TELETRAVEL SYSTEM (TTS)
TELEMATIC SYSTEM FOR THE AUTOMATIC SURVEY OF TRAVEL BEHAVIOUR

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Abstract: This report describes a telematic system called "TeleTravel System" (TTS) that will be used to survey individual travel behaviour. The TeleTravel System is based on the GSM-Standard. It collects data concerning travel behaviour automatically, prepares it, and stores it in a central data base. Information about all changes of location an individual has made within a fixed period of time are provided. Individual attributes of trip are always supplied. The equipment and survey technique of the system are explained as well as the functional components, especially a GSM-based positioning algorithm.

Keywords: behaviour, acquisition of data, positioning systems, telecommunication, telematics, transportation.

1. INTRODUCTION

Valid and detailed data about regional structure, settlement, transportation infrastructure, as well as actual travel behaviour, and the current traffic conditions is required for the suitable planning of traffic infrastructure, and to meet the social and environmental requirements of guiding transportation. Whereas data, concerning regional structure, settlement and transportation infrastructure is widely available, information about the individual spatio-temporal behaviour generally is not. To attain this information for the use in transportation planning there are two types of surveys: observation (without participation of road users) and individual questioning (needs participation of road users).

Observation records visual behaviour and external attributes in a clear spatial and temporal range. Observation provides considerable advantages, because it may be used irrespective of the readiness or the ability of road users to give information. The real widely pristine travel behaviour can be measured. What, however, cannot be measured is the preceding or future behaviour, e.g. motives, attitudes or reasons for the observable behaviour. Observation is in practice confined to the use in traffic surveys in small areas. A spatial and temporal extension of the survey area would lead to unjustifiable costs and requirement of personnel.

In contrast to observation, questioning provides not only information about individual travel behaviour, but also situative causes and subjective motives of behaviour. This procedure records human travel behaviour aspecting time, area and sociodemographics over a prolonged period of time. Individuals can be interrogated about their intended or concluded travel activities as well as for reasons and causes of behaviour. In general, home surveys (written, oral or by telephone) are performed on a random sample of households. They provide information about concluded trips of individuals of 6 years at age and over. A disadvantage of such common cross-section surveys is, that comprehensive temporal information is not available, but in fact only a snapshot of travel behaviour. For those reasons, it is not possible

- to make predications about the frequency of trips of an individual per month or week,
- to differentiate between inter- and intrapersonal variability, and
- to survey trips lasting longer than one day.

To gain valid data it is therefore essential to survey a random sample of individuals over a prolonged period of time (panel survey). However, the expenditure for a panel survey is disproportionately high. Panel members deceasing, changing residence and refusing information a.o. (panel mortality) must be substituted. In addition to that, panel surveys provide other procedural problems called „panel effects“. Those effects are a.o.t.:

- fatigue-effect (the increase of missing and faulty pretences),
- effect of memorization (the surveyed person remembers previous answers), and
- spontaneity effect (the surveyed person starts to observe his own behaviour and loses spontaneity).

These panel effects reduce the quality of answers and increase the already imminent distortions, inevitable in written surveys performed on a random sample basis. Random sample surveys not only lead to a calculable random error, but mainly to distortions by individuals who do not answer questions (non-response) or give incorrect reports.

Currently, experts have to ascertain, that there is no survey procedure being in a position to supply data about the individual travel behaviour

- over a prolonged period of time (week, month, year),
- respecting wider spatial areas,
- for a sufficiently large random sample of individuals (e.g. to determine an O-D-matrix for a country wide transportation planning process),
- with sufficient reliability (e.g. complete number of trips), and
- with sufficient precision in respect to indication of time, location and route information in particular.

2. INTENTION

Availing recently developed equipment for positioning, communicating and transmitting data, and integrating each into one system, has been developed by the research project TTS – TeleTravel System. This procedure surveys the specific behaviour of road users with a higher precision than traditional survey procedures do. At the same time the acquisition of data is widely automated in order to relieve the surveyed person. With this system, knowledge about traffic requests will increase, and the comprehension of individual travel behaviour will be intensified.

The TeleTravel System utilizes the advantages of both sociological survey procedures (observation and questioning) by recording data partially automatically, thus independent of road users. An automatic acquisition of trip data including the attributes of start, end, origin and destination of a trip, transport mode, purpose, route a.o. eliminates or decreases the deficits of the traditional procedures described in chap. 1. The ideal panel survey of individual travel behaviour is

- without panel mortality and panel effects,
- without spatial limitations,
- with the complete number of trips,
- without faulty or inaccurate pretences of location and time,
- with information about routes and more relevant information about traffic (e.g. differentiation of purpose for special surveys of recreational traffic), and
- with less and manageable non-response.

The basis for the panel survey is the telematic system TTS. The survey tool is a conventional mobile telephone. The system components, especially the mobile phone, will be described in the following chapter. The positioning of a mobile as a central function of TTS, will be shown in chapter 4 accompanied by an example.

3. STRUCTURE OF TELEMATIC SYSTEM

3.1 System components

The acquisition system is based on a telematic system consisting of different components of technical and conceptional equipment (see fig. 1).

The main component of the telematic system is the survey tool, a typical mobile telephone including a specially programmed Subscriber Identity Module (SIM). The mobile is able to edit mobile-specific data by using algorithms which results in traffic-relevant information (origin, destination and route of a trip). Further necessary particulars may be gathered manually. To gather traffic-relevant information the mobile has to be connected to the GSM network, and the receiving mode has to be set. Since, it is not necessary to make a call or to use other services of the net provider. TTS will work in either mode: the idle-mode or the connected-mode. The system records relevant data independent of the transport mode. It is restricted to the individual whose behaviour should be surveyed.

Measured data is latched in the mobile and is transmitted periodically to a receiving unit. This unit receives the data, tests it with regard to correct and complete transmission, and stores it in a data base of unworked data. The processing unit computes the required data of travel behaviour from the unworked data, tests it with regard to plausibility, and finally stores it in a resulting data base. A major function of the position finding algorithm is to investigate the position of the mobile by referring to specific data from the digital cellular telecommunications system. This is the basis of the automatic coverage of origin, destination and route of any trip. The receiving unit and the processing unit could either be in one EDP-system or in separated systems. For a mass survey providing huge amounts of data, it is reasonable to also physically separate both conceptionally different systems.

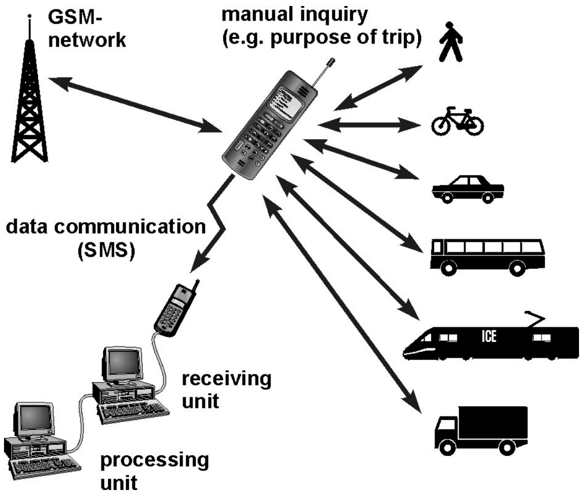

Fig. 1. Structure of the TeleTravel System

The transmission of data between end device and receiving unit is realized by the Short Message Service (SMS). SMS enables a mobile to receive and to send short messages up to 160 characters. A transmission is relatively cheap and independent of the size of the message. Another essential advantage of SMS is the rapidity of the transmission.

The delivery of data from the end device to the receiving unit is processed as follows: relevant data of travel behaviour is transmitted to a SMS-centre (SMS-C). The SMS-centre promptly transfers the message to the receiving unit. This unit receives the data, tests it with regard to correct and complete transmission, and saves it in a data base of unworked data.

3.2 Survey tool

The equipment for the survey of travel behaviour consists of two technical components. These are a mere mobile phone plus a specially programmed SIM. The mobile itself can primarily be seen as user-interface, i.e. communication between the operator and measuring instrument is performed by using the key pad, voice, audible signals a.o.. Moreover, the end device serves for the automatic acquisition of mobile-specific data, which is the basis for the later analysis of spatial data of a trip, in the processing unit. Finally, it serves for the manual acquisition of further information important for the transportation planning process.
The „intelligence" of the survey tool is in fact found in the SIM, a chip as small as a thumbnail. Without this SIM a mobile would not function. The SIM chip stores information that is required to log onto the cellular phone network (e.g. personal identification data such as the number of SIM, personal directory a.o.). The mobile will not function until the net provider has released the SIM chip.

Apart from the basic functions of the SIM, user identification and logging onto the network, transmissions of short messages or dial-up can be monitored by this chip. By using a special application, called SIM-application, it is possible to technically realise the required functions for an automatical survey of travel behaviour. Features of the SIM-application are:

- mobile-specific data, essential for the automatic survey (of the spatial component) of travel behaviour is requested and saved to the SIM
- further information important for the transportation planning process is manually entered by key pad and also requested and subsequently saved to the SIM
- saved data is transmitted periodically to the receiving unit per SMS

Thus, the key-components are, on the one hand, the SIM-application and, on the other hand, the positioning algorithm in the processing unit. For this reason, each new mobile phone with a specially programmed SIM (incl. SIM-application) can be used as survey tool.

4. GSM-POSITIONING

A key-function of the survey tool is the positioning algorithm within the processing unit. Through this the spatial data of travel behaviour (origin and destination of trip) can be computed.

The determination of the position of a road user is based on the European Telecommunication Standard GSM, i.e. a positioning can be executed by a custom mobile phone. The developed procedures of positioning make use of data, registered inside the mobile for a dial-up anyway. The following data occurs inside the operable mobile periodically and is relevant for the positioning algorithm:

- the identification of the serving cell[1] by CI (Cell Identification), MCC (Mobile Country Code) and MNC (Mobile Network Code),
- BCCH (Broadcast Control Channel) and BSIC (Basestation Identity Code) of the serving cell,
- BCCH and BSIC of (maximal six) neighbouring cells,
- RXLev (Receiving Level) of serving cell and neighbouring cells.

[1] Cell, providing connection between network and mobile phone

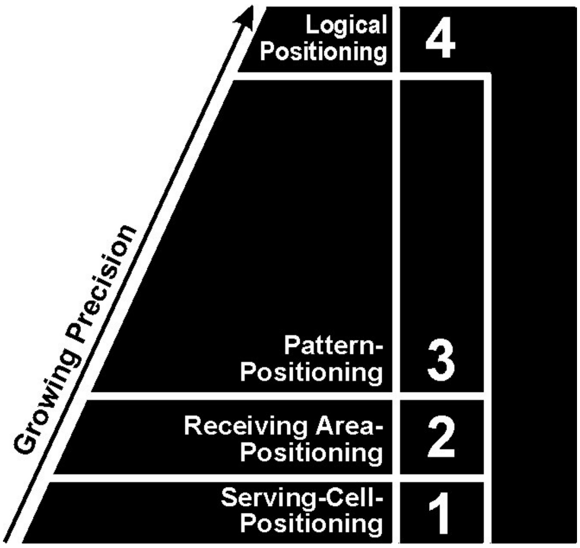

Fig. 2. Levels of GSM-Positioning

The positioning procedure requires various mobile-specific data as input parameters. Altogether three positioning levels have been conceived, differentiating in precision and positioning expenditure (see fig. 2). The computing and transmission expenditure of data increases depending on the growing positioning precision, so that it is possible to select the adequate level with regard to the task and aim of a traffic inquiry. On the first level, positioning precision is appointed by the dimension of communication cells. On level 3 (pattern-positioning), the number of received cell-levels is relevant for a precise positioning. (Garben *et al*, 1999).

By combining each level of positioning with the so called „logical positioning“ (level 4), the precision increases and a projection of the traffic network (road network, public transport system) is possible. Previously detected positioning areas are compared with traffic networks, assigned to one or more elements of that network, and fitted into the temporal context (previous positions are considered).

The serving-cell-positioning (level 1) has not only been proven to be technically feasible by representative trips, but also practical in an experiment with 160 randomly selected individuals. The positioning procedure in level 1 is described in the following paragraph and the results are illustrated in an example.

Each switched on mobile is in constant touch with at least one but mostly with several antennas (better: communication cells) of surrounding basic stations. This is essential in order to locate and identify a mobile in the case of a dial-up. Thus, actual information about serving cell, esp. identification data is always available from the apparatus.

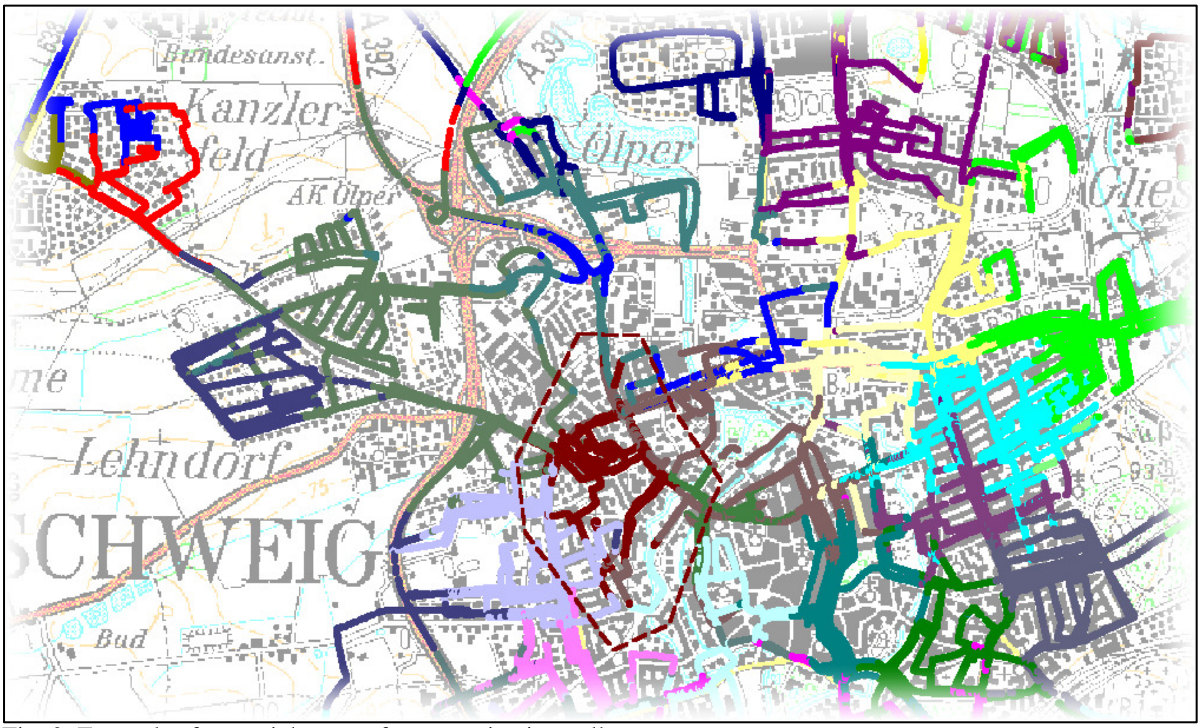

Fig. 3. Examples for spatial areas of communication cells

The positions of basic stations, the angles of radiation of their antennas, as well as the areas supplied by the respective cell (serving cells), are precisely known or can be determined by performing measure trips or by using EDP-based models. Hence, the measure trips performed by the net providing companies for the use of quality assurance and advancement of their telecommunication infrastructure are basic for a so called reference data base, storing the identification data of serving cells (CI, MCC, MNC) and their spatial position. While performing measure trips, not only positioning-relevant data accrues, but also GPS data about positions. With these additional particulars a reference of a serving cell to its spatial location is possible. An exemplary result of several measure trips, performed in the city of Braunschweig by the German net provider E-Plus, is shown in fig. 3.

Different greyscales clarify areas in which several cells assume the function of a serving cell. The principle of serving-cell-positioning is based on

- the identification of a serving cell inside the mobile phone with CI, MCC and MNC as well as
- a subsequent allocation to a spatial area in the processing unit.

The allocation results from a comparison between the received serving-cell data with the information stored in the reference data base. Result of the positioning is a spatial area with the size of the actual cell (see fig. 3). In the course of the further process this positioned area can be projected onto the relevant network elements (e.g. traffic zones or one ore more road-sections).

An exemplary result of the serving-cell-positioning, a trip from the city of Cottbus to Klein Marzehns (administrative district of Potsdam-Mittelmark, Brandenburg) is shown in fig. 4. The positioned areas on basis of communities have been mapped. Whereas the origin of the trip definitely can be assigned to the city of Cottbus, the accurate restriction of destination to a community is not possible. But, in contrast to the usual survey procedures, predications on the route of this trip can be made. Even if the actual route cannot be specified, it is possible (when selecting the highway network) to isolate the links to few alternatives. By combining this procedure of positioning with the logical positioning (this includes a.o.t. control of travel time) possible routes are once more isolated and the ideal case is that the actual chosen route can be ascertained.

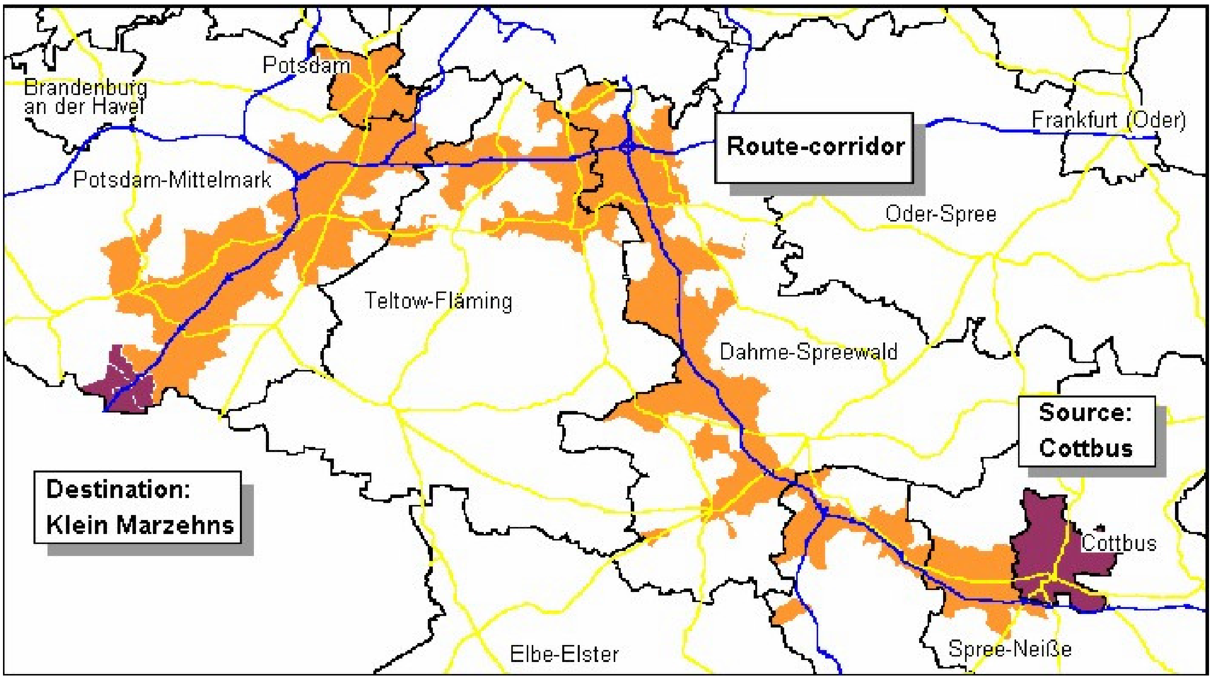

Fig. 4. Example for serving-cell-positioning: trip from Cottbus to Klein Marzehns

The precision of positioning depends decisively on the size of the cells, thus on the dense distribution of basis stations. In urban areas, a close network is generally existent, because of much generated traffic (for the purpose of mobile communication) that needs many cells to provide the users of the mobile communication system. In rural areas the basis stations provide a larger area. With regard to the precision of positioning it must be ascertained that in urban areas the positioning is more precise than in rural areas. Hence, the precision is e.g.

- in the area of the fair terrain Hannover approximately 200 – 500 m,
- in the capital of Berlin app. 1.500 – 2.000 m,
- in the rural area of the administration of Brandenburg app. 6.000 – 12.000 m.

The correlation between cell size and population density is equal to the usual correlation between the size of traffic zones resp. density of traffic network and the population density in traffic planning. Therefore, the precision of positioning is in about the requirements of models of area and network, which are less precise in sparsely populated areas. However, this does not implicate a less precise overall result.

The serving-cell-positioning with its simple and less expendable procedure allows for absolutely sufficient precision for the acquisition of long-distance traffic data. Only in long-distance traffic there is no or an insufficient data base concerning the individual travel behaviour available. The last countrywide survey in Germany concerning individual travel behaviour (called KONTIV) took place in 1989 and holds limited validity, because of its procedure, to investigate on a single key-day on a small random sample. In addition, it can be assumed that long-distance travels are underrated. Today an automatic survey of long-distance traffic on the basis of the serving-cell-positioning is technically feasible and could provide essential parameters of the spatio-temporal behaviour with higher precision if employed as a long-period-survey.

5. ELECTRONIC QUESTIONNAIRE

Besides the spatial attributes, origin, destination and route of a trip, which are gathered automatically by the GSM-based positioning process, a characterization of individual travel behaviour (temporal start and end of a trip, transport mode, purpose a.s.o.) is possible.

The purpose, as well as temporal information of a trip (start, end or probable change of transport mode), as well as every used transport mode is surveyed manually in this primary phase of realization. These attributes are gathered by menu prompting, i.e. they are manually entered by using a key-pad. The menu is the so called „electronic questionnaire", implemented on the SIM. Even though the purpose of a trip cannot be measured automatically, it is imaginable and desirable for temporal attributes and the transport mode. This would result in a decrease of faulty pretences made by the surveyed individual.

An algorithm for the automatic detection of the start and end of a trip has already been developed and transcribed into software (Loehner, 1999). The question is, if this algorithm can be implemented as a SIM-application without further effort. Indeed, it can be foreseen, with regard to technological improvements, that the automatic acquisition of temporal attributes of trips will be possible in a medium term.

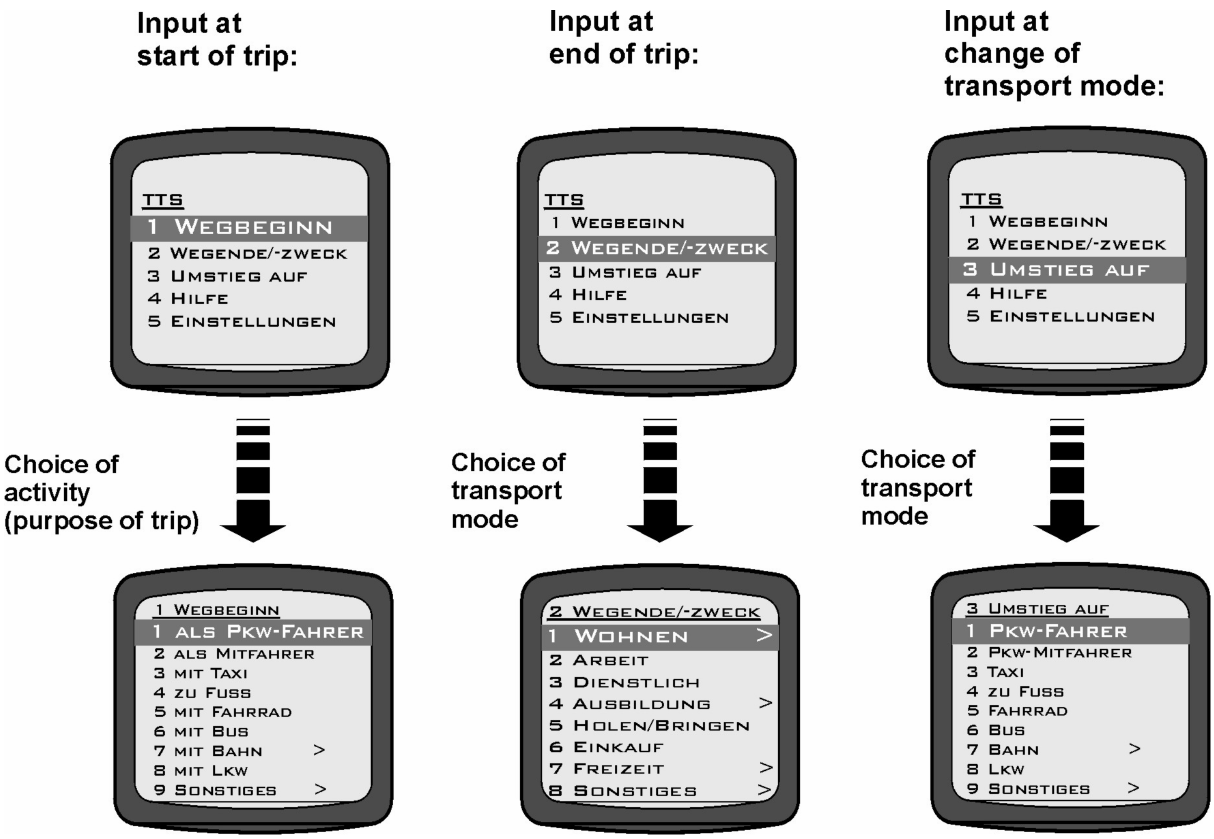

Fig. 5. Electronic questionnaire

For the manual input of additional travel information the user disposes of different menus (see fig. 5). The trip-menu („Weg-Menü") asks for the temporal attributes; start of a trip as well as in case of a change of transport mode for the time of change. If the choice is „start" („Wegbeginn") or if it is „change of mode" („Umstieg"), the user will be lead into the transport mode-menu („Verkehrsmittel-Menü"), where he may choose from different categories of transport mode. Analogically, if the choice is „end" („Wegende/-zweck"), the following activity-menu („Aktivitäten-Menü") asks for the input of the purpose of the last trip (the activity taking place at the destination of this trip). The structure of menus can be varied and enlarged to a certain degree. Also any desired content of menus is possible. (Sommer, 1999).

Number and content of menus primarily depend on the purpose of the survey. A survey e.g. on recreational travel requires other differentiations of purposes than a survey on the analysis of working day travel behaviour. Fig. 5 shows examples of the acquisition of purposes and transport modes. These examples refer to behaviour-relevant questions, usually applied in home surveys for the analysis of working day travel behaviour.

5. SUMMARY AND PERSPECTIVE

The recently invented TeleTravel System provides technical basics for a current and valid acquisition of data concerning individual travel behaviour. Technical components are usually available and cost-effective devices, i.e. special new or advanced product developments of hardware are not necessary. Especially the use of implementation of usual mobile phones equipped with a specially programmed SIM to be used in behaviour surveys, has to be mentioned. The mobile today, but especially in the future, is the most applied device for information and communication and the most accepted by users. The advantages of TeleTravel System in contrast to the usual survey procedures are recapitulated in the following paragraph (Wermuth, 2000):

Less non-reported trips
Automatic acquisition of trip-data enables (at least partially) the identification of non-reported trips. Non-reported trips due to obliviousness or want of care of surveyed individuals can be markedly reduced by using the benefits of telematics. Thus, non-reported trips will accrue less than usual.

More precise particulars of location and time
False trip-information, caused willingly or unintentionally by manual input of a user can be identified and partly corrected by plausibility tests in the processing unit. Gathered trip-data shows higher quality than data from usual surveys. Especially particulars of location, gathered without any user-action automatically in already the first realized step of TTS, are more reliable and valid.

Less individual non-response
For the majority of individuals, the acquisition of trip-data during a trip, quasi online, is less expendable and consequently more convenient than filling in a questionnaire. The percentage of non-response, caused by negligence, lack of time or disinclination to fill in questionnaires can be reduced.

Panel surveys without decrease of quality
Effects of panel attrition, occurring in surveys over a prolonged period of time, such as increasing individual and trip non-response as well as faulty and missing particulars, will be reduced by using the automatic survey system TTS. This effect arises from the diminished effort of the surveyed individuals. The effort is limited to carrying along the mobile and entering further trip information. If a user forgets to enter this information, data is not completely futile. Predications of individual behavioural characteristics can be made anyway.

Immediate availability of traffic data
Road users data, automatically surveyed in the mobile phone will be transmitted immediately to an EDP-system processing it within few hours. This data is quasi available online and it is possible to use it for the short-dated and continuous comprehension and analysis of traffic influencing measures.

The TeleTravel System not only offers new opportunities and options in the domain of survey procedures, but can also be seen as basic technology for further applications in and out of the parish of transportation. Currently, partners of the project are developing the online-ability of GSM-positioning. With this ability, it will be possible a.o.t. to realise services concerning the domains of mobility, transport and information, that may contribute to an optimized course of transportation and logistics. The TeleTravel System offers significant information for a mode-spanning traffic management centre by offering an online-acquisition of person-related traffic data. Overall, there are further fields of application:

- By means of online acquisition of individual position data it is possible to derive traffic conditions (floating person data). This makes possible an individual inter-modal supervision of a road user possible.
- In the field of public transportation, valid and contemporary positioning data of vehicles serve as a basis for dynamic access safety and passenger information systems. Vehicle prosecution is substantially optimized by an online acquisition and –evaluation.
- In the field of logistics online acquisition is already available. It is assisted by means of GPS. But, whereas the use of GPS requires the employment of supplementary communication-

equipment, TeleTravel System combines communication and positioning in one standard device without requiring direct line-of-sight to satellites to operate.

- Technical customer services profit from the contemporary positioning by establishing a basis for new possibilities of organising their service. This possibility mainly arises from the person-relation of a mobile in contrast to the usual vehicle-relation.

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