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TRANSPORT BEHAVIOUR AND DIFFUSION OF TELEMATICS: A CONCEPTUAL FRAMEWORK AND EMPIRICAL APPLICATIONS

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Abstract

The potential impacts that may be expected from new information and telecommunication systems applied to transport are considerable. However, as is the case with any new technological innovation, at the basis of success of transport telematics lies the acceptance by potential users, which suggests that there is a clear need to investigate the user side of these technologies. Given this need to explore the interaction between human behaviour and transport telematics, the aim of this paper is to investigate behavioral factors and their interrelationships in the use and diffusion of new telematics technologies. We will focus our attention on those systems which provide information to various categories of users, viz. public transport users and private car users.

A conceptual framework is presented that covers all variables of interest for the investigation of user responses to these technologies. An important explanatory variable for acceptance of new telematics technologies is user segmentation; it has to be recognized that the effects of respective technological innovations will vary between various groups of transport users. In analyzing in more detail the dynamics of individual behaviour, we will also present a theoretical concept of information use by travellers .

The usefulness of the concepts presented is illustrated by two case studies in conjunction with real pilot tests of new telematics applications in Europe. One case study concerns a real-time passenger information system for buses in Southampton in the UK. The second one concerns a motorway driver information system using variable message signs in the North Wing of the Randstad in the Netherlands. The surveys carried out provide various interesting conclusions regarding both the potential impact of such information systems on travel choices as well as the potential market for the diffusion of this type of information by means of private equipment.

Results show that the introduction of passenger information systems seems to allow a new flexibility in trip making. However, good quality real time information does not seem to improve significantly the perceived quality and reliability of the bus service, which is the most important issue for all bus users is a reliable and frequent service. It is also concluded that the commercialisation of traffic information among the broad public might be more limited than initially expected. Furthermore, it is noteworthy that clear user segments can be distinghuished, for which the market penetration is likely to vary significantly. Socio-psychological and economic factors will ultimately have important consequences for the future diffusion rates of the new telematics technology .

1 Introduction

Anyone who regularly uses Europe's roads will recognize that traffic congestion is often the normal state of affairs rather than an occasional inconvenience. The most obvious effects of congestion are: increased joumey times for both private and commercial motorists; escalating traffic accident levels and environmental damages resulting from higher pollution levels. In order to deal with these problems, (super)national and local authorities have implemented various traffic management schemes. The development of new technologies in the transport sector may offer additional solutions. In this context the interest in the blend of telecommunication and informatics, coined telematics, is noteworthy. Especially telematics technologies, which nowadays are becoming widespread available, are gaining increasingly importance world-wide, witness the stimuli provided by major research programmes like DRIVE (Europe), IVHS (United States) and VICS (Japan). The range of transport telematics options comprises inter alia:

- route planning (e.g., in the case of individual travellers by in-home/office travel and traffic information, and in the case of logistic operations by fleet management systems)
- substitution of physical transport (e.g., teleworking, teleshopping, tele-education)
- automatic debiting (e.g., for toll roads or road charging)
- traffic guidance (e.g., by motorway control and signalling systems and car navigation systems).

The *potential impacts* of these transport telematics systems can mainly be found in four areas. First, they will have a significant influence on ***network efficiency***. The efficiency can be improved by distracting traffic from bottlenecks in the network. To illustrate this, a framework plan in the Netherlands for the implementation of transport telematics shows some optimism on infrastructure management: an increase of traffic throughput in 1995 with 10% and in 2010 with 1525% seems to be a realistic target (Rijkswaterstaat 1992). Second, telematics may have impacts on the environment by a ***substitution of physical transport*** (e.g., Quaid et al. 1992 and Vanderschuren et al. 1993) and/or ***an improvement of flow efficiency*** of traffic (e.g., by motorway signalling), leading to less pollution. Third, telematics may improve ***safety***. Accidents are one of the most severe implications of large-scale transport systems. Information on weather conditions or on traffic jams are obvious examples of tools reducing sociai costs of transport, In the longer run, board computers, speed/distance keepers and vehicle guidance systems may lead to significant reductions in fatalities (Malaterre et al. 1993). Finally, the use of telematics will have a favourable impact on ***energy use***. The energy use of traffic is formidable. The use of telematics may lead to more energy-efficient transport systems, saving both the environment and the earth's natura1 resources. Besides a better use of cars (e.g., driving style) by advanced computer-controlled vehicle technology, also the choice for more energy-saving transport modes may be favoured by telematics. Avoidance of traffic jams is another beneficial factor, as the energy consumption of a car in a traffic jam is relatively very high.

Considering the above potential impacts, the potential and promises of transport telematics are considerable. However, as is the case with any new technological innovation, at the basis of success of transport telematics lies the acceptance by potential users. The user acceptation (and diffusion potential) manifests itself by the attitude, usage, change in travel behaviour and willingness to invest (intermediate users) or buy (private users) with respect to certain types of telematics. It should be stated a priori that the interrelationships between these indicators are often complex and rather unpredictable. For instance, the diffusion of individual route guidance equipment would not only be dependent on the actual need for the information provided to make travel decisions, but could also turn into a status product, whose feature might in the end become a main market driving force.

Given the need to explore the interaction between human behaviour and transport telematics, the aim of this paper is to investigate behavioral factors and their interrelationships in the use and diffusion of new telematics technologies. We will focus our attention on those systems which provide information to various categories of users, viz. public transport users and private car users. The next section will start with a genera1 description of the dynamics between travel behaviour and the diffusion of transport telematics technologies. Subsequently, in Section 3, a conceptual framework will be presented that covers all variables of interest for the investigation of user responses to these technologies, followed in Section 4 by a discussion of a theoretical concept of information use by travellers. The concepts used will be illustrated by two case studies recently carried out in Europe. One case study concerns a real-time passenger information system for buses in Southampton in the UK, and a second one focuses on a motorway driver information system, which has been implemented in the Netherlands. Finally, some important lessons drawn from the previous experiences will make up the ingredients of the last section.

2 Some dynamics of travel behaviour and diffusion of transport telematics

The character of the diffusion process of transport telematics can be outlined in the conceptual model presented in Figure 1. First of all, the introduction of transport telematics will have an impact on individual travel behaviour in a *direct* sense and an *indirect sense.* Direct impacts are envisaged by systems aimed to influence travel behaviour (e.g. route guidance), while, indirectly , also impacts on travel choices are to be expected from systems improving travel conditions (e.g. driver assistance facilities and public transport information). If a direct impact of new technologies on travel choices can be expected, then together with the influence of user segmentation factors on travel choices there will be an impact on the awareness leve1 of the users. Moreover, if also a significant indirect impact of new technologies is to be expected, this will affect via improved travel conditions the awareness leve1 of the users (Argyrakos et al. 1994).

A functional classification of the wide range of transport telematics applications currently in development is shown in Table 1, together with the type of impact expected. Furthermore, it is in the interest of the system's manager that the purpose of the irnplementation will reach a maximum awareness of the public, especially where it concerns system-wide public applications (e.g. environmental area licensing in cities). The character of the purpose will depend on the type of driving force of the applications, which can be market driven or policy driven, as is outlined in Table 2.

Figure 1. The dynamics between travel behaviour and diffusion of technological innovations in transport.

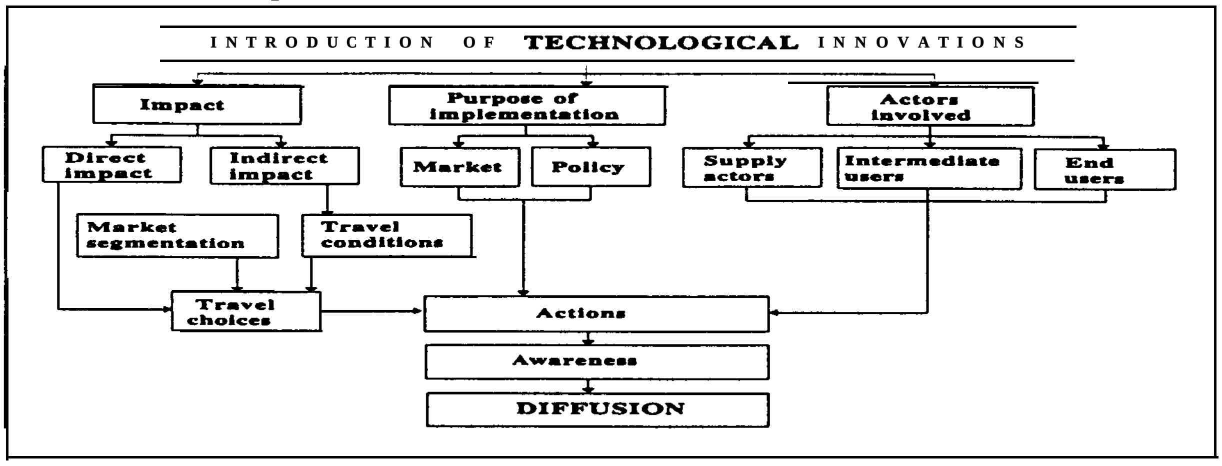


Table 1. Technological innovations and the impact on travel choice.

Group of telematics	Impact on travel choice
Demand management Travel & traffic information Urban traffic management Inter-urban traffic management Public transport management	Direct
Driver assistance Freight and fleet management	Indirect

Table 2. Technological innovations and type of drivingforce.

Group of telematics	Type of main driving force
Demand management Public transport management	Policy driven
Urban traffic management Inter-urban traffic management	Policy and market driven
Travel & traffic information Driver assistance Freight and fleet management	Market driven

Finally , there are various actors involved with the introduction of new technologies. The public awareness levels are limited by the type of actors involved with specifíc groups of applications (Table 3). There are supply actors or developers (producers of hardware and software, the automobile industry and also road managers and public transport operators), intermediate or collective users (national and local authorities, road managers, public transport operators) and end- or individual users (car drivers, public transport users and freight forwarders).

On its turn, growing awareness levels will favour the diffusion rate of transport telematics, where it concerns both individual systems for the end-users and public systems for intermediate users.

Table 3. Technological innovations and actors involved.

Group of telematics	Actors involved
Demand management Public transport management	Intermediate users End users
Travel & traffic information Driver assistance Freight and fleet management	Supply actors End users
Urban traffic management Inter-urban traffic management	Supply actors Intermediate users End users

3 A nested approach

In the complex and dynamic process which ultimately will lead to the diffision of transport telematics as outlined before, a critical success factor will be the social acceptation by the end-users. In the field of assessing the social impact - including changes in travel behaviour - which will result from the introduction of transport telematics, relatively little conceptual analysis has been undertaken in the past. Such investigation requires a coverage of a wide range of relevant (dynamic) behavioral issues. A comprehensive (nested) approach to deal with all relevant aspects should include the impacts of a full range of areas of operational interest in telematics (BATT 1992). The benefits of applying such a comprehensive approach are inter alia expected to:

- provide behavioral parameters to those involved in the development of telematics systems;
- inform authorities of the best ways to implement the new technologies and to increase the success of ATT technology;
- inform the industry of better ways to promote and market ATT technologies to meet user requirements.

The above mentioned nested approach integrates the elements described above allowing the impacts of telematics to be measured at three separate *levels of reference:* first, at a strategic level, second, at the leve1 of market potential and tbird, at the leve1 of market responses.

At *the strategic level, the* concern is with the overall system wide impacts, given certain types and certain levels of introduction of ATT. Within this framework, various changes can be assessed in terms of user and producer benefits, the direct and indirect environmental impacts, reductions in accidents, energy savings and the use of the infrastructure. The assessment may cover total performance of the system, the distribution and equity implications and the technological achievements. At the *market potential level,* the concern is with the means by which the potential for ATT can be maximised in terms of acceptability and penetration to the various parts of the market. Part of this marketing is to access market awareness of the product, while the other part is to identify which segments of the market are likely to represent the greatest potential for telematics. It is realised that some people will be more positive about the use of telematics than others and that not all people will use it in the same way. The identification of different markets is a very important part of applied research and will provide a link between research and the telematics industries. At ***the market response level, the*** concern is with the costs of the technology, changes in individual behaviour and the scale of implementation. The focus here is on the cost effectiveness and the direct benefits to the individual users of ATT, the range, scale and timing of introduction of ATT and the rate of behavioral change which might follow. Much hypothetical research has already been carried out on the impact of telematics , often in terms of the most optimistic scenario if saturation of the technology is achieved over a very short period of time.

Table 4 brings together these three levels into a composite table. The three levels of reference are put off against three categories of evaluation criteria, namely technical, socio-economic and political/dynamic criteria. The cells of this table contain the main areas of investigation.

Table 4. Head elements of a nested approach.

	Levels of reference		
Evaluation criteria	**Strategic**	**Market Potential**	**Market Response**
Technical	Performance	Marketing	Cost of technology
Socio-economie	Distribution & Equity	Segmentation	Behaviour
Politica1 & Dynamic	Technological Perspective	Awareness	Diffusion

It should be noted that not all telematics applications are likely to feature in each element of this concept. For instance, traffic information and public transport information will be evident in all cells, but other telematics applications,‘ e.g. demand management, will only relate to ‘market response’, since it is system wide and affects all users.

Given the emphasis on the end-user side, some elements of this table need a further refmement: segrnentation, behaviour, awareness and diffision. Here the focus is on the behavioral response in combination with segmentation factors that are necessary to establish the market potential. These four issues are elaborated below.

Behaviour

The argument here is that user behaviour will change as a result of the introduction of ATT, but that changes may vary according to the individuals, the situation and the type of ATT being tested. A range of behavioral responses has been identified which might be anticipated for a particular journey at one point in time. These include: mode shift, departure tirne, change in route and destination, trip generation/ suppression, trip scheduling, parking choice and adherence to advice (see Table 5). They are elaborated below:

Mode shift: The impact of ATT may be to cause users to shift mode in order to gain time or to save costs or meet their constraints.

Departure time : A shift may occur in departure time, given the ATT information on the current level of congestion or the generalized cost of the prospective trip if individual utility is to be maximized or to meet specified preference constraints.

Route : Provided that the technology is available, route choice may be modified. Route diversion or adherence to advice supplied by ATT may be influenced, not only by items cited in the segmentation (such as familiarity), but also by reliability of the information provided.

Destination : Decisions may be made to select altemative destinations if the route previously selected is congested or if the ATT system can give information on altemative opportunities. Destination choice is clearly relevant to some types of discretionary trips.

Trip generation/suppression : Technology may influence the decision whether to make a trip or not, as advice on congestion may result in trip deferral or cancellation within the decision period considered. Purpose and need of the joumey will be decisive in establishing possible changes with respect to whether a trip is cancelled or not.

Trip scheduling: This arrangement within a determined user dependent time period may be considered if satisfactory or non-acceptable alternatives are suggested by **ATT** (e.g. route, trip timing, parking).

Parking choice: parking decisions may be influenced by access to ATT information regarding the location of car parks, the availability of space, and depending on the route followed.

Adherence to advice: Adherence to information provided may be influenced by many factors such as the quality of the information being provided, reliance on such information, familiarity of the network, previous experience and user characteristics.

Table 5. Important market uotential and market resnonse parameters.

	Market Potential	Market Response
Socio-economic	**SEGMENTATION** 1. car availability 2. age 3. social group 4. income group 5. experience 6. familiarity 7. purpose	**BEHAVIOUR** 1. mode shift 2. departure time 3. route 4. destination 5. trip generation /suppression 6. trip scheduling 7. parking choice 8. adherence to advice
Political & Dynamic	**AWARENESS** 1. exposure to ATT 2. acceptability 3. publicity	**DIFFUSION** 1. pre-conditions 2. take-off 3. saturation levels 4. adaptation

Segmentation

Here the concern is with the mam socio-economic characteristics of the individual which might influence both the decision to acquire a particular form of ATT and the actual use of that ATT at one point in time. The argument is that not all people require access to the same technology and that even if they would have that technology, use patterns will vary. Meaningful segmentational factors would include:

Car availability: the availability of a car identifies not only social groups, but also provides information such as existence of altematives or dependency on the public mode. It may be important to select segments of both groups. This segmentation has proved to be useful by many previous studies.
Age/sex : It can be expected that the penetration of ATT may be differentiated by age and sex of potential users. Younger people may be more likely to respond to innovation than older people and men may be more responsive than women.
Social group: Socio-economie group, type of employment and some measure of class may all affect patterns of use of ATT, both in terms of actual takeup and in terms of marketing.
Income levels: Closely related to the social group is income which is likely to be the main factor in the decision to acquire the ATT technology or to obtain access to it.
Experience: positive or negative experience may modify the usage of ATT. Past experience has been found to be traded off against ATT supplied information on the current situation. Increased reliability of current information must be maintained and improved. This factor is related closely with user familiarity and awareness of the altematives available.
Familiarity: The issue of familiarity has been identified in previous research as important in determining whether pre trip information is required in home (unfamiliar trips) or during the trip (familiar trips).
Purpose: Trip purpose may also help to identify which types of activities have the greatest potential for ATT. Discretionary trips (e.g., social, leisure and shopping) may present greater opportunities than regular trips (e.g., work and education) where there is a much greater degree of familiarity.

Awareness
Innovation takes time for people to become aware of, while awareness often relates to exposure or experience. Part of that process is publicity, but equally important is the public acceptability of innovation and the perceived necessity and benefits. Some relevant issues are:

Exposure to ATT : Previous knowledge and exposure to the technology may be decisive in the usage of any future application. This exposure relates to knowledge, experience and acceptability as well as to user characteristics.
Acceptability : Apart form awareness of technology, there is a considerable problem conceming the public acceptability of technology (e.g., the debate on road pricing and privacy). Innovation takes time to become accepted and the market response may be seriously affected if social factors are not positive towards it.
Publicity: Awareness and acceptability can be raised by publicity and marketing which will both promote ATT technology and help to allay any concerns that people may have.

Diffusion
Innovation diffusion also takes time as the market does not respond instantaneously. Even when all conditions are favourable, responses have to be monitored and evaluated over a significant period of time, as standardisation becomes possible and substantial economies of scale prevail. Critical diffusion parameters are:

Pre-conditions: These are the necessary politica1 and technical conditions which have to be in place prior to any large scale application of ATT and relate to a willingness to address environmental and traffic problems.
Take off: as diffusion takes place, initial interest begins to snowball and market penetration expands at a faster rate after reaching a critical acceptance threshold which depends largely on the conditio&
Saturation levels: With maturity, a saturation leve1 is reached, but suppliers then identify new markets to ensure the total market for all ATT continues to expand.
Adaptation : The closely linked dynamic process outlined in the move from pre-conditions through take off to saturation is not a unidirectional process. There are also important feedback effects, as individuals and companies modify their behaviour patterns and change habits.

4 Travel information and travel behaviour: some conceptual issues

The framework of relevant variables discussed above does not yet provide insight into the ***individual decision chain*** which determines the individual need and use of more advanced types of travel and traffic information. Modelling such individual travel behaviour is a difficult task and requires some critical assurnptions on the basics of human behaviour. Such assumptions conform to the classic economic model of utility maximisation where the decision to make a trip is followed by a trip planning stage which results in a ranking of the key trip characteristics according to individual utility before the choice is made (Banister et al. 1994). This choice could include all of the trip planning variables or a subset thereof. The assumptions made here include:

- rationality in choice: if the same choice set is presented again the same decision will be made;
- complete knowledge: the individual decision-maker has access to information conceming the accepted altemative together with knowledge of any rejected altemative.

Individuals act so as to maximise some benefit or utility, with the individual being represented as exercising his or her choice over the full range of available options, limited only by constraints of time and money. In transport this choice is normally represented as discrete altematives between mutually exclusive modes, but it can be used to analyze other parts of the travel decision. The addition of ATT information systems (e.g. on public transport, VMS or route guidance) reinforces the knowledge assumption in the utility maximisation model, as decisions would be based on the best available information prior to the trip being made and during the actual trip.

An altemative model would argue that decision makers are not utility maximisers but satisficers (Banister et al. 1994). The individual makes choices in a situation of partial knowledge. When certain thresholds are reached (e.g. significant foreseeable delays), action will take place. Such a procedure explicitly involves feedback with the result that each new trip has been modified by previous experience, which could be positive or negative .

Such a model gives rise to a more complex decision process and would suggest a more selective use of any pre-trip or in-trip ATT information, as all information is modified by previous experience. In turn, this would suggest this ATT information has to be selective and targeted to individual users, as more genera1 information may not be relevant.

Information given to ATT users would also have to be accurate, as any failure in the system would result in the strengthening of the individual's own experience as opposed to the experience from the information system. Any such reduction in the quality of ATT information would reduce reliance on it, the market for it, and the price that would be paid for it. Selective use of ATT information is a key research area about which little is known.

Information can either be provided at no direct cost to the user (Type 1), in which case utility will be increased, or at a cost to the user (Type II) in which case the increased quality and value of that information will have to be balanced against the cost of that information. Similarly, on the supply side, information can either be provided to users in genera1 (e.g. VMS and public transport information systems) or to the user on an individual basis (e.g. route guidance). Examples of pre-trip and in-trip information product types are shown in Table 6.

Table 6. Examples of pre-trip and in-trip information supply.

Pre-trip

	Type 1 - No cost	Type 11 - Cost
Genera1	CEEFAX ORACLE	In home terminals PROMISE MINITEL
Particular	Timetables	Route planning Telephone inquiry

In-trip

	Type 1 - No cost	Type 11 - Cost
Genera1	Variable message sign Passenger transport information system	AUTOGUIDE TRAFFIC MASTER
Particular	Radio data system	Route guidance

Given these different user and supplier constraints, there will also be differences in levels of adherence to advice. Using the utility maximising framework with no direct cost to the user, utility should be increased with a greater use of both pre-trip and in-trip information. If there is a direct cost, then there will be a situation where no use of ATT is made (no change in utility) or where there is use of pre-trip and in-trip information, thus increasing utility, either with full adherence to advice or partial adherence to advice. It is here that the changes in utility may be difficult to assess, as well as the conditions under which advice is accepted or rejected.

Using the satisficing behaviour framework, some further differences may be observed. If the trip is a new one, then behaviour is similar to utility maximising, but if the trip is one which has been made before, then satisfaction and feedback become important. Selective use will be made of ATT if there was dissatisfaction with the previous trip, but if that trip was perceived as satisfactory, then there is no need to have any new information. Again, adherence to advice can be either complete or partial, dependent on the type of information required, previous experience and levels of satisfaction. This is where concepts of experience and familiarity become important - behaviour may become routinised.

In both models, the determinant factor in the success of different forms of ATT depends on the quality of the information and when and how it is presented. In-trip information has to be more genera1 in the level of advice given and is limited by the size of the display available. To expect major changes in behaviour resulting from such information may be optimistic, as the information is not only relevant to that particular route. Altemative routes are not given on VMS or public transport information systems. Unless the traveller has good knowledge of altemative routes (the assumption in utility maximisation), the perception might be that there is no choice and so the action would be to remain in the queue at the bus stop or on the road. The benefits of such systems are that they are provided free at the point of use and they are likely to raise levels of satisfaction with the service being provided: a reassurance utility.

There is a much greater potential with respect to pre-trip information where options and choices can be made on a much wider variety of behavioral variables. It is here that decisions on trip timing (including trip scheduling or trip suppression), altemative modes, different destinations and the best route can all be made. The range of information and the personalisation of the relevant parts of that information can be made available to the user, so that the assumptions of rationality and knowledge can be met. However, this requires people to spend time prior to making a trip extracting the relevant information. This again involves a cost in the time spent, and may only be appropriate when a new or exceptional trip is being made or when problems are expected. Similarly, many people may argue that their degrees of freedom in terms of mode, destination, start time and even route are limited. Route guidance systems attempt to address some of these problems, but again the information given relates to route choice, not to the other factors which make up the trip. For example, it does not offer the opinion to suggest to the driver to park the car and take the train to the destination, or to give a range of altemative destinations (e.g. shops).

It seems that there are a series of major conceptual issues which need to be thought through on ATT systems. To some extent they depend on the theoretical model being used, but more generally they relate to the type of information being given to the traveller, when and where the information is given, and the relatively narrow range of options available to change behaviour. To expect major behavioral changes resulting from the types of ATT currently being developed may be optimistic. With these limitations (e.g. on measurement and change) in mind, it is stil1 meaningful and possible to set up experiments and collect data for analysis and evaluation.

5 Some European case studies

Measurement of user responses to transport telematics presents certain conceptual difficulties. These include a large range of user responses (see the above nested approach), a small response scale and a long time of reaction to change. These three problems represent the classic dilemma for social research: the range, scale and timing/diffusion of innovation make it very difficult to measure. Even if it could be measured, the difficulties of sample identification and Capture generate problems for obtaining sufficient data to place the results on a solid statistical basis.

The use of the nested framework requires the possibility to monitor behavioral changes in the dimension of time. The measurement of these changes is limited by the character of empirical field trials, which are smal1 scale applications in a limited time of major technological innovations. Therefore, not only current travel behaviour resulting from the introduction of the applications should be measured, but also the changes of perceptions and preferences (stated or revealed) with regard to the applications. This holds in particular for the assessment of the dynamic aspects of awareness and diffusion.

Recently in Europe some interesting case studies have been carried out which aim to assess behavioral responses of end-users to transport telematics applications (Argyrakos et al. 1994). Efforts have been undertaken to systematically assess the impacts of a range of information telematics, using the nested methodology. Three case studies in conjunction with field trials have been carried out which all made use of this common approach:

1) In *Birmingham* (UK), a public transport traveller information system has been tested for buses. The main objective of this trial was to create conditions in which people would increasingly choose public transport for their joumeys, especially joumeys to work. This trial consists of a hotline enquiry service, interactive in-street terminals, real-time countdown displays at bus stops along a single corridor and interactive in-home terminals. Together, these media would provide users with information on timetables, fares, optimum routes, route maps, disruptions and special services.

2) In Southampton (UK), a real-time bus information system by means of displays at bus stops similar to those in Birmingham, has been tested. Also at this site the aim was to improve the overall quality of the bus services which might in turn increase patronage.

3) In the *North Wing* of *the Randstad* (Netherlands), an inter-urban motorway driver information system by means of Variable Message Signs was tested. The aim of this application was to relieve parts of the motorways in this area that are highly congested during traffic peak-hours, by re-routing traffic to underutilized parts.

User surveys have been carried out at each of these sites, following different strategies, since the types of behavioral change aimed for and expected vary between these applications. Where appropriate, cross-sectional, before/after and longitudinal surveys were carried out. In Table 7 is illustrated how these different case studies are linked to each other by the commonly used conceptual approach.

Table 7. Parameters of the nested approach covered by three European case studies.

	BIRMINGHAM	SOUTHAMPTON	NORTH WING RANDSTAD
ATT AREA	Public Transport Management	Public Transport Management	Integrated Inter-urban Traffic Management
Nested Approach Parameters	*Behaviour:* Trip generation; Mode; Adherence	*Behaviour:* Trip generation; Mode; Adherence	*Behaviour:* Route; Departure time; Adherence
	Segmentation: Car availability; Age/sex; Social group; Income; Familiarity; Purpose/Distance	*Segmentation:* Car availability; Age/sex; Social group; Income; Familiarity; Purpose/Distance	*Segmentation:* Age/Sex; Profession; Purpose/Distance
	Awareness: Exposure to ATT; Acceptability; Publicity	*Awareness:* Exposure to ATT; Acceptability; Publicity	*Awareness:* Exposure to ATT; Acceptability
	Diffusion:* Pre-conditions; Adaptation	*Diffusion*:* None	*Diffusion*:* None

* among end-users

In the following will be presented the respective case studies and their main results in Southampton and, into greater detail, the North Wing of the Randstad in the Netherlands .

6 Passenger transport information (Stopwatch) in the UK

One of the key problems for passengers using urban bus services is the unreliability of the service, mainly caused by congestion within the system. Real time infonnation systems allow passengers to make decisions based on the actual arrival time of the service and it may also provide a greater satisfaction with the service being provided.

The trial corridor in Southampton is seven kilometres long and covers twelve different bus routes being operated by two bus companies. The bus location is transmitted from in-bus units to roadside beacons and then transmitted to a centra1 computer. This data, together with historic joumey times, is used to calculate the expected arrival time of the bus at particular stops. The system has been installed on 114 buses and displays are now in operation at 44 bus stops on the main bus corridor into the centre of the city from the north.

Behavioral surveys have been carried out on bus users before and after the installation of the real time information system (Stopwatch). About 11% of the before sample (1538 respondents in total) were aware of the plan to introduce the system, with those who were frequent users having greater knowledge. About 16% of respondents stated that the Stopwatch system would increase their use of the bus, but that this would be most significant among occasional and first time bus users. The most positive responses came from those who used the bus for social and shopping purposes, particularly among the young. However, when compared with the survey after the installation of the passenger information system, very different results were apparent. In the after survey were 1702 respondents and only 4 % had actually increased their trip making as a result of the Stopwatch system. There seem to have been an overestimation of the impact on the trip making pattems of bus users about three times. The difference between behavioral intention and actual behaviour is clear.

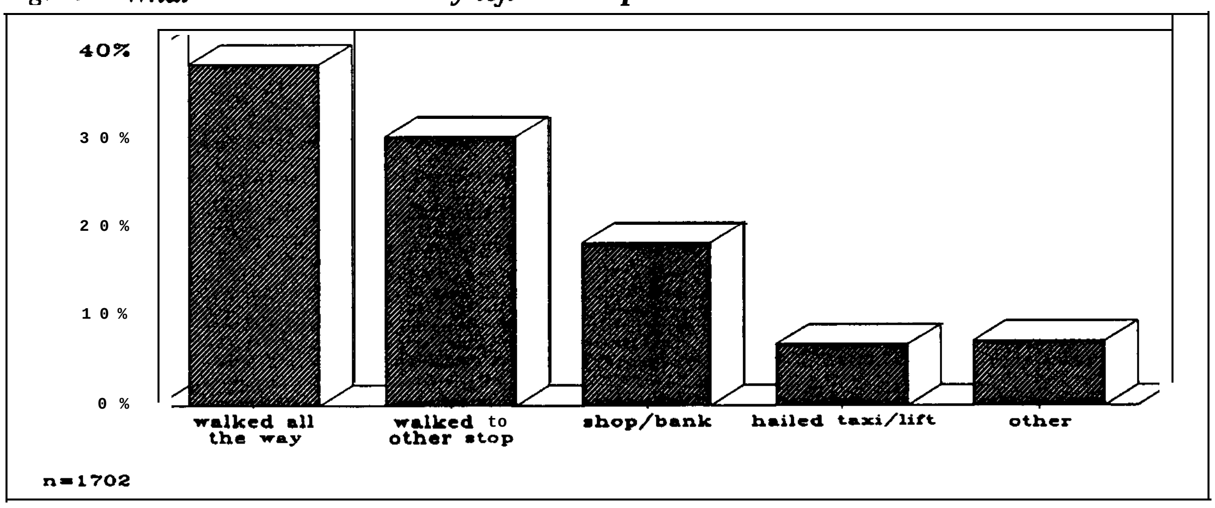
Nevertheless, there were three main ways in which Stopwatch seemed to have had an effect on travel behaviour. There are a substantial number of new users of public transport, since the introduction of Stopwatch. These new users were young, usually travelling for education or leisure purposes, and they often had high levels of car availability . They had a very positive view towards Stopwatch, but made a less than average amount of use of the bus service. The new users seem to form the basis of a revitalised interest in new types of public systems, and the importance of high quality real time information to this group of users. The marketing of Stopwatch to this group is important to the success of information systems as these new users have generated more bus travel (Table 8).

Table 8. Summary of the Stopwatch effect in Southampton.

Travel Characteristics	New Bus Users	New Trips from Existing Bus Users	Stopwatch Switchers	All Sample
. Trip Purpose				
- Work	20.7%	25.9%	21.5%	23.5%
- Education	14.6%	15.7%	13.6%	8.4%
- Shopping	34.1%	45.1%	40.2%	39.6%
- Other	30.6%	13.4%	24.7%	28.5%
. Car availability	47.5%	19.7%	13.2%	17.8%
. Non car owing households	52.5%	68.2%	57.9%	55.5%
. Never used the car	15%	24.7%	18.5%	14.8%
Socio-economic Characteristics	**New Bus Users**	**New Trips from Existii Bus Users**	**Stopwatch Switchers**	**All Sample**
. Women	56%	60.7%	63.6%	63.1%
. Under 34 years	69.7%	67.7%	62.2%	50.3%
. Full-time employment	28.8%	40.7%	34.1%	38.9%
. Full-time student	37.2%	25.1%	40.1%	23.3%
Sample size	**406**	**55**	**214**	**1702**

The second Stopwatch effect has been to encourage existing bus users to make more trips on the improved service. This 4% mentioned earlier have a high level of knowledge of Stopwatch (73% as against the sample average of 59%), and they actually make use of the electronic display information (35% as against the sample average of 22%). All of this group's respondents used the route before the electronic displays were installed, and over 80% looked at the displays on several occasions (sample average 53%). This group of users came predominantly from non car owing households and they were never likely to use the car. They were young people on shopping or education purpose trips. It seems to be possible to increase the use of buses, even among captive users and heavy users of the existing services through marketing a better quality services with real time information systems. These increases in bus use are small, but as the overall quality improves, further trips should be generated. The third effect is the Stopwatch switchers. These are bus users who have left the bus stop during the last fortnight because the electronic display showed that the bus would not arrive for some time. Some 214 (12.5 %) responded positively in this way and they either switched route to another bus or stop, or went to a local facility and then retumed to same stop or another stop (Figure 2). The total mode shift effect resulting from these figures is 45%.

Figure 2. What users did when they left the stop.



So, actions can involve modal changes, route changes, timing changes, activity changes or destination changes. The introduction of the Stopwatch system has allowed a new flexibility in trip making that seems to have been well received, particularly by the young people in education. However, there is also a concern over the accuracy of the information and the most important issue for all bus users is a reliable and frequent service.

The use of technology in bus services provides a better quality service, particularly in a deregulated bus market such as that in the UK. One of the major losses caused by deregulation has been the poor quality of information about the bus services which are available. The numbers of services running in the Southampton area and their frequency has increased, but that information is not available in the bus. Good quality real time information does not seem to improve the perceived quality and reliability of the bus service. Moreover, even after only 10 months of the Stopwatch system in Southampton, these users are making more joumeys, although on a modest scale.

7 Route Choice Information (RIA) in the Netherlands

The Northem Wing of the Randstad in the Netherlands (the Greater Amsterdam area) suffers from severe traffic problems on its inter-urban roads. The major roads connecting Amsterdam with surrounding towns are heavily congested, especially during the peak-hours. One of the main traffic problems is the crossing of the river IJ which is splitting Amsterdam just north of the inner city into two parts. Every day, a large flow of commuters is travelling from the residential areas north of the river IJ to the employment centre in the southem part of the agglomeration. This development caused the need for the completion of the orbital motorway in the Amsterdam region, which is a very important link for all regional and through motorway traffic (Buijn et al. 1994). Major parts of the western and southem side were already completed in the 1970's and 1980's. In September 1990 the last part of the Amsterdam orbital motorway was completed, opening up the northem and eastem segments .

The completion of this orbital motorway provided new routing altematives for a considerable number of users of the regional inter-urban road network, owing to the new capacity to lead traffic along the eastem and northem side of Amsterdam. A dynamic traffic management application consisting of Variable Message Signs has been implemented by the Dutch road manager (Rijkswaterstaat) to support users of the ringroad in selecting their route. The system is called Route Information Amsterdam (RIA). RIA provides users approaching the ringroad with information on traffic queues (including tbe length of tbe queues) and with information about closure of tunnels or driving lanes. The type of information provided is specifically meant for those road users who are familiar with the network, knowing their route possibilities when passing the VMS signs. Furthermore, the longer the distance driven on the ringroad, the closer tbe altematives to go clockwise or anticlockwise over the ringroad are. It is thus expected by the road manager that the information is useful for tbrough traffic and a certain part of traffic with Amsterdam as destination.

In November 1991 the fust variable message sign was put into use at the most strategic location, namely on the motorway from the nortb before the junction with the ringroad. In April 1994 another three identical signs were installed on the three access motorways from the south, each just before the respective junction with the orbital motorway . Therefore, it is an interesting question how much the degree of acceptance of this particular technology has been.

A behavioral survey was carried out among users of the motorway network concemed approximately three months after the full implementation of all four variable message signs. The survey target was formed by car drivers visiting less or more frequently Amsterdam via one of the four main motorway access roads where VMS signs have been installed, and who made use of the ringroad. The survey had a sample size of 826 observations. The revealed character of the survey made it possible to investigate in-depth the market potential and -response elements from the presented nested approach via segmentation of the survey sample and the measurement of attitudes and actual behavioural changes to this operational telematics system.

It was hypothesized that important segmentational variables should be sought in the the age, **gender** and **income/social** group of the respondents as **well** as their travel characteristics like their experience with dynamic driver information, frequency of travelling (and inherently the familiarity with altemative routes) and trip purposes. Looking at the possible **effects** of the kind of information provided on travel behaviour in the context of this **site, the** emphasis was given on choice options related to route followed and departure **times** of the trips. The relatively long-distance character of **the car** trips made implied that it was unlikely that there would be an impact on **other** travel behaviour parameters (like **changes** in destination choices or trip rescheduling).

Several considerations underly the possible impact of the information on route choices. For instance, the change from a **planned** route under **influence** of dynamic information would **depend** in the fust **place** on the **existence** of **any** possible altemative routes available in the **specific** situation. Secondly, the **demand** for altemative routes would be determined by the (expected) duration and **cause** of the queueing ahead on the followed motorway. Personal preferences of motorway drivers with respect to **traffic** delays and rerouting and travel features like distance and **time** restrictions play an important role here. If, for example, the expected delay ahead on the followed route is equal to the **detour time** of **any** other possible route, a yet unknown share of drivers would change route. **This** type of reaction **however** is to be expected more likely to take **place when** the travel distance is **longer** and the same **detour** distance is therefore relatively shorter. The uncertainty which sterns from using **such** an altemative route **may also** retain an unknown share of drivers from this type of reaction, particularly those **who** are less familiar with the area.

Table 9. Survey characteristics.

	per cent (1)		per cent (1)
<u>sex</u>		<u>age</u>	
male	83.8	<24	4.4
female	16.2	25-34	44.1
		35-44	26.9
		45-59	22.8
		>60	2.8
<u>trip purpose</u>		<u>frequency of using rinsroad</u>	
commuting or work-work	56.2	≥ 5 days a week	47.8
business	35.2	3-4 days a week	17.4
otheruise	8.6	1-2 days a week	ia.0
		< once a week	16.8
<u>ftexibilitv of arrival time</u>		<u>averase trip distance</u>	
impossible to arrive late	43.9	< 10 km	1.0
possible to arrive late	56.1	10-25 km	10.5
		25-50 km	35.0
		> 50 km	53.5
<u>alternative routes availabte</u>		<u>passing frequency of RIA sign</u>	
Yes	57.1	> once a week	77.9
no	42.9	once a week	8.4
		< once a week	13.6

(1) Missing values were omitted.

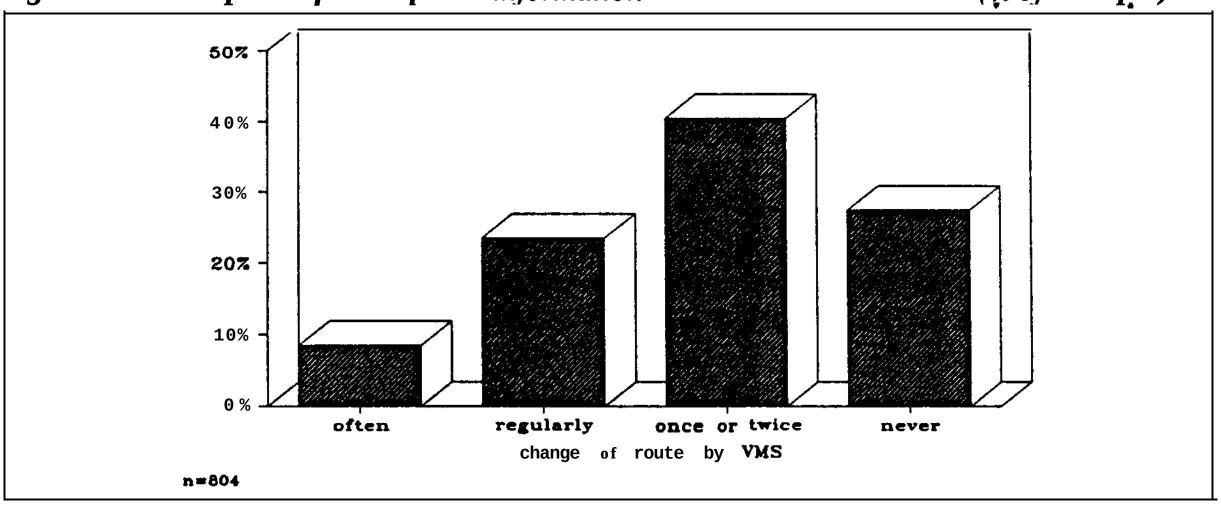
In Table 9 some important characteristics of the survey are shown. There were **significantly** more **males** than females in the sample; 84% was male. It was remarkable that the females were slightly younger than the males. The majority of the respondents, 80%, had a full time employment. In short, the population surveyed can be characterized as mainly male, full time workers, whose age was between 25 and 60, and who had much driving experience.An important feature is the usual purpose of the trip. Business appointments were mentioned by nearly 35% of the respondents as one of the dominant purposes of trips. They were relatively stronger represented in the male group. Around 56% were commuters or freight or delivery drivers.

It appeared that 55% of the respondents were able to follow more than one route without a significant time delay to their destination. Those drivers having route altematives were also asked whether they ever made use of an altemative route. From these respondents approxirnately 31% regularly took an altemative route. This high route choice flexibility and use of more than one route was quite encouraging for the possible usefulness of the driver information provided.

The attitudes towards the system were in genera1 very positive. In total 90% of the respondents stated that they found the provided information (very) pleasant. This percentage was the same for both those drivers who had route altematives as well as those who did not have route altematives. This indicates that besides travel time, drivers may obtain other forms of benefits from the information, like for example a reduction of uncertainty with respect to the traffic situation.

The impact on route choices of drivers seemed to be considerable. Some key figures were the following: about 72% declared to have ever been affected in their route choice by the VMS information. About 23 % changed route regularly and 9% even often (Figure 3). It may be concluded that a really significant number of drivers has been affected by the information in their route choice since the VMS system was installed.

Figure 3. The impact of VMS queue information on driver'sroute choice (% of sample).



It was also investigated to what extent different VMS stimuli had impacts on route choice. From those drivers being affected by the information, 30% declared to have taken this decision once or more when seeing a message of a queue length between 0 and 2 km. About 50% took this decision only when seeing a message of a queue of at least 2 km. To 16% a minimum queue length of more than 4 km was reason to change route and 4% change route only when queues of more than 6 km were indicated. The satisfaction rates with alternative routes were encouraging. Nearly 38% of the route switchers declared to be better off with the other route, 13% felt not to be better off. Ahnost half of the respondents (49 %) did not know.

The alternative route was usually by motorway for just over half of the route switchers. The other half declared to take altemative routes which were partly off the motorway. The high number of route switchers using secondary city roads, which is not the intention of the VMS application, suggests that the information might also potentially generate some negative side-effects that might conflict with targets to keep motorway traffic as much as possible outside urban areas.

Route changes and driven detour distances appeared to depend clearly on trip purposes. A significant relation was found between the frequency of route changes and the relevant trip purposes. The respective shares of business drivers, commuters and discretionary drivers who often changed route by the provided information were 10% , 8% and 6%, respectively. In the case of never changing route, these shares were 20%, 3 1% and 36%. Thus business drivers seemed to be slightly more sensitive for route change than others, while commuters did also change more frequently than people with discretionary purposes. This result could be expected on the ground of the higher value of travel time and lower perception of travel costs by business drivers.

It seemed that men were in genera1 more sensitive to route change than women: males changed route more often, and also reacted more intensively to messages of smaller queue lengths. Explanations could probably be found in psychological differences between the two sexes, but also here some correlation occurred between the gender and the trip purpose because it was found that men travelled relative more for business purposes than women. This difference between males and females confirmed the results of other behavioral studies (e.g. Mannering et al. 1993).

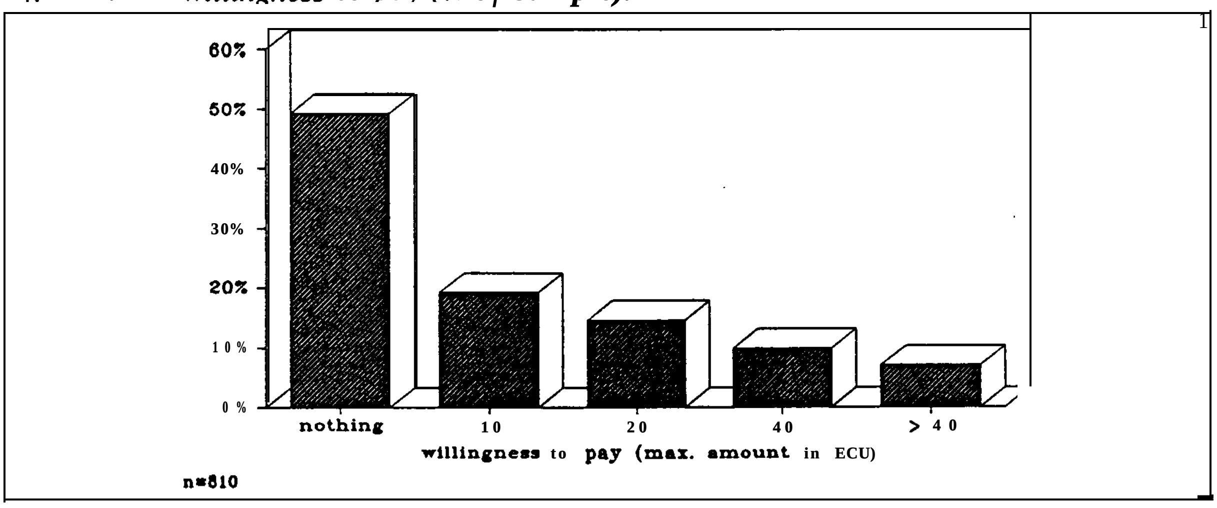
The impacts on route choices appeared also to be to some extent positively related to the frequency of driving (and inherently, the familiarity with the road network) in which case a slight relationship was found. Of those who drove very frequently (five days a week), 32% of the people appeared to reroute their trips often or regularly, while some 68 % only rarely (or never) made a rerouting. Those who drive less than once a week changed route to a lesser extent: 19% often or regular and 81% rarely or never.

Furthermore, there appeared to be a positive relation between the average distance of the trip and the length of detours made. Of those drivers travelling distances longer than 50 km, 71% make detour distances of more than 2 km while this percentage was substantially lower (53%) for those who travel shorter distances of up to 25 km. Thus it seems that the reluctance to additional kilometers decreased as the joumey is longer. But also some correlation existed here with the trip purpose: those travelling longer distances consisted relatively more of business drivers. Of those travelling more than 50 km, 40% had business motives, while of those travelling less than 25 km, this percentage was only 26%.

Besides the impact on route choice, another aspect of the information provision which may not at forehand be discarded is the possible effect on departure time of drivers. It may be hypothesized that in some cases habitual behaviour related to departure time choice may change (for example, by a 'return to the peak' effect) because drivers may get used to a reduction of uncertainty by the provided information or, more directly, because individual travel times may be repeatedly reduced. Figures show however that from the whole sample, most respondents (82%) were never affected in their chosen departure time by the system.

The VMS system concemed was a public system implying no cost of the information provision to the end-user. In order to obtain an indication on the potential market for individual systems providing the same type of traffic information, the willingness to pay was investigated for in-car systems continuously providing this kind of information. It appeared that the willingness to pay for the information was in genera1 quite low (Figure 4). Almost half of the respondents was not prepared to pay anything. Only about 7% were prepared to pay more than 40 ECU a year.

Figure 4. The willingness to pay (% of sample).



As expected, a relationship was found between the willingness to pay and the usual trip purpose. Relatively many respondents with regular business appointments were prepared to pay higher amounts. Approximately 13% would pay more than 40 ECU a year, against 4% and 1% for commuting and discretionary purposes respectively . The group with discretionary purposes was very unwilling to pay anything: 62% did not want to pay anything, against 44% and 5 1% for business and commuting purposes, respectively .

Neither very surprising was the relationship between the willingness to pay and the availability of route altematives. Respondents not having an altemative route available were less prepared to pay for road information than respondents having an altemative. However, stil1 a considerable high number of 43% of the respondents without route altematives was willing to pay something. This result re-affied that the individual benefits from the VMS information are also obtained by those who had no route altematives available or do not actively react to the information by rerouting their trip.

Another important issue that was found from the survey was that the information provided by the VMS was mainly used by those drivers who had experience with and already use other (more conventional) means of traffic information, for example traffic information broadcasted by radio. Of those who regularly or often changed route owing to the VMS information, 90% once or often also rerouted their trip owing to traffic information provided by radio, while for those never changing route by the VMS this percentage was 48%. Furthermore, the willingness to pay for the continuous availability of the VMS information was relatively higher among those who were frequent listeners to radio traffic information. Of those never using radio traffic information, 37% were prepared to pay a certain amount for the VMS information, while this percentage was higher (56%) for those often using radio traffic information.

This led to the conclusion that for the user group that had a relatively large propensity to listen to conventional traffic information, the VMS information might be a substantial complement to these other sources of information, since if the VMS information did not add any value, then drivers listening to radio traffic information should not be willing to pay anything for the additional VMS information. Consequently, the leve1 of acceptance of a new invention may also be complementary to the use of a related invention.

8 Lessons

The potential beneficial impacts that may be expected from the introduction of new advanced transport telematics systems are considerable. However, positive technical and operational test results are often seen as a guarantee for the success of the developed systems. In this paper the focus has been on another critical success factor, namely the interaction of the technologies with the potential users of these systems. This means that acceptation and diffusion are important issues.

The process of innovation and diffusion of transport telematics is dynamic and complex, like any other new technology. Very important factors in this process are the behavioral responses of transport users in terms of changes in travel choices, but also the range and types of actors involved and the implementation purposes direct the size and rate of the potential diffision of the respective technologies via growing awareness levels. The fundamental role in this process played by the potential users suggests that more emphasis should be placed on a coherent and systematic investigation of the user side. To this aim a framework was presented which covers the full range of dynamic issues related to the strategic aspects, the market potential and the market response of transport telematics applications. This framework has the advantage that it is generally applicable, covering a range of telematics functions.

It should be noted that the effects of technological innovations will vary between various groups of transport users; this emphasises the importance of a thorough user segmentation. For instance, it can be hypothesized that certain user groups making repeatedly the same trips (e.g. commuters) may show a satisficing travel behaviour, in which case only use will be made of travel information provided by telematics if there were dissatisfaction with previous trips made.

The usefulness of the framework presented was illustrated by a set of three case studies in conjunction with real pilot tests of new telematics applications in Europe. In particular, our empirical work focused on real-time passenger information systems for buses and motorway driver information systems. User surveys carried out on two sites provided various interesting conclusions, on both the potential impact of such systems on travel choices and the potential market for disseminating travel and traffic information by means of private equipment.

The awareness of the passenger information system in Southampton was high; before the system was installed about 11% were aware of the plan to introduce the system, with those who were frequent users having greater knowledge.

There were three mam ways in which Stopwatch seemed to have had an effect on travel behaviour. In a first place, there were a substantial number of new users of public transport, since the introduction of Stopwatch. These new users were young, usually travelling for education or leisure purposes, and they often had high levels of car availability.

In a second place, existing bus users were encouraged to make more trips on the improved service. This group of bus users had have a high leve1 of knowledge of Stopwatch (73% as against the sample average of 59%), and they actually made use of the electronic display information (35 % as against the sample average of 22%). It seems thus to be possible to increase the use of buses, even among captive users and heavy users of the existing services through marketing a better quality services with real time information systems. These increases in bus use are small, but as the overall quality improves, further trips should be generated.

In a third place there were Stopwatch switchers. These were bus users who had left the bus stop during the last fortnight because the electronic display showed that the bus would not arrive for some time. About 12% responded positively in this way and they either switched route to another bus or stop, or went to a local facility and then retumed to same stop or another stop. The total mode shift effect was 45%.

The introduction of passenger information systems like the Stopwatch system seems thus to allow a new flexibility in trip making, being particularly well received by the young people in education. However, good quality real time information does not seem to improve the perceived quality and reliability of the bus service, which is the most important issue for all bus users is a reliable and frequent service.

The awareness and attitudes towards a driver information system in the Netherlands were in genera1 very positive. In total, 90% of the sample stated to fmd the provided information (very) pleasant. This percentage was the same for both those drivers who had route altematives as well as for those who did not have route altematives. This indicates that besides travel time, drivers might obtain other forms of benefits from the information, like for example a reduction of uncertainty with respect to the traffic situation.

The impact on route choices of drivers was considerable. It appeared that route changes clearly depended on the purpose of the trips made. The group of drivers regularly travelling for business purposes did more frequently follow alternative routes caused by the provided information, while it also seemed that men were in genera1 more sensitive to route change than women.

About half of the respondents declared to be willing to pay anything for having the dynamic traffic information provided by the VMS continuously available in the car. This willingness is higher for business drivers. Considerable high shares of drivers who declared not to have reasonable route altematives and of drivers who had never changed route stil1 declare to be wiling to pay anything for the information, re-affirming that other kinds of benefits than saved travel time may be obtained from the information.

The survey also indicated that the information provided by VMS is mainly used by those drivers who have experience with and already use other kinds of traffic information. This confirms the conclusion that for this group of drivers the VMS information may be a substantial complement to other sources of information.

A final lesson from our empirical work may be that the commercialisation of traffic information among the broad public might be more limited than initially expected - in light of the generally low willingness to pay in the sample -, but also that clear user segments can be distinghuished as identified in the presented nested approach among which the market penetration is likely to vary significantly . Such socio-psychological and economic factors will ultimately have important consequences for the future diffusion rates of the new telematics technology.

References

Argyrakos, G., G. Giaoutzi and *K.* Petrakis, ***Travel behaviour and the diffusion of new technofogies,*** Proceedings of the 7[th] International Conference on Travel Behaviour, Valle Nevado, Santiago, Chile, 13-16 June 1994, pp.771-785.

Banister, D., P. Nijkamp, P. Camara and G. Pepping, ***The analysis of user response to advanced transport telematics - measurement, methodological and conceptual issues,*** BATT, DRIVE 11 Programme, EC, DG XIII, Brussels, 1994.

BATT, ***Identification of requirements (deliverable 2)***, DRIVE 11 Programme, EC, DG XIII, Brussels, 1992.

Buijn, H. and W. Schouten, ***Route choice informution Amsterdam ,*** Proceedings of the 27[th] ISATA Conference, Aachen, Germany, 31 October - 4 November 1994, pp.143-150.

Catling, 1. and H. Keller, The LLAMD Euro-project: expected impacts of dynamic route guidance systems in London, Amsterdam and Munich, ***in: Advanced Transport Telematics,*** *proceedings* ***of the Technical Days,*** EC, Brussels, 1993, pp.70-74.

Malaterre, G. and H. Fontaine, The potential safety impacts of driving aids, ***Recherche Transports Sécurité (English' issue),*** no .9, 1993, pp. 15-25.

Mannering, F., S. Kim, W. Barfield and L. ***Ng, Statistical analysis of commuters ' route, mode and departure time flexibility and the influence of traffic information*** , Research report, University of Washington, Seattle, 1993.

Quaid, M., L. Heifetz and M. Farley, ***The Puget Sound telecommuting demonstration: program description and preliminary results, 1992.***

Rijkswaterstaat, ***Dynamic traffic management in the Netherlands,*** Ministry of Transport, Public Works and Water Management, Transportation and Research Division, Rotterdam, The Netherlands, 1992.

Vanderschuren, M., M. van der Vlist, and E. Rooijmans, ***Verkeersmanagement, energie en milieu: de effecten van telematicatoepassingen,*** INRO-VVG Report, Delft, Netherlands , 1993.