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THE DESIGN OF ENVIRONMENTALLY AWARE TRAVEL DIARIES

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Any policy addressing the concerns and trends associated with the impact of travel on the environment should be based on a solid understanding of the activities giving rise to them. While the measurement of the total environment loads by air or noise measurement stations is essential, it needs to be matched by the observation of the human behaviours creating them. This is especially true in the transport sector, which has been rightly or wrongly identified as having the potential to make a substantial contribution to the reduction of air and noise pollution. While the contribution of freight transport is of growing concern and importance, this paper focuses on the measurement of passenger transport throughout.

In the past transport planners have largely relied on the travel diary as their prime instrument to measure traveller behaviour. The travel diary is a survey instrument designed to record all movements during the course of one or more days including their relevant details. It is complemented by spearate household and personal forms for recording general information. In the following paper the term travel diary implies all three elements (the diary, the person form and the household form).

The remainder of the paper discusses to what extent and how the travel diary can be used to capture data for the assessment of policies directed at reducing the impact of transport on the social and natural environment. The requirements of a travel diary and the potential uses of new technologies in realising such a travel diary are then presented. A brief outlook on the possibilities of reasling such a diary concludes the paper.

KEY WORDS: Travel surveys, travel diaries, survey design, computers, environment.

1 INTRODUCTION

The impact of travel on the environment is the focus of growing attention in Europe and worldwide. In the UK, for example, the transport sector's share of primary energy consumption was 32.3% in 1992, and 89.9% of CO emissions, 23.7% of CO_2 emissions, 48.5% of HC emissions, 60.0% of NO_x emissions in 1991.[1] Most of these shares continue to grow, in particular the share of the greenhouse gas carbon dioxide. Equally, the concern about the impact of road transport on the structure of the urban and rural (natural and social) environment and the attendant consumption of land and social space is growing. The recent publication of *Planning Policy Guidance 13* in the UK, for example, is a vivid expression of that concern,[2] as it signals the reversal of a decades old pro-development and pro-car bias.

Any policy addressing these concerns and trends should be based on a solid understanding of the activities giving rise to them.[3] While the measurement of the total environmental loads by air or noise measurement stations is essential, it needs to be matched by the observation of the human behaviours creating them. This is especially true in the transport sector, which has been rightly or wrongly identified as having the potential to make a substantial contribution to the reduction of air and noise pollution.

While the contribution of freight transport is of growing concern and importance, this paper will focus on the measurement of passenger transport throughout.

In the past transport planners have largely relied on the travel diary as their prime instrument to measure traveller behaviour. The travel diary is a survey instrument designed to record all movements during the course of one or more days including their relevant details. It is complemented by separate household and personal forms for recording general information. In the following the term travel diary implies all three elements (the diary, the person form and the household form).

The remainder of the paper will discuss to what extent and how the travel diary can be used to capture data for the assessment of policies directed at reducing the impact of transport on the social and natural environment. The next section will discuss the data requirements, while the then following section will outline the current state of the travel diary. The translation of the requirements into items of a travel diary and the potential uses of new technologies in realising such a revised diary will be sketched in the following sections. A brief outlook on the possibilities of realising such a diary concludes the paper.

2 DATA REQUIREMENTS

The design and evaluation of environmental policy requires two basic types of data:

- data on current levels of pollution and disturbance
- data one the potential for change

The first data need implies a comprehensive inventory of the levels of pollution and disturbances. In the traffic context that translates into data on at least the following:

- noise levels by location, time-of-day and time-of-week
- emission levels by location, time-of-day and time-of-week for the different emission components
- perception of the usability of urban/rural space for different activity types, e.g. production, movement by various modes, social interaction in the public/private space, by location, time-of-day and day-of-week
- number of people (amount of flora and fauna) at risk by location, time-of-day and day-of-week.

The concept of usability must be defined for each use made of the environment. For example, the criteria used to define usability of a sidewalk for shopping will differ from those for through-traffic on foot. Equally, the criteria of the residents living in the homes abutting a road will be different from the criteria used by those who are travelling on it. This specificity implies complex data collection procedures, both for the measurement of the status-quo and of the value of change (see, for example, the literature on Contingent Valuation[4] or Stated Preferences[5]).

The second data need requires information of a widely differing nature, as change could affect persons, vehicles, plant and machinery, buildings and the time-space regime of the environment (regulations, opening hours etc.). A first group of items concerns man-made artifacts:

- Buildings: age, value, replacement schedule, ease of replacement, potential for the improvement of environmental protection features, potential for future technological change

- Plant and machinery: age, value, replacement schedule, ease of replacement, environmental characteristics (noise and emissions rates), skills required for current and replacement plant, position in production chain, value added by the plant, production schedules
- Time-space regime: regulations affecting use of the environment (opening hours, working hours, traffic regulations, noise and polution regulations etc.), legal status of each element, ease of change, level of adherence or enforcement, position in social framework
- Vehicles: age, value, replacement schedules, size, noise and emission rates, potential for future technological change

The second group concerns the use people make or might make of the man-made environment:

- Resources of the people: income, social goodwill, household and social context, driving licences, vehicle ownership and access, season ticket ownership or access
- Use of the vehicle: driving style, routes chosen, speeds by location, interaction with other road users
- Use of time-space environment: Activity schedules and their flexibility, dependencies on other persons inside and outside the household, long-term activity plans or commitments.
- Use of telecommunication: possibilities of telecommunication to replace travel,[6] the use of telecommunication to organise the day.[7]
- Costs of different activities: costs of vehicle ownership and operation, costs of public transport use and costs of telecommunication use and their distribution between different members of the household or outside bodies
- Cost perception of the travellers by resource used
- Desirability of activity and location combinations as perceived by the users.

The best way of collecting the different items in this large set must be carefully checked. While the travel diary might be able to collect some well, others could only be covered badly or not at all. Given the definition of the travel diary above, it is clear that the travel diary can neither be used to collect the emissions and impact inventories, nor the information about things owned or controlled by legal entities. These have to be measured or collected by separate means; in our context this is, in particular, true of freight operations.

3 THE TRAVEL DIARY

The travel diary as used today reflects nearly fifty years of development.[8,9] The travel diary started as a trip diary, an extension of the first origin-destination surveys, which had been carried out on a large scale since the 1930s and 40s in the United States. The trip diary focused on motorized transport, often excluding walking and cycling as modes. It often asked for a surprising amount of detail on those journeys, e.g. parking type, location and costs, major roads used or bridges crossed. The changing demands of transport policy since then were reflected in changes to the design of the instruments (for a more detailed discussion see Axhausen, 1994).[10] Today there are three main forms of the travel diary:

- the linked trip design, which defines a trip as a continuous movement with one mode and allows for the trip purpose "Change Mode" (walking is treated as an access/egress mode, if the trip involves any other mode) (Figure 1).
- the trip design, which defines the trip as a movement between two activities. The definition of what counts as an activity varies, especially with regards to brief stops (Figure 2) (For a translation see the Appendix)
- the activity design, which collects movement information as an incidental to recalling activities (Figure 3). The trip is treated in the same way as in the trip design. The activity design is an improvement on the trip design, as it improves the recall of the respondents of their trips by recalling the more memorable activities first.

The classification identifies the central design problem for the travel diary as the way in which the different parts of a trip or of a journey are captured. There is no agreed terminology in the literature, but the following set provides names for the elements normally distinguished (Figure 4). It defines:

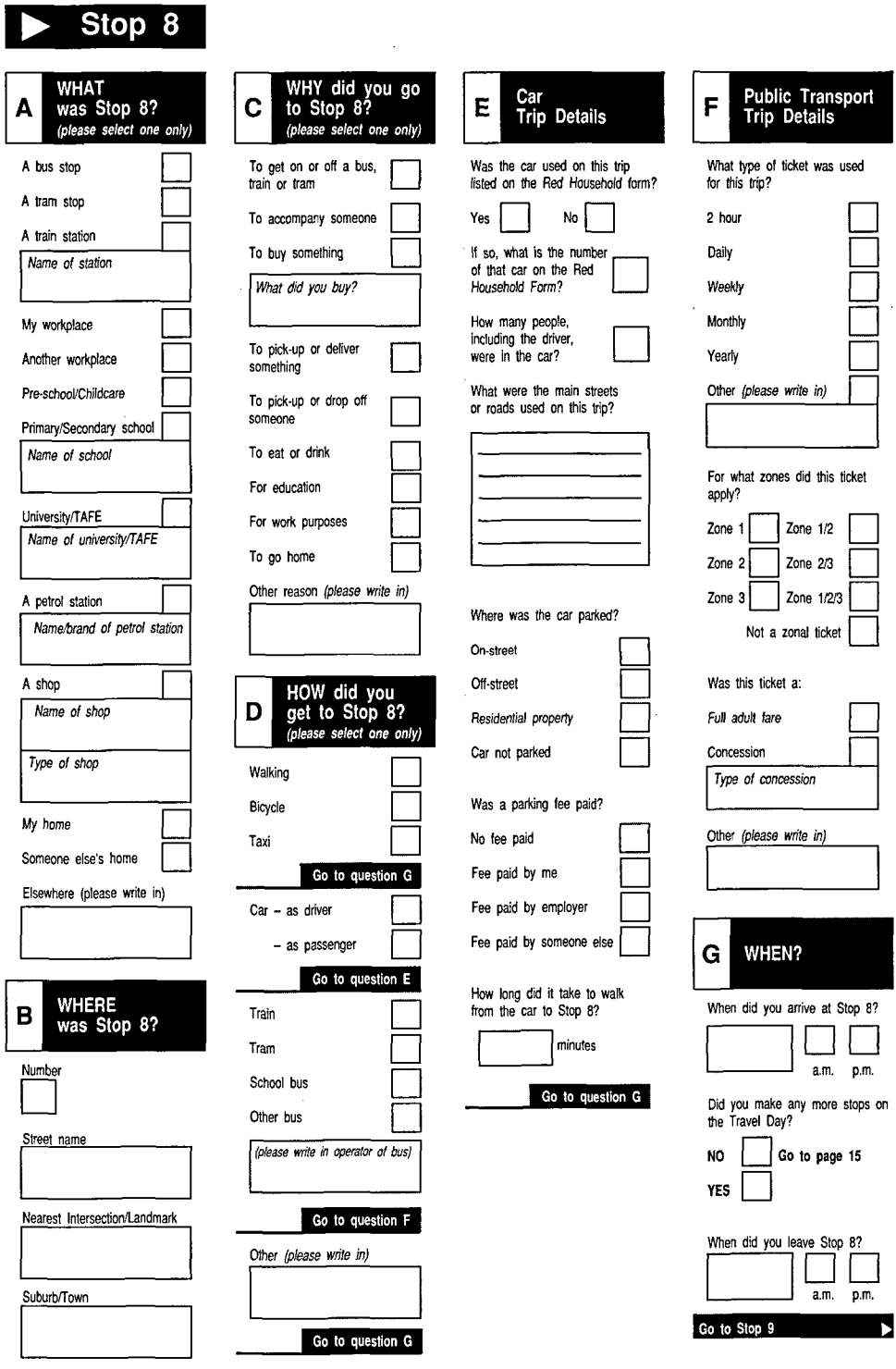
- **stages** as movements with one mode
- **trips** as movements between two well defined activities
- **activities** as a time commitment to a particular important purpose at a specific location
- **journeys** as a sequence of activities starting and ending at home
- **tours** as a sequence of activities starting and ending at the same location

Trips can be considered as activities, but the possibility to combine multiple activities while travelling, e.g. working on a train, listening to the radio while driving, creates ambiguities. These ambiguities are also important during in-home and at-work activities, where multiple activity strands can overlap easily, thereby failing to create a feeling of a clear time commitment to a particular purpose at a specific location.

The definition of the significant time commitment is also fraught with difficulty. Setting too high a commitment excludes a large number of activities, which might have been central to the choice of mode or route, but including all might overwhelm the respondent and lead to low quality returns. An example is the activity "Dropping of children at school", which might involve a substantial detour but only a very brief amount of time at the destination. The true time commitment would have to be measured by the time difference against the briefest route and not by the time spent at the destination. From an air-quality point of view, it is essential to capture these short stops as they are potentially connected with periods of extended idling or of restarting the motor, both sources of increased emissions.

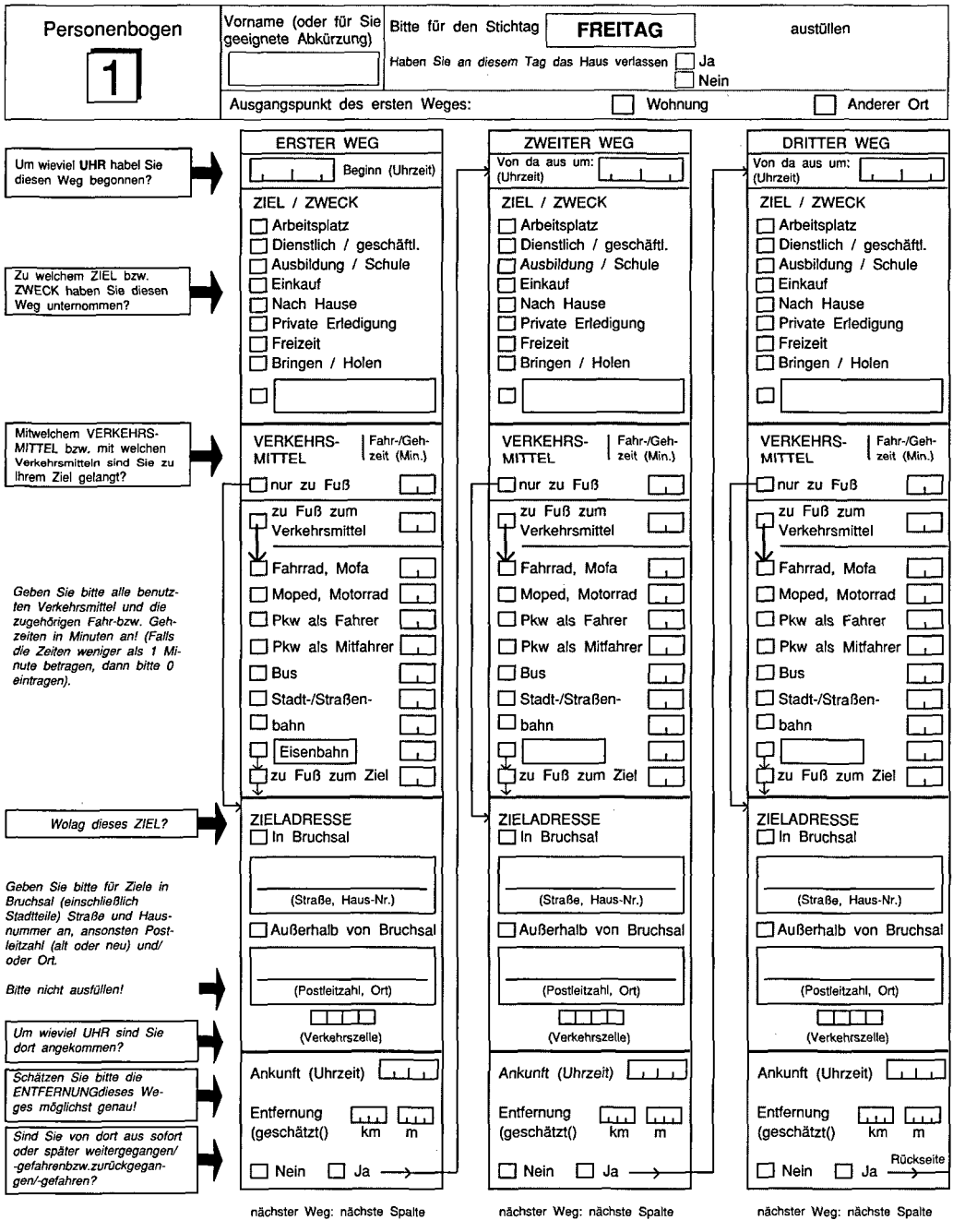
A fine resolution of the different stages of a trip and of waiting periods is also required to obtain an accurate idea of travel speeds achieved by the travellers. Figure 5 shows the implication of including or excluding certain elements from the speed calculations. Precision is especially important for an environmentally aware travel diary, as most traffic impacts have a strong functional relationship with speed. Particular care is necessary if the distances travelled are estimated by the respondents, due to the well known biases in distance estimation.[11] The user data should be verified and supplemented by data derived from network models.

The travel diary has to some extent already taken up items to allow an environmental assessment of travel. In recent years travel diaries have started to include more detailed questions about the cars owned by the household, in particular about technological details. In addition, the travel diaries are trying to establish which vehicle was used for which trip by asking the respondents to identify the vehicle used for each trip. This allows crude estimates of energy consumption and emissions.



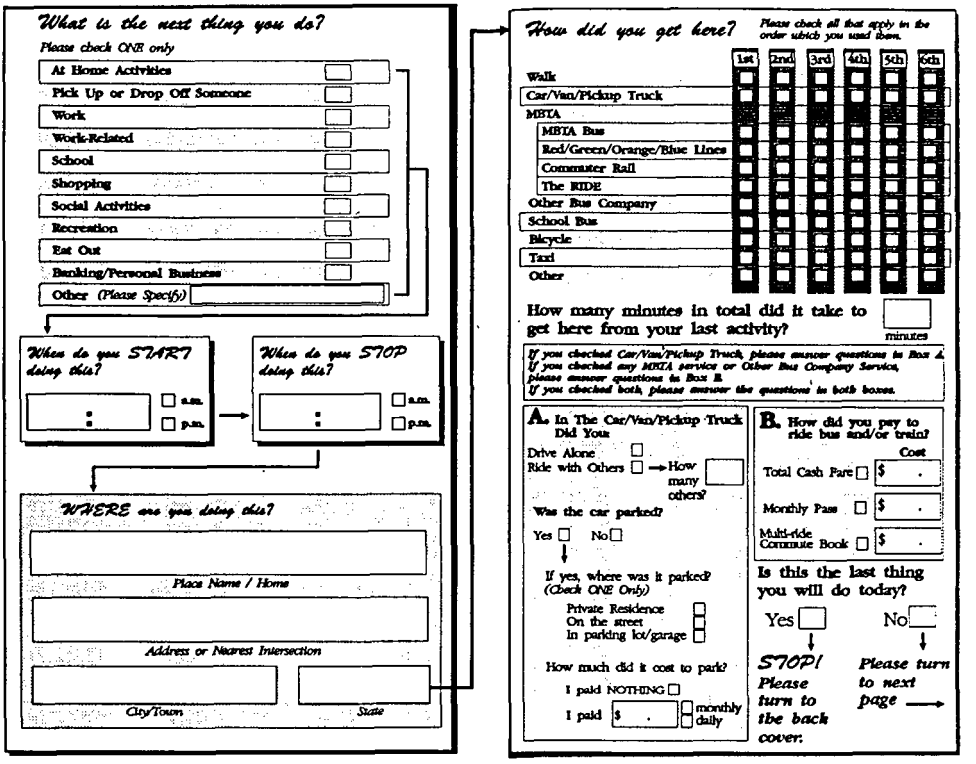
Source: VITAL survey form designed by Ampt (1994)

Figure 1 Example: Linked-trip design.



Source: KONTIV-based design for City of Bruchsal by PTV System (1993)

Figure 2 Example: Trip design



Source: Boston Bay Survey by Stopher (1991)

Figure 3 Example: Activity design.

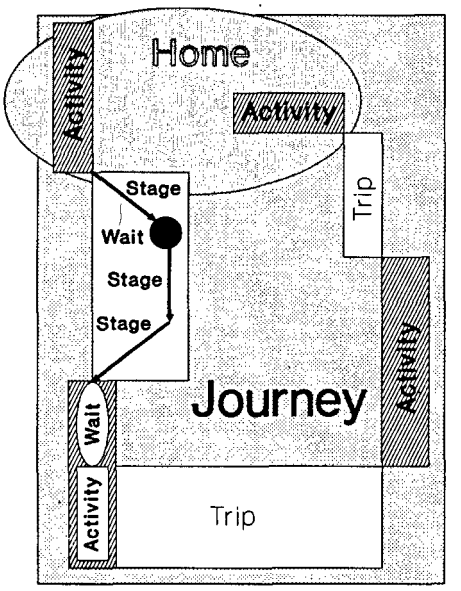


Figure 4 Definitions.

While this is useful information, other aspects of the travel diary have not been changed to reflect the increased urgency of our need to understand how people might change their behaviour in response to the available policy instruments. These can be grouped in the following way:

- changes in the cost structures
- changes in the time-space regime
- changes in the information regime
- changes in the service levels.

From a transport perspective the most important cost elements, which could be changed by policy, are those associated with travel, although the cost of housing will be equally important over the longer term. It is therefore necessary to collect the costs of travel in a comprehensive and detailed manner. This allows the policy maker to identify the leverage of different changes on the overall costs of travel and on travel behaviour. It should be pointed our that there is no real consensus in the literature about which cost elements are important for which decision at what time horizon – especially the proper allocation of the fixed costs to the daily mode choice decision horizon.

The time-space regime defines the activity opportunities for travellers. It is therefore necessary to establish if the travellers are constrained by the current regime and how relaxations might be used. This implies collecting information about the flexibility of activities, especially to what degree they can be rescheduled, cancelled, substituted or handed over to somebody else. Our modelling capabilities of these processes are rather limited at the moment, but without the suitable base information they can never be built.[12,13]

The information regime is currently undergoing dramatic change in the transport sector with the introduction of dynamic route guidance, comprehensive and localized public transport information systems and improved radio-based traffic information.[14] These new tools will allow travellers to update their perceptions of their choice environment. This

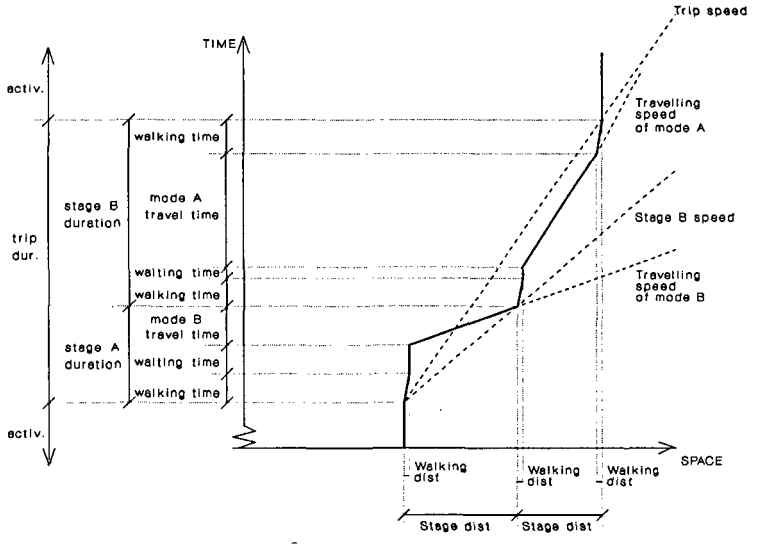


Figure 5 Time elements and speeds during travel.

in turn requires a better understanding of the current perceptions of this environment by the travellers and an identification of the decision relevant elements of those perceptions. Equally important is an understanding of the updating process and the relative weight given to different information sources within that process.

Potentially even more important for the travel experience than the improved traffic information will be, possibly the wide spread, adoption of various forms of teleworking and other flexible working arrangements in the wake of the current reengineering of manufacturing and administration. The increase in the already large pool of part time workers of different levels of skills, ranging from the traditional "temp" or "Kelly-Girl" to the consultant/subcontractor, will change the patterns of road use whose consequences have not yet been fully explored or understood. The travel diary should reflect these changes by recording the current levels of interactions steered and generated by telecommunications (phone, radio, television, or computer networks).

The observation of the effects of the transport system's level of service quality on travel behaviour is the traditional task of the travel diary. The measurement of the service level as such was, in general, not the task of the diary. These data were calculated using external models such as assignment models or independent inventories. The uncertain capability of such models to calculate appropriate service levels in today's highly congested and dynamic traffic situations puts tighter requirements on the travel diary – especially when they are combined with the increasing awareness of the different weights given by the travellers to different elements of the travel experience (waiting, driving, transferring etc.). This reinforces the point raised above about the need to measure the time elements of a trip properly for improved measurement of travel speeds.

While the travel diary can provide data of known accuracy for the alternatives used by the traveller, it cannot provide such data for the relevant alternatives not used. It is possible to ask the respondents for such data, as it is frequently done in Stated Preference experiments, but it is very difficult to assess the quality of such data without further information about the frequency of use of that alternative. In addition, a number of potential biases will be introduced by the respondents, for example, a bias to justify the chosen alternative, strategic biases and bias due to recall problems.

The collection of all of these items increases the load on the respondent considerably. The designer of the instrument has therefore to find ways to make that load as easy as possible to bear or to reduce it to the minimum necessary. Also, the designer should avoid the temptations of spurious accuracy. For example, including a question about waiting times might return answers, but these answers might be consistently wrong, as respondents might overstate small waits or completely ignore them, or even worse they might adjust the other travel times to accommodate the wrongly perceived waiting times.

4 ITEMS

It is not possible here to discuss the shape and content of the diary which reflects all of the data needs raised above. The paper will concentrate on a smaller number of items/item groups, which are particularly important:

- the description of the respondents
- the description of the vehicles and season tickets for public transport
- the description of trips/activities
- the description of parking

4.1 *Description of the Respondents*

Travel diaries currently collect as a rule the following items about the respondents:

- gender
- age (preferably as year of birth)
- household position, normally defined in relation to the head of household
- working status, often excluding the possibility of substantial other outside commitments, such as part-time education or community services
- amount of work as part time or full time using a relatively arbitrary boundary between those categories
- licence holding

From the discussion above, it is clear that a number of important items are missing:

- the diary should collect information about all substantial and regular commitments of the person to indicate the level of flexibility in activity scheduling. It should maybe even allow the person to distinguish between the normal situation and the particular week of interview. A possible minimum set of categories could be:
  - work
  - education
  - organized sport
  - community services (church, politics, clubs etc)

  It might be possible to establish the number of activities of each type per week.
- the degree of flexibility of working hours should be established, i.e. at least information about fixed working hours, if any, and the nature of the work (shift work, flexitime, fixed hours).
- the different driving licences held by the respondents should be distinguished.

In addition, any permanent mobility handicap should be established.

4.2 *Description of the Vehicle*

An accurate description of the vehicle in terms of its technology, costs and access arrangements is essential for an environmentally aware travel diary. This discussion applies equally to bicycles.

At the moment travel diaries will reguarly include questions about:

- the number of vehicles
- the vehicle availability or ownership of household members without necessarily identifying which particular vehicle is owned by whom in the household and less frequently
- technological details (age, type of fuel used or motor size)
- funding arrangements (The UK National Travel Survey (NTS) is an exception in its thoroughness in this respect).

It is obvious that a detailed description of the vehicle technology is required, but the level of detail should mirror the level of detail of the impact models to be used. There is no point in asking about the details of maintenance of the vehicle, such as time since the last emissions tune-up, if the emission model is based on engine size alone. The following items should be included:

- model
- make
- chassis type
- age
- odometer reading and annual mileage
- motor size and characteristics (e.g. existence of catalytic converters)
- fuel type used
- fuel mileage

Recently travel diary designers have given more attention to the issue of vehicle costs. This issue is especially difficult, as multiple persons and bodies might be involved in paying for the car and its use. But a correct understanding of these flows is necessary to understand the cost perceptions of the different users of the vehicle. An adult dependent of the family, who does not contribute to the vehicle costs, will have a different perception from the head of household, who receives a partial but not complete subsidy for it. Without any prior experiences documented in the literature it is problematic to design appropriate questions, but the following set should be appropriate:

- fixed costs
- insurance costs
- responsibility for routine maintenance
- responsibility for major repairs
- fuel costs

which should be broken down by the different possible contributors, which should be clearly identified:

- owner
- users
- employer
- other household members
- other family members
- state (through tax incentives or disincentives)

Data about other variable costs, such as tolls or parking fees, should be collected in conjunction with each stage. The responsibility for these costs should also be established there. Parking will be discussed in more detail below.

The third complex associated with the vehicles concerns access and availability. Although the concept of availability is promising in principle, it is very difficult to implement in a survey context. Availability is both subjective and context dependent. For example, a vehicle might be available to a household member after extensive negotiations, but not on an unquestioned day-to-day basis. The vehicle might be available, but might require a payment in time or goodwill. It is better to confine the concept of availability to the sense of physical availability at a specific point in space and time without any restrictions on its use (for the planned duration of the activity). In this restricted sense it might be included with any trip- or stage-related questions.

Still, it is necessary to get an idea of who has used the car and therefore might be entitled to use it again, that is, would include it in his or her choice set. It should be possible, although this has not been tried in a travel diary context, to ask the respondents for the following for each vehicle:

- the legal owner
- the person legally responsible for the vehicle

- the mileage driven for each person within the last month (week) combined with an indication of the trip purpose
- in the UK and possibly, elsewhere, an useful item would be a list of all persons insured to drive the vehicle

This approach avoids any household rhetoric about its internal arrangements, but is, as the information about the past always is, not necessarily a good guide for the future or even just the survey day or period.

The same approach should be taken to the recording of season tickets, especially for the tickets which are transferable between travellers, as is the case in many German cities.

4.2 *Description of Movement*

As discussed above the different types of travel diaries approach the task of collecting movement information differently. The first approach constructs the trip from the individual stages, while the second aproach asks for a breakdown of the trip. The first approach makes it easier to identify short activities, as it associates a purpose with each stage, including "Change mode". The second approach makes them more difficult to identify and invites the respondents to suppress details of the trip. Given the importance of the different time elements, this approach cannot be justified in the context of an environmentally aware travel diary. The errors made might be small enough in environments where the car dominates, such as the United States, but even there this assumption should be tested. The advantages of the activity-design should be recovered in a different way.[15]

Within the linked-trip/stage-based approach the following items are collected:

- purpose
- mode
- starting time (understood as the starting time of the movement)
- ending time (understood as the ending time of the movement)
- number of persons in the vehicle
- destination of trip

and increasingly in recent years:

- vehicle identification
- parking type and costs
- public transport fare and line

Walking access and egress tends to be treated as separate stages in the case of later public transport use, but not in the case of private transport. The times needed to get in and out of a car, which can be substantial with luggage or children, are not identified.

The stage-based approach allows a reasonable estimate of speed for each stage, but might lead to an overestimate of total travel times through the accomulation of overestimated small travel times for the various walk stages. A control total would be desirable, but which is unfortunately impossible on a paper-based instrument without undermining the whole approach.

For a more detailed analysis of emissions and impacts further details would be desirable, such as main roads used, the number of signalized intersections crossed, the time spent in queues, the time spent seaching for parking etc. It would be worthwhile to test to what extent such information can be collected without increasing the willingness of

the respondents to reduce the number of trips reported or to increase the refusal rates.

The description of the activity currently consists of its duration and its purpose. Further details are not collected. As discussed above, for an assessment of the ability of the respondents to change their behaviour it would be desirable to have information about:

- the time slot, in which the activity can take place (i.e. opening hours where applicable)
- the importance of the activity to the person
- the ease of rescheduling (time required for the rescheduling)
- the ease of cancelling or replacing it with a different activity
- the time since the activity was first planned
- the cost of each activity (entrance fees, restaurant bills etc)
- any situational handicaps, such as heavy luggage or small children)

Additionally from an information point of view it would be useful to know which role the different communication media played in the genesis of the activity:

- Was the respondent invited by telephone?
- Was there an advertisement in the paper?
- Was the respondent told by a friend?

It is obvious that more detail would be desirable, while it does not overload the respondents. Experiments with different design alternatives should be conducted to determine the feasibility of the different items and the size of the total question set.

It would be tempting to include questions about usability of different locations at this stage, but this would only be useful if the respondent identifies rejected alternatives as well. It would seem preferable to include questions of this type with the person form.

4.4 *Description of Parking*

Parking seems to be to many analysts a marginal topic in the overall context of travel, although there are a number of reasons to stress its importance. First, parking is often the only out-of-pocket cost incurred by the driver, making it the amount with which the competing public transport fare is compared; drivers generally underestimate the other costs of driving. Second, the availability of parking, or doubts about it, can stop drivers from making a trip to a particular destination or from making the trip at all, for example, if parking at home is in doubt. Third, there is a large amount of evidence which shows that free parking at work has a large impact on the mode-of-work decision. Equally, the availability of parking at home influences the attitudes towards multiple car ownership.

The problem for the designer is that parking related information could be established as part of the person, that is, for parking at work, as part of the vehicle (for example, parking at home), or as part of the stage (for example, parking elsewhere). There seem to be advantages in separating parking at home from work because this makes more detailed questioning possible, as the questions will only be raised once. The disadvantage is that these questions should only be asked if the cars have reserved spaces, otherwise ambiguities might arise. The questions for these reserved spaces should include:

- location
- type
- level of protection
- costs and who is paying for it

- walking distance to the entry of the home/work place.

In association with the stage there is only a need to establish:

- costs
- type
- sharing of costs between self/other/employer

The respondent should be invited to skip these questions for the return home and work trips to reduce their workload.

5 TECHNOLOGICAL POSSIBILITIES

The discussion has added a substantial number of new items to the schedule normally used and has argued for more detail on some which whave been included in the past. There is a clear danger that a paper-based instrument would be overwhelming and wasteful. The various forms of dataloggers, which are in frequent use elsewhere, have not been tried for travel diaries. The recent advances in palmtop computers and personal organizers should be a motivation for extensive tests of computer-based travel diaries.

The advantages of a computer-based travel diary are obvious:

- immediate coding
- intelligent routing to avoid repetitious questions
- item sampling to reduce respondent load
- on-the-spot consistency checking, especially for travel speeds
- on-the-spot help system
- support for functionally illiterate respondents in conjunction with a graphical interface or voice generation module
- prompting for activities, especially if the long term calendar of the person has been entered
- in combination with a satellite-based global positioning system, continuous location tracking and speed measurement

The possible disadvantages are:

- biases in the respondents due to "technophobia"
- expense of the instrument and of the staff-backup
- battery-life problems
- trip suppression to avoid detailed questions
- cumbersome for the respondents to carry around

It is not possible here to construct a balance-sheet of this approach. The intention was to flag the possibility of this approach and the desirability of empirical testing of this idea.

6 CONCLUSIONS

The discussion of the requirements of an environmentally aware travel diary has revealed the need for a substantial number of new items. Some of these items can be included in a travel diary, while others have to be provided by additional surveys. A detailed description of the costs of travel and of the individual elements of travel is required to be able to assess different environmental policies.

The discussion has also shown that the travel diary cannot satisfy all data needs for environmental policy, but that there is a need for additional surveys and inventories. Still, the diary can be made more useful, if ways can be found to maintain the workload of the respondents within reasonable limits. This paper has argued for the use of self-administered computer-based interviews, if their technological problems can be overcome.

Acknowledgements

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APPENDIX: TRANSLATION OF FORM IN FIGURE 2

This text below tries to match the organisation of the form in Figure 2

Personform 1	First name	Your survey day is **FRIDAY** Did you leave the house?	Yes No
	Where did you start your day?	at home	elsewhere
When did start ..... this trip?			
	PURPOSE		
For which purpose?	Work		
	Business		
	Education		
	Shopping		
	Return home		
	Private business		
	Leisure		
	Escorting		
	Other, ...		
With which modes?	MODE	Duration	
Please tick all used! If duration was less then 1 minute enter zero.	only walking	.....	
	walking to other mode	.....	
	Cycle	.....	
	Motorcycle	.....	
	Car driver	.....	
	Car passenger	.....	
	LRT	.....	
	Tram	.....	
	Railway	.....	
	walking to the destination	.....	
	LOCATION		
Where did you go?	In town (Street, Number)		
	Out of town Zip code, Municipality		
When did you arrive?	.....		
Estimated distance	..... [km, m]		
Further trips	No	Yes	