (1979), and Sackman (1974). Their critique does not touch this study in any substantial respect, since they both focus on conventional Delphi studies, where the aim is to produce a reliable forecast, rather than contribute to the policy formulation process.

Backcasting was the first source of inspiration for development of the method in this study. No attempts were made to prognosticate the most probable development or dissemination paths of certain technology. Instead, the aim was to formulate scenarios that can lead towards sustainable development. The scenarios were formulated as descriptions of how technical systems could function, and how they could be used. In this study, the second part of a backcasting study, the paths between today and the scenarios were not depicted.

The Delphi method was elaborated to overcome the difficulty of experts coming from several disciplines. Scenarios were developed within the research project and then exposed to repeated, structured external critique, in a Delphi-like manner. The experts were asked to comment on
the scenarios (for example, in terms of their feasibility and coherence to sustainable development), in order to make use of the knowledge and ideas that already exist around the world. The idea with a repeated round was to provide an opportunity for incorporation of criticism and new suggestions in the scenario descriptions, thereby hopefully improving the experts’ evaluations of feasibility and long-term effects. The repetition also made it possible to check the stability of the experts’ responses. The opportunity to change the descriptions between rounds differentiates this method from a conventional Delphi study, where the point of the repeated round often is to bring experts to consensus statements on, for example, the scale of future effects. These interactions can, in principle, continue for several rounds. In the present case, two rounds were performed: an initial round, plus one improvement round.

The choice of the expert panel can be a crucial stage of a Delphi survey. It is less important with the method developed here, but the results are still affected by the selection of respondents. Here, the panel’s task was to improve the scenario descriptions and to evaluate the feasibility and contribution to sustainable development of the scenarios. All experts were given the opportunity to formulate arguments in their own words. In this way, a good idea had the opportunity to survive in the ocean of responses, even if it was only mentioned by a single expert. In conventional Delphi studies, less emphasis is put on the comments and thus isolated good ideas have less chance of being identified.

The sustainability of a transport system is obviously affected by several different factors, e.g. development of alternative fuels, economic development, and changes in spatial structures. Therefore, the scenarios presented here, which focus on the use of transport telematics, can never be claimed to be sustainable development scenarios as such. However, provided implementation, telematics ought to make it plausible that the scenarios would contribute in a positive way to change the transport system in a sustainable direction.

In Sweden, backcasting studies have mainly been used in futures studies on energy (e.g. Johansson and Steen, 1980, and Lönnroth et al., 1980). There is also a Canadian tradition of backcasting, where Robinson is a major advocate (Robinson, 1990). Backcasting has recently become more widespread, used in the OECD EST project (Environmentally sustainable transport project), the EU DG XII project POSSUM (Policy Scenarios for Sustainable Mobility), the Dutch Governmental Programme for Sustainable Technology Development, and a Swedish transport futures study (Steen et al., 1997), among others.

The Delphi technique has been used in, among other studies, Masser et al. (1992), where three different scenarios of the geography of Europe were evaluated. It has also been used to estimate the potential of transport telematics when it comes to safety improvements (Hydén, 1995), and in the Technology Foresight Project on Transport (Office of Science and Technology, 1995), where the priority developments of wealth creation and the quality of life were evaluated.

In the EU DG XII project STEEDS (Scenario-based framework for modelling transport technology deployment: energy-environment decision support), experts were used to come up with ideas that were later integrated within the project to generate scenarios, i.e. the experts were involved at an earlier stage of scenario building than in the present study. The aim of the scenarios was also another. They were more forecasting oriented and the idea was to develop a computer-based decision support tool, to project market uptake of transport technologies, and to quantify the energy and environmental impacts of these.

Finally, in a CEST project from 1993, a survey on the use of transport telematics was carried out among local authorities. This was a variant of technology assessment related to the one in this study, but with a shorter time horizon, and without the explicit use of scenarios (CEST, 1993). A review of several different models and methods for strategic assessment of transport telematics has been carried out by Lind (1997).

The underlying ideas within the study have been presented above. The method, a combination of backcasting and Delphi surveys, has been explained and certain examples of related studies have been mentioned. In the next section follows a rather straightforward description of how the survey was carried out.

3. THE SURVEY

The survey consisted of two rounds. The first round was sent out in the spring of 1995. The responses to this were analysed and a follow-up questionnaire with the reformulated scenario
descriptions was sent out in the beginning of 1996. One scenario was cancelled in the second round, another was extensively reformulated, and the remaining two went through minor changes. Only the three scenarios that were included in round 2 (see Table 1) are analysed in this paper.

The scenario descriptions were placed in the context of passenger transport in industrialised cities. They focused on the use of information technology in transport, but did not include effects from teleworking, for example. All scenario descriptions followed the same structure. They began with a few lines about the basic ideas behind the scenario and continued with a description of the functioning of some crucial features. This was followed by examples of how trips could be carried out and explanation of more specific details. They all ended with a list of the most important functions contained in the scenario. The time perspective was left open, so that scenarios of different technical complexity, and at different stages of development, could be presented in the same way. Although the scenarios partly overlapped each other technically, they were based on different basic ideas. The full scenario descriptions can be found below in subsections to ‘Scenario Specific Results’.

The questionnaire was designed to give an idea of the experts’ views of pitfalls and advantages related to the feasibility and impact of the scenarios. The feasibility assessment consisted of questions on technical functions and acceptance characteristics. In the former, the experts were asked to state their opinion on how certain functions would affect technical feasibility. In the latter, the experts were asked to state how a certain characteristic would affect public acceptance of the implementation of a scenario. The impact assessments included market penetration and expected long-term effects following implementation of a scenario. Moreover, the experts were asked questions on the desirability, probability and economic consequences of implementing the scenarios (Table 2). Besides the structured questions, extensive opportunities were given for comment, in the respondent’s own words, on the descriptions. This article concentrates on the results of the feasibility and impact assessments. Some results from the questions on implementation are mentioned in the concluding discussion.

Except for the questions mentioned in Table 2, the experts were also asked a number of questions regarding their personal background. This, and the fact that two rounds were used, has been used to validate the survey. The validation follows in the next section.

4. VALIDATION OF THE METHOD

4.1. Biases due to the experts’ sociocultural backgrounds

The experts were asked questions on their age, sex, education, home country, workplace, field of work, and mode of travel to work. These sociocultural factors were then analysed together with the respondents’ replies. The aim of this analysis was to find out if certain groups of experts favoured certain types of scenario.

It turned out that the differences in responses between different sociocultural groups were small. None of the tested groups of experts favoured one scenario over another, at an aggregated level, when it came to feasibility and anticipated effects (Höjer, 1997).

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<tr>
<th>Table 1. The scenarios in the second round of the survey</th>
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<tbody>
<tr>
<td>Scenario</td>
</tr>
<tr>
<td>Dynamic Route Choice</td>
</tr>
<tr>
<td>Extended Public Transport</td>
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<tr>
<td>Dual Mode</td>
</tr>
</tbody>
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<table>
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<tr>
<th>Table 2. The questions</th>
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<tbody>
<tr>
<td>Feasibility assessment</td>
</tr>
<tr>
<td>Impact assessment</td>
</tr>
<tr>
<td>Implementation</td>
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4.2. Response rates

Eighty-six out of 310 experts (28%) replied to the first questionnaire. The response rate to the second questionnaire was 63% (54 respondents out of the 86 who replied to the first questionnaire). Furthermore, 11 experts responded out of the 20 who only received the second questionnaire. A broad panel was sought and the distributions on experts’ ages, home countries and fields of interest were fairly even. However, academics and men were over-represented. In Table 3 below, the profile of the panel is given. The table includes all 97 experts that took part in the survey.

The uneven gender balance, with only 14% women, is regrettable, since the planning of a transport system affects both men and women. Moreover, there are some questions that involves men and women in different ways. Most obvious here are issues that concern users’ perception of personal threat during a trip. However, the responses at an aggregated level did not differ much between the sexes, as explained in the previous section.

When policy is formed, a number of actors try to influence the process. When it comes to transport telematics, the problem is primarily not the bias of influence, but the almost entire lack of public policy. There are no ‘truths’ about what type of transport system is most desired. In this study, views were collected from people who have been working on these issues. The objective was not to perform a statistical analysis. Instead, the idea was to collect, organise, and analyse a number of expert responses via a scenario technique, and to build a basis for policy discussion about how telematics can be used to mitigate problems related to urban passenger transport. For these purposes, the composition of the panel and the number of responses were acceptable.

4.3. Stability of responses

The use of two rounds made it possible to check the stability of responses. This was done by selecting questions that were exactly the same in the two rounds and comparing the responses for each expert (54 people). Such a check shows a high stability in responses (Höjer, 1997). The experts were asked to evaluate the technical feasibility of a number of functions, and the effects on acceptance of a number of characteristics for each scenario in both rounds. The evaluation was made on a scale from 1 to 5, where 1 indicated that the function would be technically very difficult to implement (or affect acceptance of the scenario very negatively), and 5 indicated that it would be technically very easy to implement (or affect acceptance very positively). Only about 10% of the responses changed significantly (more than one step on the scale from 1 to 5) in these questions. The number was slightly higher for the scenario Dynamic Route Choice, which was the scenario with the largest changes between rounds.

In the questions on long-term effects, the experts were asked if they thought that a number of statements were true, false, or if they had no opinion. The formulation of the questions was changed between the rounds. The change was expected to lead to a greater share of experts indicating no opinion, and to a smaller share of experts indicating that the statements were false.

It turned out that 50–60% of all responses were not changed at all; 10–15% went from true to no opinion; and approximately 10% went from false to no opinion. In round 1, there were approximately twice as many true-responses as false-responses, which means that a greater share of the false-responses was changed. Very few went all the way from false to true, or the other way

| Table 3. Socio-cultural profile of the experts (age, sex, country, workplace and field of work) |
|---|---|---|---|---|---|
| Age | % | 17 | | | |
| Sex | % | Men | 86 | Women | 14 |
| Country | % | Sweden | 29 | Rest of Nordic Europe | 14 |
| Workplace | % | Private company | 13 | University | 48 |
| Field of work | % | Environment | 56 | Information technology | 37 |
|   |   | Public policy | 53 | Telecommunication | 19 |
|   |   | Transport | 73 | Sustainable development | 41 |
round. This indicates that the experts’ responses were quite stable between rounds and that, approximately, the envisaged changes occurred.

The differences between those who only responded in round 1 and those who responded to both rounds were checked. A hypothesis was that the former group was more critical to the scenarios than the latter. However, an analysis of the response patterns revealed no substantial differences between the two groups (Höjer, 1997).

To sum up, almost 100 experts from 20 countries responded to the questionnaire. The validation of their responses indicates that the method developed in this study is suitable for its purpose.

5. SCENARIO SPECIFIC RESULTS

Below follows one subsection for each of the three scenarios that were included in the second round. They consist of full scenario descriptions and summaries of the responses from the experts. The scenario description for Car Pooling can be found in Höjer (1997).

When the responses from round 1 were analysed, it was evident that a large number of experts found one of the scenarios, Car Pooling, less convincing than the others. In particular, the experts found it inconceivable that people would accept going by car with unknown people, one of the core parts of the scenario. Due to this critique, Car Pooling was not repeated in the survey’s second round. A less demanding form of organised car pooling, involving only colleagues and neighbours, was included in Dynamic Route Choice instead. Thus, Dynamic Route Choice was extensively reformulated. The other two scenarios went through minor changes in response to the experts’ assessments in the first round.

5.1. Dynamic Route Choice

Dynamic Route Choice was designed to optimise the performance of the urban transport system with the help of dynamic road user fees. Many central functions for this scenario are described in Lind (1996).

5.1.1. Scenario description for Dynamic Route Choice. Dynamic Route Choice implies that road traffic is directed with the help of a route choice model. A route guidance system and a system for vehicle intersection control are available for all drivers that follow the suggestions from the model. Road user fees are charged to cover the damages caused by traffic. The fee varies with time of departure, place and vehicle, but it is normally fixed once a driver has accepted an offered price for a drive between an origin and a destination. A system for fee calculation and fee-collection and a system for parking place reservation are also included in the scenario.

Damages from traffic on global and regional ecosystems are paid for via a fuel tax. Local disturbances caused by traffic, e.g. air pollution, congestion, noise, safety risks and perceived threats (road users’ as well as pedestrians’) are covered by road user fees. This implies roughly that it is more expensive to drive old, big cars, to drive in city centres or housing areas and to drive in peak hours. On the countryside no fees apply—only the fuel tax is paid. The exact levels of the tax and the charges are in practice compromises between the estimated costs for traffic damages and what is politically feasible.

A traffic control centre collects information about ongoing and planned trips. The centre also gets continuous information about air quality, state of the roads, road repairs and accidents affecting the traffic. Based on this information and on past and present traffic situation, the centre makes short-term (minutes) traffic forecasts.

The information about present situation, the forecasts and the politically decided charges for traffic are used as bases for regular recalculations of fees on the road links. From this a route choice model can calculate the cheapest and the quickest path between two places for a specific vehicle. All fees except the congestion fee are vehicle-specific so that energy-efficient, low-noise, small, light vehicles with low emissions pay lower fees. The payment is made through a rechargeable card that is placed in a card reader in the car.

Vehicle intersection control is implemented. This means that vehicles and traffic signals communicate so that the signals are adjusted to approaching vehicles and the in-vehicle computer calculates a suitable speed and recommends it to the driver.

A certain amount of the parking places are reserved for drivers using the route guidance system. These places have sensors connected to the traffic control centre that register if they are available.
The parking places can be booked while driving. After a reservation the guidance system takes the
car to the reserved place. The parking fee is paid with the rechargeable card. If a vehicle is parked
on a place that is already reserved the traffic control centre sends an urgent request to move it
immediately. If this is not done it will get a parking fine and the car that had reserved the place is
given another alternative.

All information is given to the driver on a display in the car. The driver can also get the informa-
tion from a pocket terminal before he gets into the car, and so he has the opportunity to adjust
his departure time to the present traffic situation.

The driver places his card in the card-reader and announces his origin, destination and vehicle
characteristics to the traffic control centre via the in-vehicle computer before the trip begins. The
centre returns information about total cost and expected time use for the cheapest and the fastest
routes. If the driver accepts one of these two routes, the price is fixed and the route guidance sys-
tem will guide him to the destination. If he decides to go somewhere else than to the original des-
tination, he can contact the traffic control centre. The centre recalculates the cost and the route
guidance system adjusts its information.

If the driver does not want to state origin/destination, or if he does not follow the instructions
from the route guidance system above, he will neither be able to use the route guidance system, nor
the vehicle intersection control. If he has placed a rechargeable card in the card reader a fee will be
charged at the beginning of each link. The in-vehicle computer gets a signal from roadside trans-
mitters telling the link fees. The charges are the same as the ones used by the route choice model,
and thus they vary with traffic situation, air pollution, vehicle type etc. The opportunity to fix the
cost before driving is not available, since the traffic control centre has no information about where
the driver is going. Visitors can buy rechargeable cards before entering the urban region.

If the driver does not want to use/does not have a card, the number plate of the car will be
photographed each time it enters a pre-defined zone. By the end of the month all entries are sum-
med and multiplied with a fixed charge. A bill is then sent to the owner of the car. This leads to
higher charges than when a rechargeable card is used.

The motivation for car pooling rises when the costs for each trip are displayed. And it is easy
to share costs, since several cards can be entered at the same time in the in-vehicle card readers.
The road user fees are always divided equally between the cards in the card reader. Moreover,
pools with neighbours and colleagues are supported by the introduction of a ‘car pooling software’
in local computer networks of any size (e.g. at huge places of work, among a couple of thou-
sand households). Anyone who is connected to such a network can either announce that he wants
a ride or that he is prepared to pick up passengers. The matching procedure is supported by the
software.

This is included in the system:

- a route guidance system;
- vehicle intersection control;
- a traffic control centre that collects and processes information and administers parking;
- sensors for air quality and for information about the state of the roads;
- a traffic forecast model and a model for calculation of the cheapest and the fastest path;
- rechargeable cards;
- vehicles equipped with card readers, computers and displays;
- sensors at parking places;
- pocket terminals for information from the traffic control centre;
- local computer networks that facilitate co-ordination of passengers with drivers.

5.1.2. Feasibility assessment for Dynamic Route Choice. The experts were asked to evaluate the
technical feasibility of a number of functions in the scenario (see Fig. 1). None of the mentioned
functions got high average scores on the 5-grade scale. On the other hand, not many functions
scored very low. This can be taken as an indication that the overall technical complexity was
expected to be more problematic than any particular functions. This was also mentioned several
times in the comments. The major difference between the rounds was that several functions that
had been criticised in round 1 for being too technically complex were omitted in the second sce-
nario description.
There were also some questions asked on the acceptance characteristics of the scenarios (see Fig. 2). The responses to those questions indicated that the experts assumed services included in the scenario would be appreciated by the users. One thing worth noticing is that direct payment was, on average, given a positive response. The characteristics that scored highest all involved providing the driver with information in order to facilitate navigation and avoid congestion. This is also the basic idea of the scenario. However, according to the comments, some panellists found the scenario too control intensive, even if it was generally agreed, among the respondents to both rounds, that the adjusted scenario description was more balanced in this sense.

5.1.3. Market penetration for Dynamic Route Choice. The experts’ judgements on how Dynamic Route Choice would be used, if implemented, are presented in Fig. 3. The evaluation reveals no major changes from car driving today. Thus, this is seen as a scenario that would basically be used by the same category of people and in the same situations as today’s car driving. This means that this scenario is expected to be used most by people with high income, middle-aged, and mainly men. It is also expected to be best suited for car drivers and big cities.

5.2. Extended public transport

Extended Public Transport was formulated to promote the attractiveness of public transport by improving information and extending public transport information services to include taxi and rental cars. A related scenario is described in Office of Science and Technology (1995).

5.2.1. Scenario description for Extended Public Transport. Extended public transport implies both that public transport gets advantages in relation to private car traffic, and that the public transport system is integrated with rental car, taxi and bicycle systems.

![Fig. 1. Technical feasibility for Dynamic Route Choice.](image1)

![Fig. 2. Acceptance feasibility for Dynamic Route Choice.](image2)
The nucleus of the system is a traffic information centre. The centre has information about all public transport time tables and all delays in relation to these. A telephone register with names and addresses and a road register are also connected to the centre. Moreover, the information centre knows if there are any available parking lots at park-and-ride facilities and it calculates an approximate ‘peak index’. The peak index gives an indication on how full the major public transport vehicles are at a given moment. It is based on reports from a number of key vehicles. All this information can be retrieved through the pocket terminals.

The traffic information centre is connected to a taxi system. If you want a taxi to wait at the destination of your public transport trip, this can be arranged via the traffic information centre. The centre forwards the order to a taxi company together with the expected arrival time. Delays in the public transport system are automatically reported to the taxi system. Taxi trips can also be ordered from inter-city trains.

The traffic information centre is also connected to rental car-companies. Rental cars are available at all major stations. Cars can be booked via the information centre. The client gets a code
and registration number of the car to confirm the booking. The car will then be waiting at the station. A personal smart card and a code, but no key, is needed to start the car. The payment is taken care of through a card reader. Rental cars can also be ordered from inter-city trains.

All communication between the traffic information centre and the traveller is taken care of through pocket terminals, terminals at public places and terminals at home.

Traffic signals are adjusted to give priority for buses and separate bus lanes are built, so that public buses get higher average speeds and better punctuality, achieving priority from other vehicles.

Payments are handled with a smart card that is put in a card reader placed at the stations. The cards can be refilled at cash dispensers by means of transfers from the card holder’s account, or with cash deposited at the dispensers.

The public transport fares are higher at peak hours than at off-peak hours. The fares are coordinated with a system for road user charges, so that at all hours it is more expensive to go by car than by public transport. The differences in price between car driving and public transport are highest at peak hours.

Bicycling is encouraged by building covered bicycle tracks along the most popular routes and separated crossings through the city centre. The commuter trains are equipped with places for bicycles that can be booked in advance via the terminals mentioned above. A route guidance system for bicycles helps the cyclist find the best way to a destination. The information from the route guidance system is received by the pocket terminal that can be fastened at the handlebars. At major meeting points, such as stations, there are bicycles for loan. To borrow a bicycle a personal smart card that identifies the user must be inserted in a card reader. This unlocks a bicycle and a deposit is taken from the user’s account. The deposit is paid back when the bicycle is returned. The system is financed by sponsors having their names on the bicycles.

The traveller begins the trip by sending departure time, origin and destination (or a name of the company or person she wants to visit) to the traffic information centre. The traffic information centre responds with information about alternative route choices with public transport and bicycle (optional) between the two addresses. If only a name has been given as destination, the traffic information centre looks up the address in the telephone register before sending the above information. The information about the public transport contains transport mode, departure and arrival times, changes, peak index and price. The information about the bicycle alternative consists of the length of the trip, wind-force and wind direction. When the traveller has chosen one of the alternatives she confirms the choice. If delays that affect the confirmed trip appear somewhere in the system, the traffic information centre will announce this promptly, and suggest alternative choices.

This is included in the system:

- a traffic information centre that has information about public transport and that is connected to taxi- and rental car-companies;
- a register of roads, addresses and bicycle tracks;
- locks to rental cars that can only be opened with a smart card and code;
- terminals at public places, homes and in pocket-size;
- public transport regularisation;
- rechargeable cards;
- card readers at stations;
- cash dispensers where the cards can be recharged;
- separate spaces for bicycles on trains;
- a booking system for bicycles on commuter trains;
- a route guidance system for bicycles;
- borrow-a-bicycle facilities.

5.2.2. Feasibility assessment for Extended Public Transport. Extended Public Transport had a lower degree of technical complexity than the other scenarios. Most functions that were proposed in the scenario have been tested, or are being tested, in different experimental programmes around the world. Therefore, it was no surprise that the evaluation of the separate functions was generally positive, i.e. no functions scored really low on technical feasibility (see Fig. 4).
The experts’ assessment was that acceptance of the mentioned characteristics (see Fig. 5) would be high. There were few negative responses. All characteristics scored positive on average. One of the most positive evaluations regarded the function used to inform passengers about relevant delays in public transport and to suggest alternative routes. A related function with very high scores was that which automatically informs the taxi about delays, if the passenger took the opportunity to order a taxi in direct connection with the trip. It seems that functions designed to minimise the risk of being late are assumed to be highly valued in public transport.

5.2.3. Market penetration for Extended Public Transport. Figure 6 illustrates the expected market penetration for Extended Public Transport, provided the scenario was implemented. We see that envisaged use fell within the same niches as today’s public transport, namely in trips between suburbs and city centres and within city centres. The customers were expected to be mainly women, senior citizens or low income groups. The system was expected to be best suited for big cities and used by the group of people that takes the bus today.

5.3. Dual Mode
In Dual Mode, the challenge was to combine the potential for efficient energy use in rail transport, the advantages of electric vehicles, and the flexibility of the private car. The scenario was a version of a Danish system that is under development (Jensen, 1996).

5.3.1. Scenario description for Dual Mode. Dual Mode vehicle system implies a new physical infrastructure. The system consists of light vehicles with electric propulsion that run automatically on light monorails with low friction. The vehicles can also leave the rail and run on ordinary roads with manual driving. The rails can be built on ground, in tunnels or be raised above ground.
The vehicles are constructed so that front and end fit to each other. On rails where speeds are high (70–200 km/h), trains of vehicles can be formed to minimise air resistance. Normal braking is regenerative, but emergency braking is taken care of with disc brakes that squeeze the rail. This is efficient and stable since the brakes are placed close to the vehicles’ centre of gravity. The vehicles can be privately owned, hired for longer periods from traffic operators or for public use. The public vehicles are cleaned daily at special stations.

All trips on the rail network are announced to a traffic control centre that directs the traffic. Driving on the network is automatic. The route choice on the network is consequently decided by the traffic control centre. Another task for the centre is to automatically connect and disconnect trains of vehicles on the network. The centre is also administering the user fees. The fees are designed to avoid congestion on the network. Vehicles can be denied entrance to the rail network if the maximum capacity is reached.

In the city the network is very dense with many stations. The system works as a Personal Rapid Transit-system, i.e. the traveller is offered automatically guided trips from one station directly to

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**Extended public transport:**

![Graph showing market penetration with regard to journey type, population group, transport mode and city size for Extended Public Transport. The experts were asked to state only the best and the worst alternative. The upper parts of the columns represent the portion of experts who believed that the market segment in question was best suited for Extended Public Transport. The lower parts indicate the portion of experts who found the segment least suited.](image-url)

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In the city the network is very dense with many stations. The system works as a Personal Rapid Transit-system, i.e. the traveller is offered automatically guided trips from one station directly to
another. Empty vehicles are distributed in the system to be available within a reasonable time from ordering.

The vehicles use electric propulsion and batteries when running on roads. A hybrid unit with a diesel engine, a generator and a fuel tank can be placed under the vehicle to make longer trips possible. This way the vehicles can be used like conventional cars, at the cost of not being able to run on the rails. Hybrid units can be hired at all major exits from the rail network. The batteries are charged when the vehicle runs on rails, when the hybrid unit is used and when the vehicle is connected to a socket.

Switching from rail to road (road to rail) is done in a semiautomatic way. The vehicle slows down to 30 km/h and the driver takes over (handles over) the control gradually.

When the vehicle runs on rail the user fees vary with the amount of traffic. When running on road a fixed fee is charged per kilometre. It is much cheaper to run on rail than on road, and it is cheaper to go with a public vehicle than with one that is privately owned or hired for a longer time. This is because public vehicles have a higher utilisation rate, since they can be used by anyone. Conventional cars pay zone-based fees each time they enter a new zone in the urban area.

The payment is handled via a smart card. The card, together with a code, makes it possible to hire public vehicles that are parked in the streets and at stations for shorter or longer periods. The driver must prove her identity to mitigate the risk for vandalising and theft. Misuse of the system can lead to expulsion. The smart card holds information about the owner’s driving license to stop drivers without a licence from leaving the network with a public vehicle.

A trip can be made in mainly two ways in this system (apart from driving on roads like today with either a conventional vehicle or with one of the dual-mode vehicles):

1. The driver can take her vehicle (privately owned or hired), drive to the nearest rail, continue automatically to her destination, leave the rail and park the vehicle.
2. The driver can order a trip with a public vehicle by stating destination and desired time of departure to the traffic control centre. There are terminals in homes, at meeting points and stations and for pocket use, from which the order can be sent. The trip can be specified with e.g. desires of room for extra luggage and child safety seats.

When it is hard to find parking places for the privately owned vehicle, it can be left on the rail network at a low cost. The empty vehicle will then circulate in the system, or be parked at a station with excess capacity, without anyone else being able to use it. When the owner needs the vehicle again she uses a terminal to send for it from wherever she is.

This is included in the system:

- vehicles with electric propulsion that can run on either rail or road;
- hybrid units with a diesel engine, a generator and a fuel tank;
- a traffic control centre that directs traffic on the rail network and administers charges;
- a monorail network with entrances and exits to the road system and with stations;
- smart cards that give access to public vehicles and handle identification (when a vehicle is hired) and payment;
- terminals for ordering public vehicles or sending for parked private and hired vehicles.

5.3.2. Feasibility assessment for Dual Mode. Dual Mode was more futuristic than the other scenarios. It involved technology that has not yet been tested. Figure 7 presents those functions that were evaluated in terms of technical feasibility. A majority of experts were sceptical about several of these. In particular, the experts envisaged difficulties in the construction of the rail network. The demand and supply dynamics for vehicles were also strongly questioned, as was the technique for coupling and separating trains, and switching between road and rail.

The characteristics that were evaluated in terms of their effect on acceptance can be found in Fig. 8. The most positive elements were that trafficability was guaranteed on the rail network, that longer trips were possible with the hybrid unit, and that there was an opportunity for fully-automated direct trips. The first feature here, guaranteed traffic ability, is again an indication of the importance given to measures involved with limiting the risks of being delayed. Some concerns were aired as to the respect of privacy, since identification was required for using the vehicles off-rail. Some experts also commented upon the fact that the rails could be visually intrusive.
5.3.3. Market penetration for Dual Mode. Evaluation of market penetration indicates that the experts looked upon Dual Mode as primarily a substitute for the car system. This can be seen by comparing Figs 3, 6 and 9. The profiles in these figures for journey type, income group, age group, sex, and transport mode show that Dual Mode and Dynamic Route Choice are more alike than the profiles for Extended Public Transport and any of the other two. Moreover, these profiles suggest that the markets for Dual Mode and Dynamic Route Choice are among people with high and medium income, middle-aged, men, and car drivers (and public transport users for Dual Mode). These are the same categories as today’s car drivers.

The scenario descriptions and the experts’ evaluation of the scenarios have been presented above. In the next section, the scenarios will be compared directly with each other.

6. COMPARISON OF SCENARIOS

The scenarios were compared in a couple of different ways. This section concentrates on the comparisons in terms of market penetration and long-term effects.

6.1. Market penetration

In the previous sections, the best markets for the three scenarios, according to the experts, have been pointed out. The experts were also asked to compare the scenarios with each other, and thus say which scenario would work best for a specific market segment, e.g. considering journey types, population subgroups, transport options, and city sizes.

6.1.1. Journey types. It is clear that the experts did not agree upon any journey type where Dual Mode would be the most used alternative (Fig. 10). They thought that the only type where the
Fig. 9. Market penetration with regard to journey type, population group, transport mode and city size for Dual Mode. The experts were asked to state only the best and the worst alternative. The upper parts of the columns represent the portion of experts who believed that the market segment in question was best suited for Dual Mode. The lower parts indicate the portion of experts who found the segment least suited.

Fig. 10. Expected market penetration among journey types. The upper parts of the columns represent the portion of experts who believed that the scenario in question was best suited for the journey type in question. The lower parts indicate the portion of experts who found the scenario least suited.
scenario could compete with the others was between city centre and suburbs, but even here, there was a considerable number of sceptics. Dynamic Route Choice seemed to score better than the others for journeys between different suburbs, and between suburbs and shopping centres, but it was also rather competitive in other journey types. This indicates the flexibility of the car—no impossible journey types were pointed out. However, an interesting result was that Extended Public Transport also managed rather well in all journey types. This shows that the experts found it feasible to design a public transport system that can cover all the needs in urban passenger transport. On the other hand, it is just as remarkable that they were so critical of Dual Mode. This scenario was designed for flexibility. Obviously, the experts were not impressed.

6.1.2. Population groups. There were two distinctive features of response patterns to the question on which population groups would use the scenarios most (Fig. 11). The first was similar patterns for high income groups, population of active age and men. They show that these groups are expected to use Dynamic Route Choice as their first choice, and Extended Public Transport as last choice.

The second was that the patterns for low income groups resemble the patterns for children and youths, senior citizens and women. Here, Extended Public Transport was the only scenario which could attain a substantial market.

It was a surprise that the experts agreed that Dual Mode was not for those population groups most oriented towards public transport, since the system included heavy investments in a new, automated public transport system. Either the experts only considered the opportunity to use private vehicles that drive on both rail and road, or they did not believe that automated systems would be cheap enough for people with low income. The low score for senior citizens might mirror an anticipated reluctance among older generations to use new technology.

6.1.3. Transport modes. The idea with the question on transport modes was to assess what the experts thought of the influence of different scenarios on choices of transport mode. The clearest results were that car users were expected to be most attracted by the car-oriented scenario, Dynamic Route Choice, and that public transport users, bicyclists and pedestrians were to be most attracted by Extended Public Transport (see Fig. 12). Thus, the experts had little confidence in the scenarios’ capability to affect people’s mode choices. They regarded the scenarios more as improvements within each mode. Finally, we see that there was no consensus on which scenarios would attract most taxi passengers and new trips.

6.1.4. City sizes. We saw in the above section on scenario specific results that all scenarios were expected to be best suited to big cities. When comparing the scenarios (Fig. 13), we see that Extended Public Transport was assumed to attract most users, independent of city size. Another clear result was that Dual Mode was expected to be better suited, the larger the city. The high rating of Dual Mode in big cities is worth noticing, considering the negative responses to previous questions on market penetration.

![Fig. 11. Expected market penetration among income groups, age groups and sexes. The upper parts of the columns represent the portion of experts who believed that the scenario in question was best suited for the population group in question. The lower parts indicate the portion of experts who found the scenario least suited.](image-url)
6.2. Long-term effects

A number of long-term effects were evaluated, in order to see if the experts found that sustainable scenarios had been accomplished. Evidently, the long-term effects of transport systems are shaped by a number of factors other than telematics. However, in this question, the panel was asked to state only the effect of the scenarios. A prerequisite was that successful implementation of the evaluated scenario had taken place.

The experts were confronted with a number of statements on derived long-term effects. They were asked to state whether they believed in a substantial effect in accordance with the statement (‘agree’), or if they believed in a substantial effect opposite to the one stated (‘oppose’). If they did not believe in a substantial effect, or if they had no opinion, they were asked to leave the space blank. Each expert was left to interpret ‘substantial’ individually. The results are given in Table 4, with the following example: the statement that CO2 emissions would be substantially reduced was supported by 40% for Dynamic Route Choice (18% thought that CO2 emissions would increase substantially instead).

Dynamic Route Choice involved a greater lack of consensus and blank replies than the other scenarios. Quite a few experts believed in substantial negative effects on, for example, emissions, even if a higher number believed in reductions. The strongest elements of this scenario, compared to the others, had to do with increased capacity utilisation, shorter travel times, and increased traffic comfort.

Extended Public Transport received highest scores on most effects. Among others, we see that a safe majority of experts thought that it would substantially reduce CO2 emissions and other pollutants, and that capacity utilisation, safety and accessibility would increase. Moreover, it was expected to be the scenario with the highest degree of equalised accessibility.
Dual Mode also scored high on several effects, although it could not compete with Extended Public Transport. The strongest result came on safety, where 75% of the experts believed in substantial improvements, whereas nobody thought the scenario would lead to a substantial increase in accidents. The scenario was also expected to lead to reduced emissions of CO$_2$ and pollutants and to increased comfort.

### 7. CONCLUDING DISCUSSION

The results from an evaluation of three different telematics scenarios for urban passenger transport have been presented. One of the systems was based on the private car, one was based on public transport, and the third was a combination of private and public transport. The experts’ judgements were in general positive regarding the technical feasibility and acceptance of the first two scenarios. The technical feasibility of the Dual Mode scenario was, however, seriously questioned. This may reflect the fact that Dual Mode has been less tested than the others and that its implementation, therefore, lies further in the future.

A common fear expressed by the experts had to do with privacy intrusion. Since all scenarios include a traffic centre with the task of organising traffic, inherent opportunities for control are high in all scenarios. At the same time, this handling of mass information may provide substantial efficiency improvements for urban traffic. We have an obvious conflict here between risks of violation of privacy on one side, and efficiency improvements with gains for all users on the other. The solution to this conflict must be sought within the political system (see also Höjer, 1996).

The experts’ evaluation of market penetration showed that they did not expect the scenarios to change patterns of travelling much. The scenarios as such were not expected to make public transport users car users, nor the other way round (Figs 3, 6 and 9). An interesting result was that the experts looked upon Dual Mode as primarily a substitute to the car system (see also Fig. 9), although it included massive investments in public transport. If this is true, a dual-mode system might be what is needed to change car drivers’ behaviour towards less energy-demanding travel modes. Extended Public Transport was not expected to attract car users, but on the other hand it was expected to be able to cope with all journey types, according to the evaluation of market penetration. This indicates that there might be huge potential for such systems.

The effects on emissions of CO$_2$ and pollutants, and capacity utilisation, were expected to be high in all scenarios. Extended Public Transport scored best in most evaluations of long-term effects, but had shortcomings regarding travel times and comfort. Again, the conflict between individual and collective interests is clear. In spite of these shortcomings, the experts agreed that Extended Public Transport was the most desirable scenario. On average, they also stated, when asked about desirability and probability, that it was the scenario most likely to be implemented (Höjer, 1997).

In the first part of this paper, it was argued that combining the Delphi technique with backcasting is a fruitful method for scenario studies. In order to see that the cornerstones of scenarios are properly defined, it can be useful to ask experts for help, which is exactly what the Delphi technique can be used for. Experts are thus involved in the project and get the opportunity to
criticise scenario descriptions while changes can still be incorporated. This idea turned out to work well, as witnessed by the many positive comments from respondents, and the relative stability of responses between the two rounds.

Thus, there are two major conclusions from this study. The first is that the method, as described in the first section, is feasible in projects concerned with policy formation. The second is that, from the scenarios we have seen here, experts seem to primarily favour the development of telematics for public transport, in contrast to where most of development money is being spent today. Moreover, the futuristic system Dual Mode seems to involve a number of severe technical uncertainties. It could still, however, be interesting to follow the development of this system, since it was expected to have very positive effects on emissions and safety and to serve similar purposes as the car. Finally, a number of experts mentioned the risks of privacy intrusion with control mechanisms, indicating that a centralisation of private road transport might be infeasible unless it can be substantially motivated from environmental, safety or efficiency perspectives.

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REFERENCES