AN INDIVIDUAL BEHAVIOURAL MODEL BASED ON THE SITUATIONAL APPROACH (SINDIVUDUAL)

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1. BASIC SITUATION AND ABSTRACT

The fundamental critical objections to the application of the individual behavioural models in planning practice are that the data in these models are impossible to collect, too complex and thus too expensive. These negative traits are frequently shown to be typical characteristics of the situational approach (1) when this approach is critically evaluated as a representative of the individual behavioural models. Although there are incontestable advantages to this approach as far as its great explanatory value is concerned, it has been pointed out that this approach is problematical because it is difficult to generalize the results in a planning algorithm - especially for spatially differentiated measures (measures for which the impact has to be differenciated for various zones). Thus it became clear that although the complexity of behaviour must be taken into consideration (2), simplifying assumptions must be made in order to be able to derive a model which makes it possible to forecast behaviour under altered material and/or social conditions (3). It seems to be promising to develop an algorithm leading to a solution of these problems. This is the theme of the present paper. The basic principle of this solution is to keep the degree of the necessary simplification variable so that "as little as possible and as much as is necessary" of the natural complexity of human behaviour be forfeited.

Therefore, a model structure is dealt with here which analyzes changes in behaviour when measures of different sorts are introduced. The key word here is marginal model. Therefore the model presented here, develops the data which are important for the planner by using a basic model which describes the status quo without attempting to explain it and a marginal model which shows a relationship between those developments and measures which directly influence mobility and changes in these variables. Thus, in order to apply the situational approach in a concrete planning instance, this model approach requires that the status quo must be available in an individual form or that it must be ascertained. In order to identify regional differences in travel demand on an individual basis, a Monte Carlo simulation method was used. The data from the preliminary and main survey done by SOCIALDATA for the Federal Ministry of Transportation as a market analysis of long distance travel behaviour (4) was used as the basis. When viewed as a whole, the individual trips (including the characteristics of the travellers) produced in the Monte Carlo algorithm depict travel behaviour before the measure which was to be analyzed, was introduced. If the persons included in the in-depths market analysis survey are grouped according to categories, of which behavioural changes differ noticeably from other groups, information is then available on possible changes in behaviour of the (situationally homogenous) groups of travellers (<u>with</u> options). At the same time the simulation algorithm designates each individual to be included in the group of travellers changing their behaviour (or not) for the entire area being studied. The applicability of SINDIVIDUAL is demonstrated using the example:

> "introduction of a train supply which is qualitatively new" - i.e., introduction of the "Airport Express" from the train station in Düsseldorf to the airport in Frankfurt." (4)

2. MODEL STRUCTURE AND PLANNING PROCESS

First it should be pointed out, that a necessary precondition of the modelling of spatial differences in transport behaviour (5) is the fact the individual remains the basic unit throughout the total planning process. Nevertheless, using this, aggregation may be carried out at any step in the model if these aggregations are not clearly used for any further calculations. This highlights the flexibility of the approach and can be shown more easily using a small sketch which compares the proposed approach with other existing model structures.

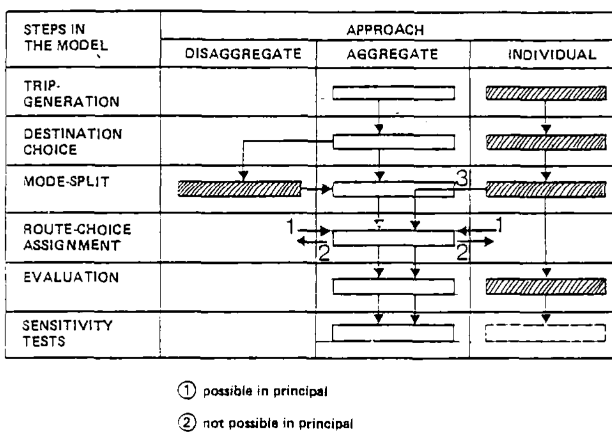

Fig. 1
DIFFERENT BASIC APPROACHES

It shows

- o that within the framework of an individual model aggregation steps can be executed at any level (e.g. for the purpose of presentation of results), if the basic procedure remains individual. ①
- o that the modelling of individual behaviour and the related variability calls for a stochastic process. (6)
- o that it is basically impossible to "disaggregate" data which have been collected for use in the aggregate. (Despite this it is applied often within the framework of conventional four-step-algorithms where the mode-

split-submodel is executed using a disaggregate approach. In doing this, although the behavioural equations are calibrated on the basis of the individual data they are applied in the aggregate.) ②

- o that it is always possible to go from an individual to an aggregate approach. This is, indeed, often done for use in special circumstances (e.g. case studies) ③ ① (7) (3)
- o that it is always possible to enter empirically gained information (i.e. interactive measured behavioural changes (8)), if the process remains individual.

In order to show at least the concept of an adequate planning model here which fulfills the above mentioned conditions, the elementary building blocks of such a concept are shown below using figure 2 as an example:

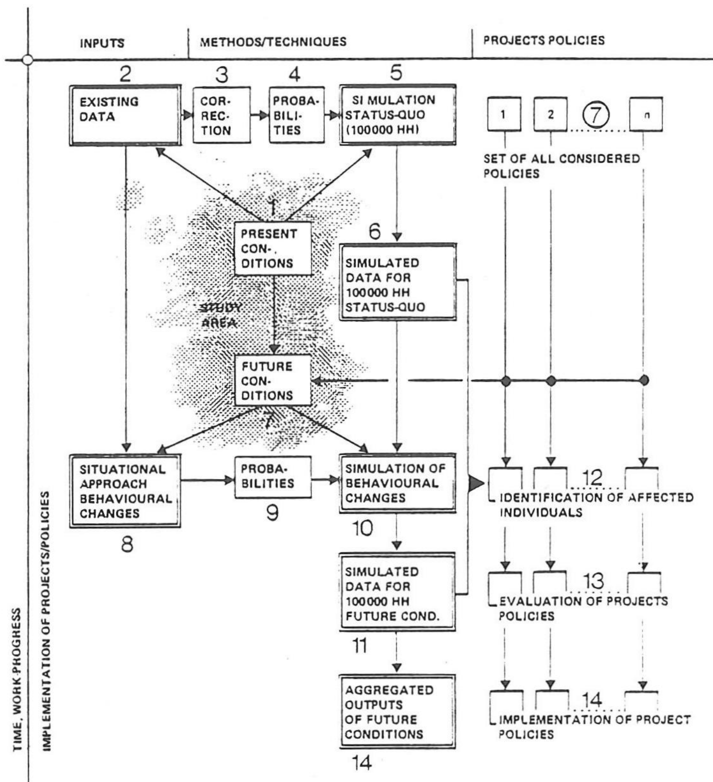

Fig. 2
General planing approach
BEHAVIOURAL

DESCRIPTION OF EXISTING CONDITIONS (STATUS QUO) -1-2-3-4-5-6-

Since existing household surveys, in general are by no means able to provide sufficient households per traffic zone to allow expansion of all traffic flows between "spatial different" zones, it is necessary to apply some type of modelling approach even at this level. In contrast to the approaches which satisfy needs described in the following sections, this approach needs to be descriptive rather than explanatory. Nonetheless, the basic concept of individual analysis should be maintained as far as possible.

A model is therefore required which

- uses as much information as possible about existing conditions in order to describe the status quo, and
- uses individual (personal) characteristics in order to maintain the basic option for analysis on an individual level.

To overcome the problem that all spatial information on traffic flows cannot be provided by any household survey, the application of an individual simulation technique is needed (see chap. 3). This technique has already been successfully applied to some very topical studies sponsored by the German Federal Ministry of Transport (9). The procedure -5- utilizes the probabilities derived from the household survey data -4- (after weighting and correction -3-) in order to describe status quo behaviour and thereby produces a record of, say, 100,000 households proportionally distributed throughout the study area -6-, containing all information on the variability of individual behaviour.

PROJECTS, POLICIES AND FUTURE CONDITIONS -7-

With reference to the general remarks mentioned above,the conditions which induce behavioural changes can be classified as follows:

- general future conditions, i.e. behavioural changes or changes of demand patterns, which are caused by external variables, (e.g. the known decline in the number of students attending tertiary institutions or the increase of unemployment).
- investment projects, e.g. an underground line increases the speed of a public-transport-system which would cause changes in modal-split behaviour.
- soft policies, such as changing price-relationships between car and public transport, which would affect general conditions for individual travel behaviour and marketing policies, which aim at reaching the desired behaviour patterns.

Interactive Measurement Techniques -8-9-

Based on a market analysis of long distance travel behaviour, a qualitative measurement technique which is suited to measuring possible behavioural changes has been applied. For further details see (10).

Simulation of Behavioural Changes -10-11-

Here again, since deterministic methods do not provide all the necessary information about all spatial behavioural changes,(e.g. of all origin-destination flows) the simulation technique described above can be used to overcome this problem as well.

Within the framework of several studies, it was shown that consistent patterns of behaviour of individuals and/or households can be modelled in this way and thus are the basic fundamental unit of the whole process -10- (see chap. 3).

This planning approach would provide information on the likely situation which would exist after the implementation of measures mentioned in box -7-. Since the information is still provided on an individual basis, it is the appropriate input for the step to be described next.

Evaluation -12-13-

Without discussing basic features of appropriate evaluation-techniques at this stage, an evaluation process can be based on the following three methods: (for all alternative projects/ policies).

- financial analysis and
- cost-benefit analysis and
- cost-effectiveness analysis and
- combinations of all

In particular, it is suggested that the basic elementary unit of the evaluation process is the comparison of individual behaviour in the with- and without-case. This seems to be the only way to obtain valid information on the nature of the likely benefits resulting from projects. In short, this analysis attempts to show policy makers and the general public how

a) even optimal alternatives depend on the population's system of values; and

b) conflicting and complementary aims contribute to the final result.

This can be done using interactive techniques again. This type of dialogue achieves the aim of making the participants more aware of the problems of others. Conflicts which are inherent even in the optimal solution, also become apparent. In addition, this leads to a sound preparation for the implementation phase with the public discussions usually associated with it.

3. THE SITUATIONAL INDIVIDUAL SIMULATION ALGORITHM (SINDIVIDUAL)

The following explanations are oriented to the model procedure shown in fig. 3.

To 2/1, 2/2 and 2/3

The marketing analysis was executed in order to give an exact view of the inter-urban travel behaviour (trips longer than 50 km) of German inhabitants and to evaluate the possible reaction on selected political measures by means of "scenarios".

S I N D I V I D U A L

SITUATIONAL INDIVIDUAL SIMULATION ALGORITHM

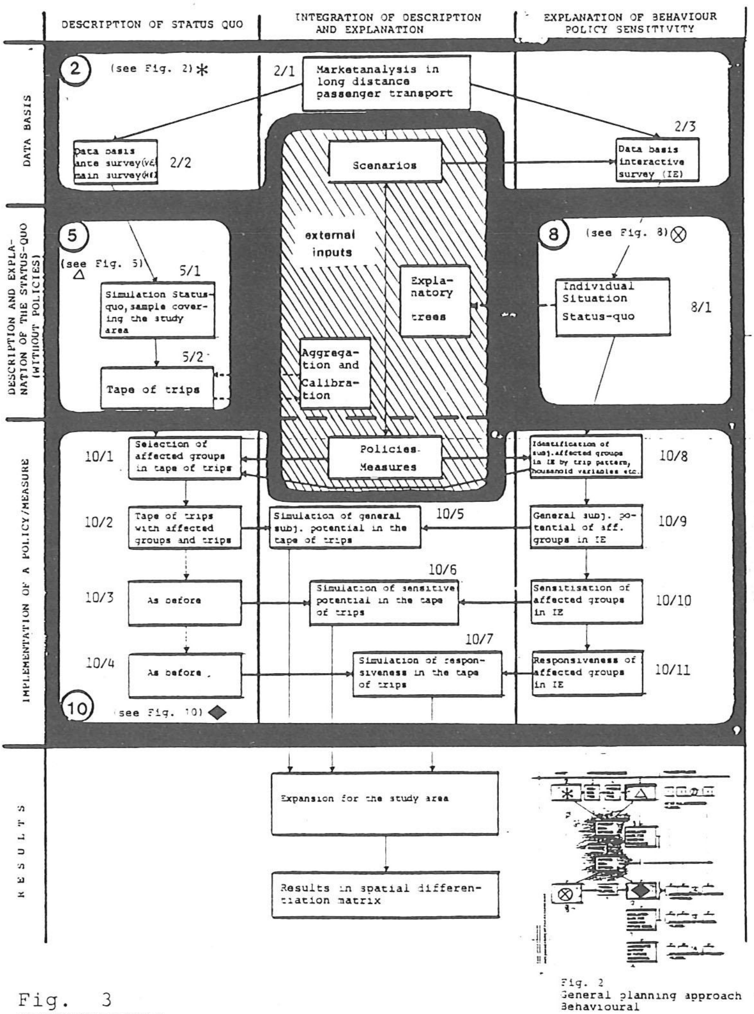

Fig. 3
SINDIVIDUAL

This differentiated need for information which was to be covered by the survey also demanded an adequately differentiated research model. For this reason, the survey design consisted of three accordingly built surveys.

The preliminary survey was to get quantitative information on all long distance trips made by inhabitants of the Federal Republic of Germany and West Berlin. The main survey served to get information on the details of the trips. In the interactive interviews, it was of primary importance to examine the reasons for travel behaviour and to measure the sensitivity of travellers to select planning policies.

Methodology and results of the survey are documented thoroughly in the volume "Berichtsband, Expertenband und Tabellenband", Munich, 1981. This volume includes a broad spectrum of information on German travel behaviour.

Concerning 5/1 A status quo simulation of individual behaviour for the entire Federal Republic of Germany

Despite the relatively large number of preliminary survey interviews, a sample covering the entire area of the Federal Republic of Germany was impossible. Nevertheless, this is necessary for a survey dealing with planning measures which differ regionally since the pertinent traffic flows and their structure vary from area to area.

If the constructive and critical statements outlined in chapter 1 are applied here, it is possible to apply the simulation model depicted below (see figure 4) in order to describe status quo travel behaviour in the Federal Republic of Germany.

The mathematical basis for this simulation is the Monte Carlo procedure. This makes it possible to use statistical methods to get quantitative solutions to given problems. Empirically measurable probabilities are used to depict an individual's mode choice f.i. (see the preliminary and main survey) by simulating it in a stochastic process. This is described below. (See figure 4)

Operational Conditions of the Simulation

The simulation model is based on hypotheses regarding the behaviour of individuals according to the model of the so-called behaviourally homogeneous groups. (11) (12).

An individual's travel pattern depends upon his belonging to such a behaviourally homogeneous group. Based on his being forced to satisfy basic needs, on his personal behaviour within the framework of the household and on the limits of his possibilities due to temporal and financial restrictions, every individual only disposes of a limited selection of trip patterns (trip patterns are a sequence of trips which an individual makes for specific travel purposes with a specific travel mode).

The traffic flows of a study area are represented as the summary of the behaviour of individuals which is documented as a "tape of trips" in which all of the simulated individuals are recorded. (This tape of trips is a listing of simulated sociodemographic characteristics and trips made by the individuals).

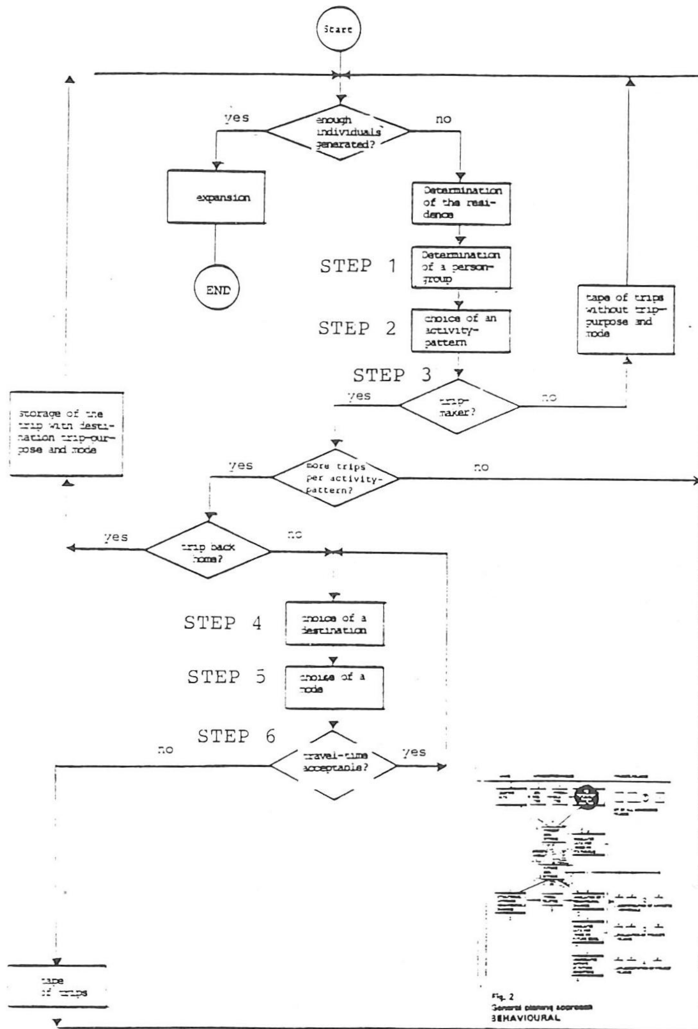

Fig. 4: Simulation Algorithm

Groups of persons

These groups are to represent traffic participants whose behaviour is homogeneous. The following characteristics are defined as comprising travel behaviour:

o activity;
o destination;
o modal choice.

The variety of groups may be limited by the fact that group characterisitcs should be prognosticable and comparable with the official statistics. For example:

1 employed person with car, city
2 employed persons without car, city
3 non-employed persons with car, city
4 non-employed persons without car, city
5 pupils, city
6 employed persons with car, country
7 employed persons without car, country
8 non-employed persons with car, country
9 non-employed persons without car, country
10 pupils, country

The cluster analysis, for example, is an appropriate procedure to define these groups of persons. Persons who were interviewed were put into groups of persons whose behaviour was as similar as possible; these groups were then differentiated from other groups showing different behaviour. In this analysis, the active variables are those which describe traffic behaviour. Sociodemographic and socioeconomic factors are used as passive variables. The groups used in this analysis had radically varying active variables; it is relatively simple to reconstruct these groups using the official statistics.

Trip Patterns

During the preliminary survey and the main survey, all trips were classified according to travel purpose. The following classification proved to be useful for this purpose:

1) trips from home to holiday destination
2) trips from home to other private activities
3) trips from home to work
4) other non-residental trips
5) trips from holiday home
6) trips from other private activities home
7) trips from business activities home

As a rule a person goes on several long distance trips per year. The sequence of purposes of these trips is called trip pattern of a person. It is important to handle all trips of one person at once, since only in this case it is guaranteed, that

o the trips are connected (origin of trip i = destination of trips i-1, if existing) and

o no useless changes of means of transport take place.

It is easy to show that each group of persons can be described by a limited number and certain types of trip patterns. This has been proven by empirical surveys.

Modal split within the model algorithm

Initially, an econometric approach was chosen to simulate the modal split since sufficiently detailed descriptions (on an individual basis) can be expected if one uses this approach. However, the econometric approach was not taken into consideration in order to explain behaviour - especially changes in behaviour.

Distribution of travel times

In order to measure the willingness of members of a group of persons to travel certain distances for a certain travel purpose, the travel time distribution is stipulated in any combination of means of transport, groups of persons and travel purpose. This distribution shows probabilities of travel time acceptance per time interval.

Algorithm

The simulation algorithm proceeds - to put it somewhat simplistically as follows (see fig. 4).

Step 1: Simulation of household decisions and the inclusion of a member of a household in a group of persons based on the information of probabilities ascertained in the main survey. In step 1 policy variables like car ownership and residential public transport facilities enter the model.

Step 2: Choice of a trip pattern according to probability scales of behaviour patterns of selected groups of persons, ascertained in preliminary survey and main survey.

With the following steps the individual trips of the selected behaviour pattern are elaborated. Mode of transport and destination for returning trips result from the according trips to reach destination. In the case of certain travel patterns the mode of transport used for the trip before is taken.

Step 3: Check, if there are still trips to be treated. Treatment of returning trips. In case all trips are treated, go back to step 1.

Step 4: Selection of destination zone via attractiveness and a decay function related to travel purpose and starting zone. In step 4 all policy variables dealing with the network enter the model via the input of the function.

Step 5: Choice of mode by an econometric approach. In step 5 network variables enter the model.

Step 6: Check if travelling time is acceptable (probability of travel acceptance). If travel time between starting zone and chosen destination zone is not accepted proceed to step 4. In the other case storage of the trip. In step 6 the overall amount of time consumption as a controlling total enters the model. This process is described in more detail in: Zumkeller, D.: "Die erstmalige Anwendung eines verhaltensorientierten Modells in der Generalverkehrsplanung, Technische Akademie Wuppertal, März 1981", an advanced version will be published in English in PTRC, 11th summer annual meeting and exhibition, University of Sussex, July 1983.

The simulation is completed when all traffic zones have been generated with the given number of persons together with the adequate personal and travel data. In this way one gets a surface covering an individual oriented sample, which can be expanded for the entire study area using the number of generated persons and the number of inhabitants.

Concerning 5/2: tape of trips

When the simulation algorithm which has been described above is used, then one gets a tape of trips with adequately differentiated information for a statistically ascertained number of interurban trips - which cover the entire area and are individual-oriented. The information in the "Tape of trips" usually includes the following:

- type of household
- group of persons
- mode of transport
- context of sequential trips and trip purposes
- origin and destination
- expansion factor

Supplementary information can be supplied by variables in the preliminary and main survey.

Concerning Aggregation and Calibration

This is necessary in order to get quantitative information on how the results of the (descriptive) simulation of the individual data relates to status-quo conditions. Therefore, the "tape of trips" is aggregated and compared with observed data (e.g., with screenlines).

Concerning 10/1 and 10/8: Identifiaction and Selection of Affected Groups

The question whether a household, a person or a single trip can be or is affected by a policy and/or a measure has to first be analyzed using the data resulting from the interactive interviews (IE). The analysis of this data makes it possible to define those groups which are or can be affected by measures. The definition depends upon those variables which have been simulated in the "tape of trips" (see 5/2). Using this information, the groups of persons which can be or are influenced by measures can be selected in the "tape of trips" (see 10/1).

Concerning 2/3: Data Base (IE) (Interactive Survey)

In approximately 1,150 households, interviews were conducted on trips which had already been recorded in the preliminary or main survey. In almost half of the interviews, a so-called "time or cost scenario" was used. This was applied within the framework of an "interactive measurement procedure" in order to estimate the responsiveness of travellers to steps taken to influence the travel time or cost involved in using different modes of transportation (for details, see (8)).

Concerning 8/1, 10/8 and 10/9: Individual Situations, Affected Groups and Subjective Potential

Since the choice situation in long distance travel can by no means be represented by a simple, one dimensional explanation of individual behaviour, ten relevant dimensions were used to depict long distance travel behaviour. The number of dimensions was later reduced to seven, including the perception of each individual. In order to depict the situation more clearly, a concrete example of "modal split" is discussed below.

Traveller X made his trip from point A to point B using his car. Could he also have made this trip by train? The dimensions listed below show if it is possible for him to travel with the other mode. Information on these dimensions is available in the data set. The dimensions are:

o <u>objective option</u> (train connection available at place of departure and destination).	yes
o <u>Constraints forcing him to use car</u> (X has two suitcases and it is unconfortable to transport these on the train)	yes
o <u>Information</u> (X knows that he is basically free to use the train for this trip)	yes
o <u>Expenses</u> (X finds that the cost for the alternative mode is reasonable)	reasonable
o <u>Time</u> (X would have to make one connection during his trip and thinks this takes too long)	not reasonable
o <u>Comfort/Service</u> (X thinks that the train is reasonably comfortable)	reasonable
o <u>Subjective Disposition</u> (X thinks that the train is a reasonable mode of transportation)	positive

In addition to this operational data set (yes, no, reasonable etc.) we have detailed qualitative information on the reasons within the dimensions which result in X's not using the train. In this specific instance, the reason is that X is "obliged" to transport two pieces of luggages and that he thinks that changing trains and the delay which this implies takes too long.

In the same manner, information is taped concerning the choice of the second alternative mode of transport - the airplane.

This model makes it possible to scrutinize each dimension to determine whether or not a traveller finds it feasible to use an alternative mode of transportation. When the different dimensions are appropriately combined and the characteristics studied, then it is possible to ascertain if an alternative mode of transportation is potentially possible. The explanatory trees (fig.5) with which the reader is already familiar (10) are an example of this.

In order for a traveller to be included in the "group with options", he must be included in the right side of the diagram shown below. (The objective and subjective potential of using another mode is described in 10/8 and 10/9, respectively.) If only one negative decision is made for any of the options, then the traveller does not have the option open to him of using an alernative mode of transportation.

In our example, our friend Mr. X would not have the option of travelling via train to make his journey from A to B because in the center boxes, he would be on the left hand side; his luggage is a constraint. Nevertheless, luggage was only one of Mr. X's problems - the other problem was time. Thus, even if Mr. X's luggage were delivered door to door, he still would not take the train. On the other hand, if the train were much faster (a newly built track, for instance) but Mr. X still had his luggage problem, it would be irrelevant how fast the train were.

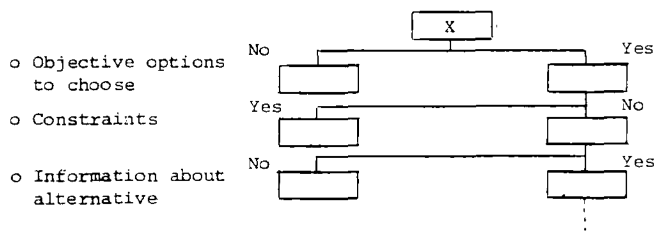

Fig. 5 Explanatory Tree for a Traveler

As already referred to in 10/1 and 10/8, the planning policies are thus analyzed in the situational part of the model. For the policy sensitivity of the algorithm as a whole, it is necessary that the influence of the policies can be modelled using the (descriptive) status quo material as well as the explanatory trees.

Concerning 10/10: Sensitization

Sensitization does not only make it possible to describe the status quo behaviour, but also to consider policies and measures in a broader sense. The actual consideration up until this point (see the explanatory trees) did not take the fact into consideration that the conditions influencing mode choice could change even if no conscious steps were taken to influence mode choice. For example, constraints within a household can be cancelled if a car is made available for more family members to use.

When this so called "threshold group" is included in the explanatory tree, each dimension must be sub-divided to include three groups of travellers - those whose differing attitudes influence their behaviour:

- o totally negative attitude;
- o potentially positive attitude;
- o totally positive attitude.

To return to our example: the impact which sensitization had is shown clearly by Mr. X's situation. Mr. X has problems transporting his luggage. Thus, the dimension "constraints" is positive for him. Nonetheless, Mr. X is a member of the threshold group since he does not always have to carry two suitcases when he is travelling. Thus, if he uses the newly introduced luggage service which the railroad is now offering (picking up and delivering suitcases) Mr. X is freed from his constraint. The result of the "sensitization" would then be depicted as follows:

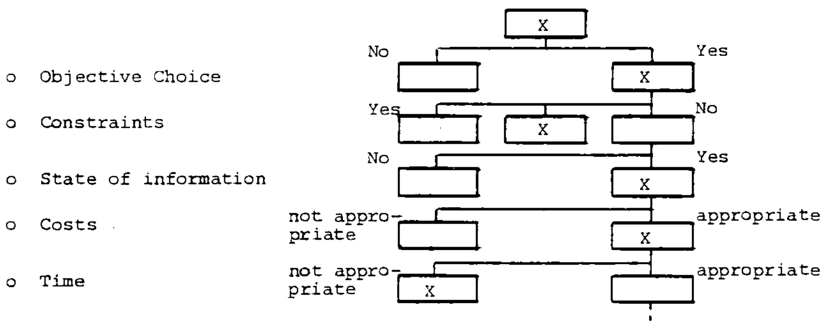

Fig. 6 Partially Sensibilized Explanatory Tree

Mr. X is now no longer in the group with constraints; however, he still has his time problem. Of course, this means that Mr. X still does not have the option of travelling via train open to him.

In the dimension "time", we are aware of the fact that Mr. X does not fundamentally think that train travel versus car travel takes too long. However, in the given instance, Mr. X would be forced to change trains and he thinks the time it would take him to wait for his connection is simply too long. Thus, Mr. X thinks that the total travel time by train is simply too long. However, if steps were taken to make the connection between A and B a direct connection and Mr. X no longer had to change trains, then he might be willing to take the train. In the dimension "time", he would then be classified as being in the threshold group (see figure 7).

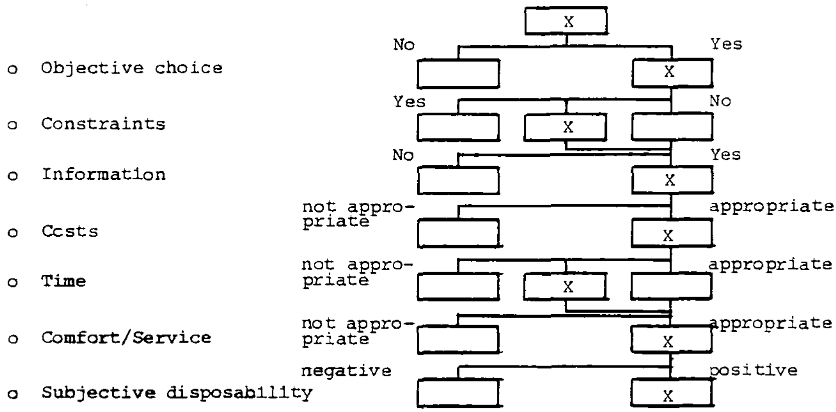

Fig. 7 Sensitized Explanatory Tree for Traveler X

As has already been mentioned, Mr. X finds the dimensions "cost" "comfort/service" and his "subjective willingness" to be either reasonable or positive as far as train travel is concerned. However, it is important to note that this is the result of "sensitization" in the dimensions "constraints" and "time".

Mr. X now belongs to that group of persons with the option of using another mode of transportation. However, his actually using another mode should not be taken for granted. On the other hand, it is clear that if only one measure is implemented (which affects either time or constraints), then Mr. X will definetely not use the train.

Concerning 10/11: Responsiveness of groups which can or might be influenced and 10/5, 10/6 and 10/7

The group of persons with options which might or can be influenced by measures sometimes reorganizes its travel during the interactive interviews. The proportion of these instances of reorganization in relationship to the entire group with options gives one a quantitative input for the simulation of the responsiveness in the "tape of trips". The same applies to the simulation of the general subjective potential (10/5) and the simulation of the sensitive potential (10/6) if these are requested. The potentials produced in the (operational) steps 10/5, 10/6 and 10/7 do not yet relate to the entire totality of the study area, but only to a surface covering sample of it.

In the last step, this sample is expanded to the entire study area and results in spatially differentiated information (origin destination matrix) for

- o (the objective potential (10/1 and 10/8)) and/or
- o the subjective potential (10/5) and/or
- o the sensitive potential (10/6) and/or
- o the amount of assumed behaviroural changes (10/7).

4. SUMMARY OF THE RESULTS OF AN APPLICATION

In order to demonstrate the application of SINDIVIDUAL, three policy/measures ex mples were calculated with different effects on the traffic demand. The examples were:

- o increase of energy costs i.e. increase of "out of pocket costs" for car users and rates in air traffic.
- o "speed limit" on federal highways of 110 km/h
- o introduction of a qualitatively new train offer i.e. introduction of "Airport-Express" on the route Dusseldorf (main railroad station) - Frankfurt (airport).

The impact of the first and second policies were analyzed in regard to the level of the general traffic volume since the impact of these measures was the same throughout the entire Federal Republic of Germany. The third measure was limited to a specific region, and therefore the description of the status-quo and the explanation of possible behavioural changes had to be modelled within the framework of traffic flows (for detailed description see (4)). Without discussing the results in detail, it seems clear that this model makes it possible to achieve results which can be applied to planning situations - even in instances in which specific local measures are dealt with.

Naturally, this model still has some wak points. However, in contrast to already existing models, this model seems to be appropriate to help solve problems which especially deal with situations in which the transportation supply qualitatively differs. In this study, for the first time, the impact of qualitatively changing the transportation system was quantitatively forecast in a situation in which the measures differed for specific areas. However, this does not mean that it is impossible to refine this conceptiually promising model structure for further research.

Perhaps to give one idea of the validity of this approach, it should be mentioned that our forecasts were compared with actual figures for the traffic volume of the Airport Express, which has meanwhile been introduced. It is encouraging to note that our forecast and the actual figures were very similar.

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