IMPACT OF NEW TECHNOLOGIES IN TRAVEL SURVEYS

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ABSTRACT
Over the past five years, several new technologies have emerged which create new opportunities and problems for travel surveys. A more recent trend is that computers, or such EDP-based systems as laptops, mobile phones, etc., are increasingly employed for data collection.

Computer-assisted data collection (CADAC) including Global Positioning Systems (GPS), mobile communication systems, Geographical Information Systems (GIS) or the Internet could improve data quality, while partly reducing costs. Computers can be used to assist observation and interviews as a means of data collection. Depending on the objectives and characteristics of a particular survey, either computer-assisted observation or interviewing may be the right tool for establishing movement data.

By using computer-assisted observing methods, spatial trip data can be collected automatically. Automatic positioning can proceed either by means of GPS or the Global System for Mobile Communication (GSM). Both techniques were integrated in a survey tool and applied in several research projects. GPS- and GSM-based observation techniques are described as well as some projects using these techniques.

Computer-assisted interviewing methods (CAI) support conventional interviewing methods (written-postal, telephone and personal interviewing) and include the option of computer assistance. They can be broken down in

- Computer-Assisted Telephone Interviewing (CATI),
- Computer-Assisted Personal Interviewing (CAPI),
- Computer-Assisted Self Interviewing (CASI).

Each type of CAI are characterised and explained with several examples in the paper.

The paper demonstrates the advantages and problems of CADAC methods as well as the experience and results of some research projects. In conclusion, the main characteristics of CADAC methods are emphasized, and an assessment is made of future developments of computer-based travel surveys.

1 PROBLEMS OF TRAVEL SURVEYS

Transport and infrastructure planning and traffic control that give due regard to the actual needs and also to social and environmental concerns have to rely on valid and detailed information on such factors as settlement structure, transportation services, as well as the actual travel behaviour and traffic conditions. While the required data on settlement structure and transportation services are generally readily available, this is normally not the case with details on the space-time behaviour of the population. These data, which reflect individual travel behaviour, are of substantial relevance for the transportation planning process and can be obtained in two different ways: one is based on observation (without involvement of the road user or traveller), while the other starts from direct surveys among the target group.

Observation methods are directed at apparent characteristics and behaviour within a spatially and temporally defined area. One of the major advantages of this method is that it does not depend on the willingness and ability of the subjects to respond, and that the data thus produced are objectively correct. On the other hand, there is the disadvantage that investigations can at one and the same time only aim at evident behavioural characteristics, while neither behaviour outside the space-time area, nor such aspects as motivation, attitudes or situational response can adequately be covered. This is why observation as an investigation methods has in the past been restricted to areas limited both in space and time.

Interviewing, on the other hand, does not only reveal evident characteristics and travel behaviour of the subject interviewed, but also not immediately apparent personal characteristics (e.g. income), travel behaviour characteristics (e.g. purpose), causes, motivation, opinion and situational response. Interviewing makes use of written-postal, telephone and personal-oral practices. With this method, data acquisition, however, has to take place during a limited period of time, which is why written-postal investigations generally refer to one particular key-day. When increasing the personal and telephone support, the investigation period may be up to one month.

One major drawback of interviews as compared to observation is that they may be influenced by so-called non-response effects, i.e. results may be falsified by a refusal to respond or by incomplete answers. The longer the interview, the higher will be the risk of non-response. In panel surveys, they may be a result of fatigue (increasing number of missing or incorrect details) and “drop-outs” (people leaving the survey prematurely). Other panel effects are memory and spontaneity effects.

From the above follows that none of the traditional investigation methods can supply valid data on the individual travel behaviour

- for more than a limited period of time (e.g. weeks, month, one year),
- for over large spatial areas (e.g. a whole town, state, country),
- for a sufficiently large number of proxies (e.g. to determine an origin-destination matrix),
- of adequate reliability (e.g. complete number of individual trips), and
- of adequate accuracy respecting time, location and, in particular, routes.
2 COMPUTER-ASSISTED DATA COLLECTION (CADAC) IN TRAVEL SURVEYS

Computer-assisted data collection can overcome, or at least reduce, the disadvantages outlined in chapter 1. In the past, transport planning has made use of computers primarily for purposes of data acquisition and evaluation, and for statistical analyses. A more recent trend is that computers, or such EDP-based systems as laptops, palmtops, mobile phones, GPS receivers, etc., are increasingly also employed for data collection, and the rapid developments in the information and communication technologies constantly open up new fields of application.

Computers can be used to assist observation and interviews as a means of data collection, and thus help improve the quality of results. Depending on the objectives and characteristics of a particular survey, either computer-assisted observation or interviewing may be the right tool for establishing movement data. In what follows, the attention will at first be directed at computer-assisted observation before turning to computer-assisted interviewing.

2.1 Computer-Assisted Observing

For automatic travel surveys it seems to be most evident that automatic positioning should be used for the collection of movement data both in terms of space and time. Automatic positioning can proceed either by means of GPS (Global Positioning System) or GSM (Global System for Mobile Communication).

2.1.1 GPS-BASED OBSERVATION TECHNIQUES

Satellite-assisted positioning is known today as a means that allows vehicles with on-board computer and GPS receiver to locate their position and find the shortest possible route to a given destination.

GPS uses the propagation delay of signals emitted by the GPS satellite until they are received by the aerial of a GPS receiver. These signal propagation delays reflect the geometrical distance between satellite and receiver.

GPS can also be used to automatically collect movement data of an individual, provided this individual carries a GPS receiver and a data recording or transmission unit. This method was applied for the first time in the US to collect data on the travel behaviour of car drivers (Murakami et al, 1997), (Wagner, 1997). While this project was a vehicle-based survey, other later research projects were person-based and covered all travel modes (Draijer et al, 2000), (Battelle, 2000).

2.1.2 GSM-BASED OBSERVATION TECHNIQUES

Data on the movement of individuals can also automatically be collected by means of commercial mobile phones, because the activated unit has to be in constant contact with a base station to be able to receive or transmit calls. The available information is not limited to the aerial (or communication cell) the mobile unit is currently communicating with, but also includes that of up to five additional cells. The data of the surrounding cells that are available in the mobile can also be used to approx-
imately localise the mobile unit. Although the accuracy of GSM positioning depends on the density of the base stations and cannot reach the accuracy of the GPS technique, it is generally adequate for purposes of travel surveys. Algorithms can in addition be used to raise the accuracy.

GPS offers the advantage that satellites are available on a global scale and at no cost. It is highly accurate, and there is the market of a mass-produced product that can be obtained at low cost. This has to be weight against a number of disadvantages, which GSM-based positioning does not have. The advantages of GSM positioning compared with GPS are as follows:

a) Unlike GPS, the GSM-based system does not necessitate an unobstructed view of the positioning satellite, which means that mobile phones can also be spotted in a maze of narrow streets, below bridges, in tunnels, within enclosed spaces, inside vehicles (without an outside aerial) including underground railways (permitting mobile radio transmission), light-rail trains, tramways and busses, or when carried along in coat or jacket pockets.

b) Again unlike GPS, the mobile unit does not require additional power for GSM positioning. Mobile units with GPS positioning feature will, with this function activated, be available for much shorter times than a GSM mobile radio transmission unit.

c) There is no or only a minor time delay when the unit is localised for the first time. With GPS, the receiver generally has to scan the entire frequency area once the system is activated, because its own position is not known. This search function may mean that the first location data will not be available until after about 10 minutes.

Table 1 shows the main characteristics of the two systems.

**Table 1: GPS vs. GSM technique.**

<table>
<thead>
<tr>
<th></th>
<th>Frequency [MHz]</th>
<th>Operation in enclosed areas</th>
<th>Communication</th>
<th>Positioning function / accuracy achieved</th>
<th>Power req.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(D)GPS</strong></td>
<td>1575.42</td>
<td>no</td>
<td>no</td>
<td>yes / 5 to 100 m</td>
<td>high</td>
</tr>
<tr>
<td><strong>GSM</strong></td>
<td>approx. 900 / 1800</td>
<td>yes</td>
<td>yes</td>
<td>yes at an additional input / approx. 50 to 100 m in congested areas</td>
<td>low</td>
</tr>
</tbody>
</table>

GSM as a method for collecting individual movement data was for the first time used in Germany in the year 1999, (Wermuth et al, 2001).

### 2.2 Computer-Assisted Interviewing (CAI)

The available literature is not consistent in the way computer-assisted interviewing methods are described and referred to. When starting, however, from a conventional classification of interviewing methods into written-postal, telephone and personal interviewing, and when expanding these methods to also include the option of computer assistance, the computer-assisted interviewing methods can be broken down into the following categories, (Ettema, 1996), (De Leeuw et al, 1996), (Hautzinger, 1991):
• Computer-Assisted Telephone Interviewing (CATI)
• Computer-Assisted Personal Interviewing (CAPI)
• Computer-Assisted Self Interviewing (CASI).

What is true of all the different types of computer-assisted interviewing is that the questions will be read from a monitor or display and that answers are entered by the respondent or by the interviewer directly into the EDP-based system. There is no more need to transmit the answers from the paper to the EDP system, a cumbersome and at the same time error-prone procedure. The different computer-assisted interviewing methods can thus not be seen as new investigation techniques. They have only been developed and optimised on the basis of traditional methods by means of the computer.

An integrated data validation function generally checks the data entered, which means that implausible answers will normally be detected during the interview and can immediately be eliminated. The data record that is available at the end of the interview has thus ideally already been checked for plausibility and can be transmitted for evaluation in a machine-readable form. There is the additional option that, depending on answers given to certain filter questions, respondents can be asked different follow-up questions. By means of automatic plausibility and interviewer checks and automatic filter control, interviewer influences known from conventional direct interviews can be reduced to a minimum, (Brammer, 1996). Immediate data acquisition and recording has the added advantage that the data collected can be checked at any time for interim evaluation, (Hautzinger, 1991).

The three categories of computer-assisted interviewing will be presented below with their main characteristics, as well as their advantages and disadvantages. The sequence used reflects current application frequencies. Chapter 3 will then provide some concrete examples and make reference to research projects using computer-assisted interviewing.

2.2.1 Computer-Assisted Telephone Interviewing (CATI)

Computer-assisted telephone interviewing is one of the oldest computer-assisted interviewing methods used in empirical social research (De Leeuw et al, 1996). The interviewers read out the questions from the computer and enter the replies directly into the EDP system. The software is developed specifically for the survey, and it takes the interviewer, step by step, through the interview. CATI does not only mean computer-assisted data acquisition. It also provides for random selection of the subjects for the survey. The telephone numbers will, again on a random basis, be produced from digital directories or by means of random digital dialling. This is a process in which systematic variation of the last two digits of the telephone numbers ensures that the probability to be included into the random sample is the same for all subscribers. The numbers thus selected are dialled by the computer, and the computer will automatically repeat the dialling process at a later time, should no connection be established, (Taumer, 1997). The fact that selection of addresses, sampling and data acquisition are combined in one and the same system is one of the great advantages of computer-assisted telephone interviewing, as both the input of time and money can be much reduced.
Because of the automatic sampling procedure also those households will be included that do not have their telephone number published (new subscribers or ex-directory numbers). Automatic sampling, however, also has some disadvantages. Households without a telephone will not be included, while those with several lines and mobile telephones stand a much higher chance of being included in the sample. It is also a typical phenomenon of telephone interviewing that people that tend to be at home (e.g. those without a job or those who are immobilised by a disease) can be contacted more easily than highly mobile people and those working outside their home. The problem can only be overcome by a proportionately larger number of dialling attempts or by arranging an appointment for a telephone interview.

Experience shows that computer-assisted telephone interviewing have the same validity as conventional telephone interviewing. The number of non-respondents (person non-response) is the same for both methods. CATI, however, means that the number of missing data can be reduced (item non-response), although this positive effect will only come to bear with highly complex questionnaires. There is no difference respecting interviewer errors in inputting and coding the data, (De Leeuw et al, 1996).

The costs incurred with the CATI method have been found to be relatively low for a large number of samples. Such inevitable investments as, for instance, for developing the required software, will pay off, because for about 1000 subjects and more the costs for organising the survey will be reduced, (De Leeuw et al, 1996).

2.2.2 Computer-Assisted Personal Interviewing (CAPI)

CAPI means that the interviewer visits the subject for a face-to-face interview for which he or she uses a portable computer (notebook, laptop, pen pads, etc.). Just like in the computer-assisted telephone interview, the interviewer reads out the questions and enters the answers into the computer. The interviewer software takes both sides through the interview. Data transfer – completed questionnaires from the interviewer to the institute conducting the survey, empty questionnaires from the institute to the interviewer – normally proceeds through modern media of data transmission (ISDN, remote data transmission/modem), (Brammer, 1996).

Modern portable computers and, in particular, lightweight hand-held computers with a pen and a sensitive screen (screen-based pad) open up completely new ways of computer-assisted personal interviewing. The multimedia properties of these systems allow the interviewers to present picture or sound sequences to the subject, or the subject’s voice can be recorded with the answers (Meier, 1996). In particular with open questions – e.g. on values, attitudes, reasons for certain travel behaviour – it may be interesting to record the answers by means of a computer microphone. When the survey includes spatial information (origin, destination, route of a trip), cartographic representations based on geographic information systems (GIS) can be a highly useful tool, as the subject can use a pen to mark a given destination on the map. This option is also available for computer-assisted self-interviewing (CASI).

CAPI surveying generally meets with a very high acceptance. Both the subjects in the survey and the interviewers tend to prefer computer-assisted interviewing to conventional personal interview-
ing methods. A closer look at the recovery of both methods does not reveal any significant differences. The quality of the data produced by CAPI corresponds to that of a traditional personal interview. The number of missing or incorrect answers is either slightly smaller or on the same level, (De Leeuw et al, 1996).

As for the costs, it should be noted that personal interviewing is a highly cost intensive method any way, which can be explained by the considerable amount of time that has to be invested when the interviewer personally visits the subjects. Computer-assisted personal interviewing involves relatively high additional fixed costs. Apart from the one off capital expenditure for hardware and software, there are in particular the costs for training and supervising the interviewers. For relatively small sample volumes of, say, 200 subjects, methods that do without computer assistance will be more cost effective. But if several thousand subjects are included in the survey – which is generally the case with transport planning – CAPI will prove to be more cost effective than conventional personal interviewing, (De Leeuw et al, 1996).

2.2.3 COMPUTER-ASSISTED SELF INTERVIEWING (CASI)

CASI has basically been developed from traditional written methods and involves direct communication of the subject with a computer or an EDP-based system (e.g. mobile phone, palmtop). An interview program guides the subject interactively through the questionnaire and waits for an input in the form of an answer. In particular the Internet enjoys more and more popularity in this context. So-called “online interviews“ or Computer-Assisted Web Interviewing (CAWI) have been in use for market research purposes for several years, (Bogner, 1996). Another CASI version is the “Electronic Mail Survey”, which can be compared to EDP-based interviewing by post. With CASI, questionnaires are sent to the subjects via the Internet or BTX, provided they have access to these media. The same channels are later used to return the completed questionnaires to the institute conducting the survey, (Taumer, 1997). In this way, not only simple questionnaires can be sent out, but also complex programs that take the subject through the interview in an interactive approach by graphical and acoustic means. This CASI version is also known as Computer-Assisted Virtual Interviewing (CAVI).

One of the major advantages of CASI is that it involves relatively little costs and human resources. Unlike CATI and CAPI, it does not require any interviewers, which means there are no staffing costs for the immediate interviews. Forwarding costs can be reduced to a minimum, as electronic data transmission through the Internet or the GSM net generally remains below the postage for letters, (Will, 1996).

The disadvantage of CASI has to be seen in the fact that it tends to be restricted to certain segments of the population. Online interviews and interviews by e-mail can only produce the characteristics of people having a computer that gives them access to the net. Apart from these technical requirements, there is the question of adequate coverage and in how far results are distorted because of coverage losses. It will, for instance, be difficult to convince those parts of the population with limited access to EDP systems (e.g. senior citizens) of this surveying method. Analyses made as part of market research programmes show that people completing and returning a questionnaire online differ substantially from the population in general, (Bogner, 1996), (De Leeuw et al, 1996). So there is
not only the question in how far this method is representative, inadequate recovery may in addition distort the value of results produced by CASI. In particular surveys that are to yield data on travel behaviour have to refer to all segments of the population. CASI methods, therefore, remain for the time being problematic for these purposes. But in view of an increasing acceptance and a more wide-spread use of modern information and communication technologies – just think of the dramatic rise in the number of mobile phone users throughout the world – the problems of inadequate representativeness and coverage losses should be reduced in a few years’ time.

When ignoring the recovery problem, the quality of the data produced by computer-assisted self interviewing can be assumed to be good. Since the CASI interviewing situation offers more anonymity and privacy, the validity of questions on issues that are generally taboo can be expected to be higher than in case of traditional interviewing methods. The characteristics non-response and the number of total errors is lower than with conventional surveys made by post, (De Leeuw et al, 1996).

3 Examples of Computer-Assisted Travel Data Collection Techniques

For transport planning, computer-assisted data collection still is the exception rather than the rule. The first CADAC methods were used in the U.S. In Europe, it was the Netherlands that pioneered developments in this technique. The following chapters will present a number of research projects, which either aimed directly at developing data collection methods by means of EDP systems, or which require data from computer-assisted surveys for their immediate objectives.

The example projects can classify in three groups: Computer-Assisted Online Surveys gather trip data, that describe individual travel behaviour, directly while persons cover a trip. Also, the real travel behaviour of a road user or traveller is collected online. Thereby techniques of computer-assisted observing (cf. chapter 2.1) are combined with CASI methods (cf. chapter 2.2.3). On the other hand Computer Assisted Retrospective Surveys collect already covered trips inclusive its characteristics as well as motives and attitude towards travel behaviour. Retrospective information about individual travel behaviour and their reasons are surveyed by methods of computer-assisted interviewing. Computer Assisted Stated Preference Methods investigate possible response of behaviour by presenting some situations of decision with different (hypothetical) alternatives. Here the survey aim and survey characteristics are different from the first two survey techniques. Response and reactions of behaviour can only obtain by computer-assisted interviewing (cf. chapter 2.2).

3.1 Computer Assisted Online Surveys (CAOS)

3.1.1 Lexington Area Travel Data Collection Test

The technology for GPS-assisted data collection was developed and tested in the U.S. in 1997. The Battelle Memorial Institute was put in charge of developing the required instrumentation and software by the Federal Highway Administration of the U.S. Department of Transportation. The suitability of the systems developed was then verified in field tests.
The computer-assisted system developed in this research project, which was to analyse individual travel behaviour, links automatic positioning by means of GPS with manual data input by the subjects, as this is expected to yield exact and reliable information on individual travel patterns.

The instrumentation used for data collection is a GPS receiver and a hand-held computer. These are connected by a serial data cable; a second cable provides for power supply from the car’s own system. Spatial travel data are automatically acquired by GPS whenever movements take place, and these data are stored in the form of an x/y-coordinate system. The spatial information, and in particular the routes recorded, are analysed by means of a geographical information system (GIS). Software developed as part of the project can, similar to the CASI methods, be used to collect relevant route information, such as purpose of the trip or number of passengers in the car.

The method primarily aims at the behaviour of motorists. While it can also be used to collect data on public transport and non-motorised transport, its field of application outside the car will be limited, as it requires the use of a hand-held computer, which in addition needs to be supplied with power.

In the Lexington area (Fayette and Jessamine County, Kentucky), the new technology was used in a survey on travel behaviour, primarily with the aim of proving the feasibility of the method. In addition, testing was to uncover any shortcomings and to demonstrate the advantages over traditional methods. The field test, which was carried out in the autumn of 1996, involved 100 households with 216 individuals, who all had a driving licence and a car. The study was limited to vehicle-based trips because the data collection equipment relied on the vehicle to power the GPS receiver and recharge the batteries in the hand-held computer.

For a total of six days, the trips for which the subjects used their cars were automatically recorded by means of GPS. At the end of the six-day period, the subjects were interviewed by telephone on one and the same day. Questions asked concerned the method and instrumentation used and details of the trips.

The field test produced the following results:

- All subjects showed a high acceptance of the computer-assisted investigation method tested in this field test. Handling and installation of the equipment did not produce any real problems.

- As compared to conventional interviewing, the GPS-assisted method produced a higher percentage of short-distance trips. When contrasting the trips established in interviews with the observations made, it was found that traditional methods tend to underestimate the actual daily trip rate (5.14 as against 4.63 trips/day).

- GPS-assisted methods produce more accurate data on place and time. In an interview, respondents tend to round off the time needed to the next full hour (or half or quarter of an hour). Spatial movement data are generally highly accurate when using GPS positioning: Unlike traditional methods, it provides valid data on the actual route taken.

With developments in the technical field, producing smaller units that can be handled more easily, it should be possible to extend the field of application to public transport and non-motorised travelling. For the time being it is still doubtful whether GPS is more cost effective way in collecting data...
than traditional methods. Although the costs of GPS receivers and hand-held computers are going down, relatively large amounts of money still have to be invested in the required hardware and software. More detailed information on this project is given in Wagner (1997).

3.1.2 Personal Travel Unit (PTU)

The Lexington study showed that trip data of car drivers could be surveyed by a GPS receiver and hand-held computer with higher accuracy than by conventional methods (cf. chapter 3.1.1). The deficit of this data collection was the limitation on vehicle-based trips.

The Battelle Memorial Institute developed a survey instrument that allowed to record trips independent of travel mode. Like the Lexington study, this project was sponsored by the Federal Highway Administration of the U.S. Department of Transportation. The objective of the research was to develop and test a small, lightweight person-based data collection device using the GPS-technology.

The survey instrument called “Personal Travel Unit (PTU)” consists of a Personal Digital Assistant (PDA or hand-held computer), and a GPS receiver and antenna. The PTU captures accurate time, location, route choice, and travel speed, while simultaneously reducing the amount of time an individual spends on completing a travel behaviour survey.

The respondent initiates the trip record (and GPS data recording) using the hand-held computer and identifies the travel mode for the trip. When the respondents later indicate the end of the trip, they are asked to identify the trip purpose from a predefined list. A trip chaining option of the survey application is included to capture multiple mode travel and sequential trip segments. Collection of these trip data could be described as a CASI-method.

The PTU as configured in this research task weighs approximately 454 g and is carried in a lightweight case with a GPS receiver mounted on a shoulder strap. Respondent survey questions are posed through a touch-screen user interface. The PTU is powered by on-board batteries and can provide approximately eight hours of available data collection time, (Battelle, 2000).

The PTU tests included six test subjects (Battelle staff) that used the PTU equipment on actual trips. These test subjects found the PTU easy to use and the burden of entering data were in the expected time range, generally one minute or less. The PTU offers a preferred alternative to other forms of travel diaries, test subjects would use this type of equipment for future studies without hesitation.

Data quality from test subject data collection was poor. The data were not consistently collected throughout the data collecting period as defined by the trip start and trip stop parameters. The PTU software application recorded trip data entered by the test subjects with only a few exceptions. However, there were numerous trips where the PTU application software “timed out” and indicated an error rather than recording GPS data. This occurrence can result from several reasons, e.g. communication timing errors between hand-held computer and GPS receiver or other system errors (Battelle, 2000).

While hardware issues hindered successful data collection in this prototype, newer and more recently available products will considerably lessen or perhaps even eliminate these problems. Be-
cause the test subjects offered no complaints about the usage of the system, similar systems with more robust data collection capabilities can be implemented in the near future.

3.1.3 TTS (TeleTravel System)

Under the research project “TeleTravel System (TTS)”, a CADAC method was developed on the basis of current information and communication technologies. TTS is a system which supplies more detailed and more accurate information on the spatial behaviour of the road users or travellers than traditional methods would do.

The project, in which a number of engineering consultants, a network provider, and a car manufacturer cooperated, was lead-managed by the Institute of Transportation and Urban Engineering of the Technical University of Braunschweig (Wermuth et al, 2001). Funding was made available by the Federal German Ministry of Education and Research. The outcome is a telematic system with data collection unit – referred to as TeleTravel System (TTS) below – which allows data on travel behaviour (origin and destination of a trip, start and end, purpose, transport mode, route, and possibly point and time of change) to be collected. Data collection proceeds online, using automatic and manual methods and easy-to-handle input control. Similar to the PTU study (Battelle, 2000), trip characteristics are not only obtained through interviews, but also without direct involvement of the proxies for the survey.

The paragraphs below will deal with the technical system of the TTS-based data collection method, data acquisition, and practical application.

**Technical System**

The TeleTravel System is based on a telematic system comprising a number of technical elements and functions (cf. Figure 1).

The core of the telematic system is a survey instrument, which is a commercial mobile phone with a SIM card that has specifically been programmed for this purpose. The mobile phone receives radio-specific data that can be translated into traffic-related information (origin, destination, route of a trip) by means of algorithms. Any additional details of travel behaviour can be entered manually. To be able to record the traffic-related information, the mobile has to check in in a mobile radio network (GSM network), which means that the unit has to be in the idle mode, while it is not necessary to actually make calls or use any of the other services offered by the provider (connected mode).

The required data are collected irrespective of the transport mode used, because the mobile only relates to the owner whose travel behaviour is to be analysed.
All the data collected are temporarily stored in the mobile phone and transmitted to a receiving unit at regular intervals. This unit checks whether all data have correctly and completely been received and stores them in a raw data bank. From the raw data, the processing unit calculates the data required for the travel behaviour, checks them for plausibility, and finally stores them in a result data bank. One of the central functions of the processing unit is a positioning algorithm, which is able to localise the mobile by making reference to the radio-specific data and thus serves as a basis for automatic determination of the origin, destination, and route of a trip (cf. chapter 2.1.2).

Data transmission between mobile and receiving unit is by means of a standardised Short Message Service (SMS), which allows short text messages of up to 160 characters to be sent and received. The advantages of SMS have to be seen in the comparatively low transmission costs and quick data transmission. Data collected in the terminal are transmitted to an SMS centre (SMS-C), which passes the message after a short delay on to the receiving unit.

The survey instrument, the mobile, is actually composed of two elements: the mobile phone proper and the specifically programmed SIM card. The mobile primarily serves as a user interface, i.e. communication between the respondent and the measuring instrument is controlled by means of keys, language, acoustic signals, etc. In addition, it provides for automatic collection of radio-specific data, which the evaluating unit later uses for computation of spatial trip data, and also for manual acquisition of any other information that may be of relevance for purposes of transport planning.

The really “intelligent” element of the data collection unit is located on the SIM card – a chip card of about the size of a thumb’s nail, without which telephoning is not possible. A chip on the SIM card stores information that is required for checking in once the unit has been activated (e.g. person-
al access data, such as SIM card number (NVI), personal directory, etc.). The functions of the mobile phone will be available only when the provider has enabled this chip card.

Apart from controlling the basic SIM card functions this chip card can also be used for sending short messages or establishing a connection. A special function, which will be referred to as SIM application below, allows the features required for automatic determination of the travel behaviour to be made available technically. The SIM application comprises the following functions:

- The radio-specific data required for automatic positioning are requested and stored on the SIM card.
- Any other individual trip data (e.g. trip purpose) which are collected manually by means of the keys on the mobile, are also requested and then stored on the card.
- Using SMS, all the data stored are transmitted to the receiving unit at regular intervals.

Aside from the positioning process, the SIM application is the key component for automatic data collection.

**Automatic data collection – Positioning process**

A key function of the TeleTravel System is the positioning component, on the basis of which the spatial travel behaviour, i.e. origin and destination of a trip and the route taken, is computed in the processing unit. These trip characteristics are collected automatically, i.e. without active involvement of the respondent, so that this aspect of the data collection procedure can be classified as computer-assisted observation (cf. chapter 2.1.2).

Like data transmission, localising the subject is based on GSM. One essential advantage is that both functions can thus be integrated in one unit, but also the rapid increase in the number of people using mobile telecommunication facilities. The radio-specific data required as input parameters depend on the positioning method applied. A total of three processes have been conceived, which differ in the positioning accuracy and the efficiency (see Figure 2). The higher the accuracy, the higher the required input in terms of computing power and data transmission. Which process should be used from case to case depends on the objective of the survey made. On the first level, the positioning accuracy is determined by the size of the communication cell, while pattern positioning (level 3) relies for a high degree of accuracy on the strength of the acoustic level received, (Garben et al, 1999).

The accuracy can be further increased if different positioning methods are combined with so-called logical positioning (level 4), which at the same time provides for projection to network elements (street or road, public transport section). The positioning areas previously established are compared with transport networks, associated with one or more network elements and matched with a time frame (consideration being given to previous positions).
Unlike positioning levels 2 to 4, serving-cell positioning (level 1) has been tested for its technical feasibility on a number of trips and, moreover, for several weeks in a field test. Operation and properties of this positioning method will briefly be explained below: The communication cells cover the whole network area of a provider, each cell is determined by its location through the position of the dedicated base station, angle of radiation of the antenna and geographical surroundings. Thus, an assignment of cell to spatial location is possible without any problems. Each mobile in connected-mode provides data about its current dedicated cell (serving cell) permanently. By saving serving-cell-data on the SIM-card and transmitting it to the receiving unit, data becomes usable for evaluating purposes. Because of the knowledge of the spatial topology of cells, spatial co-ordinates are deduced from received serving-cell-data in a processing unit. With identification of a mobile’s serving cell and knowledge about spatial topology of cells in the processing unit, an online-positioning of the survey instrument is possible.

The accuracy of this positioning method depends decisively on the density of base stations or the size of cells of a provider. In general, densely populated areas - basically inner city areas - have a higher density of base stations than rural areas. Therefore, positioning accuracy is higher in densely populated areas. As there is an approximately proportional correlation between density of traffic network and commonly used traffic zones, a matching between communication cells and traffic zones is possible. Thus, the accuracy of serving-cell positioning corresponds to the size of the cell and is adequate for long-distance traffic surveys. The requirements for data collection, transmission and evaluation are relatively low, (Wermuth et al, 2001).

**Manual data collection – Electronic questionnaire**

An “electronic questionnaire” implemented on the SIM card serves for the collecting of trip characteristics which cannot be established automatically (e.g. transport mode, purpose of trip, and time of change). These characteristics are entered manually by using the mobile’s key set. This step can be classified as a self-interviewing method similar to a typical CASI survey (cf. chapter 2.2.3).
To enter this additional information, the user has to select from different menus. In the TTS main menu, the user enters the start and end of a trip, as well as any transfer to another travel mode. This data is entered online, whenever it is relevant. When selecting the option “start of trip” in the main menu, the sub-menu asks for the following travel mode. Similarly, the trip purpose has to be entered at the end of the trip by selecting the activity at the destination in the “activity menu” (Figure 3).

Figure 3: Electronic questionnaire

The number of menus and their options can be varied as required by a given survey. When analysing leisure-time traffic, the purpose of a trip requires a differentiation which differs from that of a detailed analysis of everyday travelling patterns. Starting from the standard structure of the SIM application, the different menu variables as well as the terms used for the different menu options can be changed on the SIM card. A new questionnaire, therefore, only requires the software to be changed and does not affect the SIM card.

Practical application

For application of the TeleTravel System, not only technical questions are of relevance, but also how it works in daily use and whether or not it is accepted by its users. User acceptance is of great importance for high-quality data and a low error rate. This is why an empirical analysis of user acceptance in a situation reflecting the real conditions of a survey was included in the project. This analysis was carried out in the spring of the year 2000.

It appeared from previous investigations that use of a mobile phone and acceptance levels are determined by a number of characteristics, which also include socio-demographic aspects. To make sure that the results produced are as accurate as possible, homogeneous segments of individuals
have to be formed. A classification was, therefore, made on the basis of the criteria roles in society (persons gainfully employed, students/pupils, old-age pensioners, and other persons not gainfully employed), and mobile-phone user or not. Combination of these two characteristics produced 8 groups of about 20 individuals each. The respondents were selected on a random basis from the telephone directory and grouped as indicated above depending on their answers to the two distinguishing criteria.

All the individuals selected documented their travel behaviour on three successive workdays by means of the mobile phone. On the first day, a traditional KONTIV design questionnaire had to be completed in addition. In parallel with TTS data collection, the respondents were interviewed by well-trained interviewers every day. These interviews were made to spot errors on the part of the respondents at an early stage, but they also allowed questions to be asked on the data collection unit and user acceptance. As a questionnaire had to be completed simultaneously it was easier for the respondents to compare both methods and give their personal preference. The main findings of this analysis are described below.

More than 75% of all respondents (154 individuals) thought that using the mobile phone, and this included its special functionality, to be very easy or easy. Individuals from all social classes appreciated the mobile phone as a multifunctional unit, stressing the ease of handling and data entry.

The respondent burden obviously has an influence on the person and trip non-response rate and the quality of the data produced by the survey. Low requirements evidently mean a low-stress situation, which generally has a favourable effect on the validity of a survey. In surveys making use of the mobile phone, the input requirements are a major stress factor. More than 85% of all the respondents rated the input requirements as low or they even thought it to be no burden at all. When comparing the time at which entries had to be made it appears that the burden is slightly higher at the end of a trip than at the beginning or when changing transport modes. All in all it can, however, be said that the input requirements for a three-day survey are rated to be very low.

The respondents clearly preferred the mobile phone to traditional questionnaires as they thought it to be the “better” data collection tool; more than 80% of all respondents favoured TTS data collection. The main reasons for this clear preference were:

- low input requirements as compared to a questionnaire that has to be completed
- comfortable, easy and quick data collection
- no need to enter such data as time and place
- no need to try and remember details.

According to the results of the TTS field test, individuals forget less trips when using the TTS-based online-collection of trip data than in a retrospective interview. Furthermore low respondent burden, caused by automation and simple handling, has benefited non-response. Fatigue-effects (i.e. increasing person and trip non-response; rising of incorrect and incomplete data) could not be realised due to the short survey period of only three days. What could be realised within three days, was a decrease of the number of missing details and a lower error rate.
3.1.4 **PERSONAL HANDY-PHONE SYSTEM (PHS)**

Another mobile communications system as a tool for collecting time-space activity data was developed by Transport Studies Unit of Ehime University in Japan. Similar to TTS, this research examined the possibility of using a mobile communication system, called **PERSONAL HANDY-PHONE SYSTEM (PHS)**, to collect individual trip data.

In a survey conducted with the PHS, a micro-cell mobile communication system in Japan, latitude and longitude coordinates are measured on the basis of mobile specific data. In contrast to TTS, data on field strength of serving and neighbouring cells were gathered as a basis for the positioning algorithm. This difference gives a higher accuracy than the serving-cell positioning of TTS. Like TTS the trip data could be surveyed automatically and in real time.

A survey based on PHS collects origin and destination, start and end as well as the route of a trip in a totally self-controlled manner. A message indicating the start of a survey is sent to a subject’s PHS phone. Upon receiving the message, the PHS phone sends the number of the base station with which it is currently communicating and the field strength to the base station. The transmitted data are converted to latitude and longitude coordinates by a geographic information system (GIS). These raw data are aggregated in terms of the number of trips per day, trip length, mode of travel etc., by using a specific developed program for converting positioning data into trip data.

The main difference between PHS and TTS mainly lies in the processing unit. Based on the measured subjects’ position data the distance and the speed between two sets of position coordinates are calculated. If the calculated speed is higher than a certain threshold value, the subject observed is moving, i.e. it is making a trip with high probability. This means for example that if the speed exceeds 200 km/h, it is judge to assume a movement. Based on this algorithm, a trip and activity could automatically be determined.

The developed surveying and processing system was tested over a period of two weeks. The objective of this test was to verify the efficiency of the PHS-based survey method by comparing its characteristics with those of a conventional survey approach and to identify any problems involved. The target subjects were ten persons living in the city of Osaka or its environs. Three types of surveys were conducted to verify the efficiency of the system. One was a traditional personal trip survey (written-postal interview with questionnaire), another was a simple activity diary survey and the third was the PHS-based survey. In view of the large burden for the subjects in filling in a questionnaire, they were asked to complete the questionnaire only for two days during the survey period. The simple activity diary survey was used to complement the PHS-based survey. The subjects were asked for activity start and end times as well as for activity details, because this information could not acquired by the PHS-based survey.

The main results of the field test are described below:

- Positioning accuracy to within 60 m on an average was obtained with the PHS, which is better than that of TTS. The accuracy varies with the location, depending on the base station density.
• A PHS-based survey reproduced around 90% of the total number of trips that actually occurred. There is a high reproducibility of a subject making a trip by car and by train, with reproducibility rate of train trips being 100%, while that of trips on foot or by bike was low.

• It was confirmed, that route data could be collected as well as origin and destination of a trip.

• The combined use of a simple activity diary survey and a PHS-based survey reproduces individual travel behaviour nearly perfectly.

While only ten persons participated in the two-week survey, position coordinates were collected at nearly 42,000 points. In order to carry out large-scale surveys, there is a strong need to have an algorithm that can manage the enormous volumes of data collected at one time with a mobile communication system. Nevertheless, the results of this study show the potential effectiveness of a PHS-based observation as a new survey method (Hato and Asakura, 2001).

3.2 Computer Assisted Retrospective Surveys

3.2.1 CHASE, REACT!

The program “Computerized Household Activity Scheduling Elicitor“ (CHASE) developed by Doherty and Miller aims at the activity scheduling behaviour of individuals, (Doherty and Miller, 2000). The data collected serve as a basis and as input variables for activity scheduling models. This data base can be evaluated with respect to the relationships between variables and principles of scheduled and realised activities and travel behaviour.

CHASE was applied for the first time in 1997 in a survey conducted in Hamilton, Ontario. Included in the interview were 42 households connected with the McMaster University.

CHASE records the order in which the members of a household add activities from their activity agenda to their weekly schedule within the course of a week (the reporting week), or in which they change or delete activities already entered. The user making these entries, as well as data and time of entries are automatically also recorded. The activity agenda lists the activities with attributes, which the members of the household can actually realise in the course of the reporting week, (Rindsfüser and Doherty, 2000). From this agenda, subjects select those activities which are scheduled for the reporting week and which are actually realised. The weekly schedule is a true picture of the reporting week, into which the activities are entered the moment they are planned. It is to be updated during the reporting week so that it always reflects the actually scheduled and realised activities, and at the end of the reporting week it should show all the activities realised as well as their parameters (cf. Figure 4).

The program was installed on three laptops that were passed on from one household to the next at the end of each reporting week. The laptops were handed out Sunday evening and collected in the evening of the following Saturday. In an introducing interview conducted on Sunday, the activity agenda of each household member was established. Additional questions referred to the socio-demographic background of the household, availability of transport modes, and living conditions. The interviewer entered these details directly into a Microsoft access data base, using forms pre-
pared by means of VBA (Visual Basic for Applications). This is the data base that CHASE refers to during the reporting week. The household members were given explanations on how to use the software. Immediately after the end of the introducing interview they were to enter all activities scheduled for the reporting week into the weekly schedule. In the course of the reporting week they should log into the program at least once a day. During the reporting week, activities were continuously added to or deleted from the weekly schedule, or activities or their attributes were changed. Any additional information on the activities was requested automatically. Supplementary questions were to supply background information on the activities scheduled. Logic tests and completeness checks were made with every login and every interaction with the program. If required, the program produced input dialogues with additional questions. A final interview was conducted to allow the interviewer to check the entries made.

Figure 4: CHASE weekly schedule with entries completed until Friday, (Rindsfüser and Doherty, 2000)

At the end of a week, detailed records were available on the activity programme actually performed during the reporting week and the underlying planning and decision taking processes of all members of the household, while the respondent burden remained relatively low and there was only a minimum of fatigue effects, (Doherty and Miller, 2000).

REACT! was developed on the basis of CHASE by the University of California, Irvine (UCI), (Lee and McNally, 2001). This was done with the intention of using the Internet to collect data on the activity scheduling behaviour, as this would much reduce the effort and time that has to be spent on field work, while at the same time increasing the sample volume. An added advantage is that this
supplies data on a continuous and long-term basis. REACT! was also improved to eliminate problems identified with CHASE.

A pilot study was conducted in 2000 for 47 households at the University of California, Irvine, (Lee and McNally, 2001).

To reduce field work costs, REACT! did not use laptops during the reporting week, and there were no personal interviewer visits for the introducing and the final interviews. This is why only households with private or office computer access to the Internet or e-mail connection could take part in the survey. The introducing and final interviews were computerised so that the household members could enter the required data without the help of an interviewer. The program was loaded into the local computer, from where it was also operated. Any data entered were transferred to a server by the respondent on a daily basis.

The graphical user interface was modified in respect of the weekly schedule and the way an address is entered. The weekly schedule had been changed, because its detailed calendar form might encourage respondents to enter activities with starting and end points, even though these may not have been fixed yet. They might also want to fill gaps between activities with activities that have not actually been planned. Under REACT!, activities can be entered into the weekly schedule without detailing the day for which they have been planned and also without an exact time. It was now also possible to leave several attributes of scheduled activities open when making entries. CHASE only permits this in respect of the transport mode used and the time of travel, even though additional attributes may not have been known at the time of planning. The address can now also be entered directly by means of a map or a description of an address, by making reference to junctions or other distinct points (cf. Figure 5).

![Figure 5: REACT! address entry (Screenshot by Lee, Dec. 2000)](image)

The pilot study showed that the respondents are in a position to install the software themselves and to conduct the survey independently. The aim of reducing the field work input has thus been
achieved. Other intended developments concern the form of the weekly schedule, simplified co-
ordination of entries made by the household members, as well as interaction with the server.

The advantage of collecting data on the activity scheduling behaviour by means of CHASE and RE-
ACT! has to be seen in the fact that conventional data collection methods would probably not have
produced these data, or, if so, only at a much greater input of work. As the data produced during the
introducing interview were used during the reporting week, and as each interaction with the pro-
gram was saved automatically, the data were collected with a minimum of respondent burden. Inde-
pendent local installation and execution of REACT!, as well as the fact that the data were transmit-
ted by the respondents through the Internet very much facilitate field work and allow a much larger
sample to be handled.

3.2.2 CHASE-GIS

The software CHASE-GIS is also based on CHASE. CHASE-GIS especially allows the collection
of behavioural data with spatial aspects, using remote entry into an activity diary with interactive
vector maps. CHASE-GIS was developed at the Institut für Stadtbauwesen, RWTH Aachen, Ger-
many, in co-operation with Dr. S.T. Doherty, currently Wilfrid-Laurier-University, Canada, and
PTV AG, Karlsruhe, Germany, (Kreitz, 2000).

The first application of CHASE-GIS took place in Summer 2000 in Karlsruhe, Germany, with 30
households which were provided with laptop computers for this purpose.

According to the research purpose of the CHASE-GIS survey, the main emphasis was on testing the
spatial survey aspects. For this reason, only revealed behaviour was of interest. The prompts imple-
mented in CHASE that related to the activity planning behaviour were temporarily disabled for this
survey, so that the respondent burden did not get out of hand.
The aim of CHASE-GIS is the collection of detailed spatial information on the household members’ mobility behaviour during one reporting week. Similar to CHASE, all interactions with the program are reported. The same weekly schedule is used, but the entry dialogue was completely modified regarding the amount and type of information gathered and the additionally implemented map which serves as display and data entry facility, see Figure 6. CHASE-GIS draws on an expanded version of the MS Access data base.

During the introducing interview, all necessary data on socio-demographic parameters and activities of the household members are added to the data base by the interviewer. In addition to CHASE, detailed spatial information can be given. In the introducing interview, activity locations are defined by means of the map. Activity locations can be added by clicking into this map, and giving a name to the new location. Geo-coding takes place automatically. Users are advised that they may indicate the location with only the degree of detail they feel to be adequate regarding data privacy. Also, “activity areas” may be defined, e.g. for activities as “walking the dog” which are usually round trips starting and ending at home, or “jogging”, which takes place within an area, with no detailed paths within this area of interest.

During the reporting week, all information is added in the activity-travel entry dialogue, which pops up after adding or modifying an activity in the weekly calendar. The entry dialogue contains the same zoomable GIS-based vector map of the study region which was used in the introducing interview. The map shows activity locations, the most likely routes between the current and the last activity location (depending on the transport mode used for this trip), and further details associated with the vehicles (e.g. parking areas, public transport lines and stops). All information shown in the map can be selected by clicking. This information is automatically transferred to the entry dialogue. The user is able to define himself or herself new locations and new vehicles (regarding public transport: new lines and stops) in the entry dialogue, using the map as a means of entry. In the case of private transport, he or she can also modify the proposed routes, if they do not represent the ones actually used. The route length is calculated automatically.

The day after the reporting week, the interviewer picked up the laptop and checked the entries. This 7-day survey could not have been made with conventional methods. Because of the large amount of data collected (and the amount and detail of the spatial data) and the high level of representation and interaction with the map, use of a CASI method was indispensable.

The advantages of this CHASE-GIS survey are:
- Collection of complex spatial and behavioural data at a relatively small extra respondent burden,
- representation of (updated) maps and the amount of detail given,
- automatic coding of data entered,
- possibility of reusing information already entered,
- possibility of changing entries previously made.
Since laptops were used, individuals who do not have their own computer at home but were confident that they were able to handle this computer-assisted survey could be included. The computing power and the (13 to 14") displays of the laptops were such that the graphical elements were displayed at an adequate speed and with the required graphical quality. As already mentioned for the CHASE survey, the disadvantage of this laptop-based method is again the considerable amount of time and personal effort that has to go into it.

The CHASE-GIS software, the surveys carried out with this software and the results produced will be illustrated in a separate presentation during this conference.

3.2.3 **Computer-Based Intelligent Travel Survey System**

The Resource Systems Group developed an Internet-based CASI travel survey tool in the research project called “Computer-Based Intelligent Travel Survey System”. The project was sponsored by the Federal Highway Administration of the U.S. Department of Transportation. The purpose of this project was to improve travel survey instruments by including interactive geocoding and the additional “intelligence” that is provided by this geographic information, and by improving the way in which surveys are administered.

Software was developed for two particular travel survey applications. Like conventional travel diaries, the first application allows trip data to be collected with a special focus on geographic information. This tool is similar to the CHASE-GIS software described in the previous chapter (cf. chapter 3.2.2). The second application is used for stated preference surveys to support mode choice model development. For both applications, the Internet served as survey instrument and was used like a complex electronic questionnaire (cf. chapter 3.1.3).

The respondent-interactive geocoding module is common to both survey applications developed in the project. The geocoding module supports four alternative respondent input options:

- selecting a location on the map
- entering the closest intersection,
- entering the street address, and
- searching a list of business address.

The respondents’ entries can be validated, and respondents can be provided with a visual representation of their trip. These options result in an efficient way of geographic data collection and validation (Adler and Rimmer, 1999).

The geocoding module was tested in a survey in which 600 residents took part. The field application demonstrated that respondents use, and often need, each of four the options to accurately identify the place they visited. The majority of home and work locations were geocoded using a street address, while trips made for other purposes were geocoded using all methods. The respondents often did not know an actual street address for non-home and non-work destinations, so they preferred to use business names and map point-to-click options (Adler and Rimmer, 1999).
The field experience indicated that respondent-interactive geocoding is a feasible approach and that respondents use a variety of methods for specifying geographic locations. It is also clear that a sufficiently large and diverse segment of the population currently has access to the Internet (nearly 50% of all adults in the U.S.) so that an Internet survey option should be provided. Although the Internet population is not representative of the full population, it could be used for travel surveys of some groups (e.g. students).

3.3 Computer Assisted Stated Preference Methods

Stated Preference Interviewing (SP) aims at the preference respondents have for one of two hypothetical situations. The situations they are confronted with are produced with the aid of a test plan.

SP used in the Mobiplan project was conceived by the IVT of ETH Zurich, Switzerland, and was implemented by PTV AG, Karlsruhe, Germany, (König, 2000). It is to show relationships between the choice of the place of residence, travel behaviour and choice of transport mode. Together with the results of the traditional (PAPI) survey carried out as part of the project to collect data on decisions respecting change of address and where to take up residence, the findings are to arrive at a model of behaviour deciding on the choice of residence.

SP interviewing took place in the spring of 2001 in Karlsruhe, Germany. A total of about 150-180 individual were interviewed. Under the Mobiplan project, a consulting tool, the “MOBIPLAN”, was developed, (Kreitz et al., 2000), which runs in the Internet (www.mobiplan.de). On the basis of data entered by the user, effects and alternatives of his or her personal mobility behaviour are computed. SP produces hypothetical situations from a situation the user has entered in the MOBIPLAN consulting tool. The Internet is used for interactive interviewing, and a conventional questionnaire, as well as a final interview round the survey off. Interviewing is directed at three elements:

- **SP 1: Choice of transport mode**
  The respondent takes a choice between private and public transport for a typical trip. Influencing factors include travelling expenses, travel time, and service frequency (cf. Figure 7)

- **SP 2: Transport availability for the household**
  Respondents are presented with always two residential situations with different mobility parameters (e.g. length of trip to work and for shopping). They then list the availability of transport or of public transport tickets for each household member. The total costs resulting from the residential situation and transport availability are updated and presented to the respondents before they take a final choice.

- **SP 3: Choice of residence**
  Respondents are presented two of the scenarios of residential situation and transport availability that were produced in SP 2.
The advantages of interactive Stated-Preference Interviewing through the Internet have to be seen in:
- the fact that SP starts from a real situation which the respondents have themselves entered in a first step,
- automatic computation of the scenarios, using the test plan as a basis and also the real situation, and additional entries made by the respondents,
- automatic coding of the replies.

Basically, SP could have been conducted from any computer providing access to the Internet, which means that the respondents could have taken part in the survey from their homes or from work, and they need not have spent any extra time (and possibly money) on trips to the institute conducting the survey. But since in this case SP was made in conjunction with two other surveys that required the presence of an interviewer and that were installed locally, this advantage did in this case not come to bear.

4 CONCLUSION AND OUTLOOK

Computer-assisted surveys can assess some characteristics of mobility behaviour with greater accuracy and reliability than conventional methods of data collection. Since CADAC methods can dispense with manual data entry and coding, this possible source of errors is eliminated, which means that these methods produce results of a higher quality.

Computer-assisted observation allows spatial and temporal movement data to be collected automatically, i.e. without direct involvement of the respondents. It is, therefore, no longer the respondent who has to be seen as a possible source of errors, but the technical tools used. GPS and GSM allow automatic online data collection to be made with different degrees of positioning accuracy. Routes used can for the first time be determined over prolonged periods of time and at very high confid-
ence levels. Linking the spatial information thus produced with a GIS-based evaluating system, opens up new ways of analysing, interpreting and controlling typical route selection behaviour. The new methods do not tend to underestimate certain routes in the same way as typically observed in traditional data collection methods; spatial and temporal information is characterised by a higher validity. In contrast to traditional methods the automatically collected data is sent directly to an EDP-system and is processed by this system within short time. For data being available nearly online, the effects of traffic influencing measures could be recorded and analysed rapidly and continuously.

As for computer-assisted interviewing, advantages should in the first place be seen in the possibility of automatic filter control and the use of acoustic and, in particular, graphical tools. Visualisation options can be utilised to confront respondents in a realistic manner with actual or future situations and so produce exact data on certain circumstances. Graphical possibilities of the computer technology in addition help increase the respondent motivation and willingness to participate in the survey.

For large sample volumes, the costs involved with computer-assisted surveys normally remain below those of conventional methods. This is, in particular, true when low-cost and generally available hardware and software can be used, as for instance in surveys based on the mobile phone or in online interviews through the Internet. Specialised tools and applications for specific surveys, on the other hand, tend to be expensive and cannot be recommended.

Developments expected in the information and communication sector favour CADAC methods in transport planning. The costs of the tools and their operation can be expected to go down, while more options will be available for visualisation, data transmission and data storage. More widespread availability of the technology involved means that more people are familiar with it and show less reluctance in using it. Any bias due to insufficient market penetration of new technologies will decrease in the future.
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