MAKING OUR MOBILITY MORE INTELLIGENT- A FRAMEWORK OF A PERSONALIZED MULTIMODAL TRAVELLER INFORMATION SYSTEM

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ABSTRACT

In recent years, traveller information services have found increasing popularity in the consumer market. These services support route planning, navigation and location-based services using static and dynamic database services on both commercial and non-commercial terms. It is expected that the next generation of traveller information systems, will be based on real-time transport information from multiple sources and in addition support personalised planning, in terms of user travel preferences. In this paper, which is part of the i-Tour project, funded by the European Commission, we propose a framework for developing a personalized multimodal traveller information system which is capable of providing user-tailored travel advice in real-time environments, monitoring persons' activity schedules and incrementally learning user preferences from their response patterns. To implement this system, a supernetwork representation will be employed to model the multimodal transport system. Then, a complex set of conditions including personal preferences, real-time information and activity schedules will be taken into account to specify generalized cost functions that include environmental impacts. Personalized optimal route advice will be provided using routing algorithms.

Keywords: multimodal transport, personalisation, advanced traveller information system

INTRODUCTION

With the boom in motorization, urbanization and population growth over the last century, transport has played a fundamental role in the development of the economy and society, and as a direct consequence has shaped daily life. However, transport supply has often been unable to fulfil the rapidly increasing demand for it, and has itself contributed to a number of problems including congestion and pollution. Solving these problems by suppressing demand or expanding supply is not realistic as in either case there are constraints in place. However, the rapid development of information and communication technology in the last few decades provides new opportunities to manage and perhaps alleviate such problems. Intelligent transport systems (ITS) in which knowledge of transport patterns, preferences of the transport users, the status of the transport infrastructure and other factors are brought together may help in better managing the factors that cause these problems. The beneficial impacts are expected to be centred on more efficient use of the available transport infrastructure on behalf of its users with additional benefits in improved safety, and reduced vehicle wear, improved journey transportation times, and reductions in the overall energy consumption of the transport infrastructure. ITS are generally classified into five categories: Advanced Traveller Information Systems (ATIS), Advanced Traffic Management Systems (ATMS), ITS-Enabled Transportation Pricing Systems, Advanced Public Transportation Systems (APTS) and Vehicle-to-Infrastructure Integration (VII) and Vehicle-to-Vehicle Integration (V2V) (ITIF, 2010). As a integral important part of ITS, ATIS will provide travellers with real-time advice on navigating through a dynamic transportation network, where conditions may change rapidly many times in the course of a typical day (Joseph,2008).

In the academic research area, many researchers and organizations have conducted a substantial amount of research on ATIS. Chorus et al. (2006) summarized research about the relationship between travellers' choice behaviour and travel information. Their review demonstrates that the majority of this work is concerned with explorative empirical research or with the exploration of alternative theories to model such behaviour. More importantly for the present study, most of this research concerns public, descriptive information; considerably less is known about the next generation of travel information systems that will be based on personalized, dynamic descriptive and prescriptive information. Most research has looked at the correlation of information use (e.g., Goulias et al., 2004; Hato, et al., 1999) and willingness to pay (e.g., Molin et al., 2007); less has been done on the development of theories and models to understand traveller responses. Chorus argued that the next generation of ATIS will be concerned with mobile, multimodal, dynamic and personal services. It is also to be expected that commercial firms will develop such services.

The aim of our project is to contribute to this emerging field of research and development. ATIS usually includes basic services like route planning, navigation, real-time traffic information, parking information, weather information, while some key technologies involved include GPS, GIS, wireless networks and mobile telephony, transport data collection and the required algorithms to link these data sets to be able to provide user information. By now, several commercial applications have been developed that may be useful for ATIS: Google has published Google Transit and Google Maps Navigation. The former provides route planning for walking, car or public transport and displays real-time road traffic flows. The latter provides mobile navigation services (turn-by-turn). Companies including Tomtom and Navman are planning to provide real-time personal navigation devices and Garmin and Polar both provide such devices for a number of sports activities (see Garmin sponsorship of professional bike racing for example). 9292, a Dutch travel information company, combines public travel information and mobile GPS services. These are just a few examples. Others include Transportdirect, 511, Viamichelin, Transperth.

However all of these systems and services improve traveller's mobility only to a limited degree. Most current applications only provide travel information for discrete travel modes, i.e. walking or car or public transport. It is expected that systems for multimodal travel (i.e. walk and drive) will become more important, especially with the current focus in public transport policy of shifting traffic from the car to alternative modes or to mixed use. Furthermore, most current systems only evaluate route by travel distance, travel time or travel cost. As in some cases these metrics are unable to give sufficient granularity to make informed choices regarding suitability it is envisaged that the value of ATIS systems can be increased by the addition of additional parameters covering congestion, delay, parking availability at destination or at waypoints (specific to each transport mode), number of transfers, seat availability, walking distance, weather. In particular it is felt that current systems are imprecise or unable to indicate the environmental impact of a trip. This may be evaluated by the amount type of air pollution produced on a trip. With more informed data made available through an ATIS system this has the potential to promote behaviour that is more environmental friendly.

Where travel is undertaken for social and work purposes better access to information may allow more detailed planning of activities.

As a final benefit for consideration in ATIS is the ability to tailor the information received from ATIS from the preferences expressed by the user. To achieve these goals, we propose a framework for a personalized traveller information system.

The aim of this paper is to sketch the general framework of the intended system and to indicate that available knowledge should be sufficient to successfully develop it. To that end, in the next section, we will first discuss the general framework and examine some of the system components. This will be followed by a discussion of relevant available knowledge that we can use to solve particular problems. The paper is completed with conclusions.

FRAMEWORK

General description

The general framework of this system is composed of several parts:

- first is a reliable and secure data collection facility and approach which is able to benefit both from sensor networks giving a view of real-time public transport load, and from information provided by the users;

- second is a modular infrastructure based on standard open technologies which can be adopted by public transport providers to develop harmonised transport-related services;
- third is a personalized routing service which is capable of providing user-tailored travel choices and capable of adaptively learning users' preferences from their inputs;
- fourth is a user-friendly travel information portal which can promote sustainable travel choices based on a multi-modal transport system concept;
- last is a system to incorporate trust, virtual communities and privacy.

Of the above functionalities, routing plays a key role in the whole system. In this paper, we focus on the framework from the view of the routing information service or routing system component.

Before providing more details about the framework, we first describe the basic functionality of the system with regard to this component. We assume that the first time the system is used user preferences will be requested and made known to the system. These preferences may be concerned with transport mode, route type and schedule adaptation strategy, and may be context-dependent. The user can keep a longer-term calendar of his/her activities. At the start of the day, the system supports the scheduling of the activities planned for that day. The system may give advice regarding the optimal sequence of planned activities and associated travel plans. In terms of a travel plan, the i-Tour system consistently considers the general case of a multi-modal trip, e.g., trips that may involve a transfer from some private mode (e.g., car) to some public mode (e.g., train). Thus, a travel plan includes an advice regarding transport mode choice, which may include mode switches, as well as routes across the transport network for each modality involved. During the implementation of a travel plan, the system manages the travel plan in the context of the broader activity schedule. Whenever an unforeseen event occurs, the system brings this to the attention of the user and provides re-planning suggestions on either the travel plan or activity schedule level. This may relate to schedule delays (e.g., caused by congestion during travel), unforeseen activities (e.g., bumping into a friend and have a drink in a café) or new schedule opportunities that arise, for example, due to re-routing of a trip. Advice of the system on trip or schedule level is generally presented in the form of a list of choice alternatives ranked by assumed preference of the individual user and a recommendation. For each choice alternative the system provides information on expected consequences in terms of dimensions (travel time, monetary costs, safety, comfort etc.) that directly concerns the travellers' own interests as well as the environment (emission of greenhouse gasses and, generally, environmental impact). The system may give similar updated advice en-route. The user may accept or reject the advice, in each case giving learning input to the system which the system may use to modify the stored preferences.

Based on this functionality the anticipated system can be described in terms of UML diagrams (O' Docherty, 2005). In the use case diagram of Figure 1, there are two actors in the system, the user (traveler) and the data collector (e.g. camera, sensor, real-time transport information). The user can perform the following operations: set general preferences regarding travel options and activity re-schedule options, specify an activity schedule for the day (given a longer-term activity calendar), query or plan a trip (transport mode(s) and route(s)), compute the quantity of greenhouse gasses and other air pollutants produced by a trip.

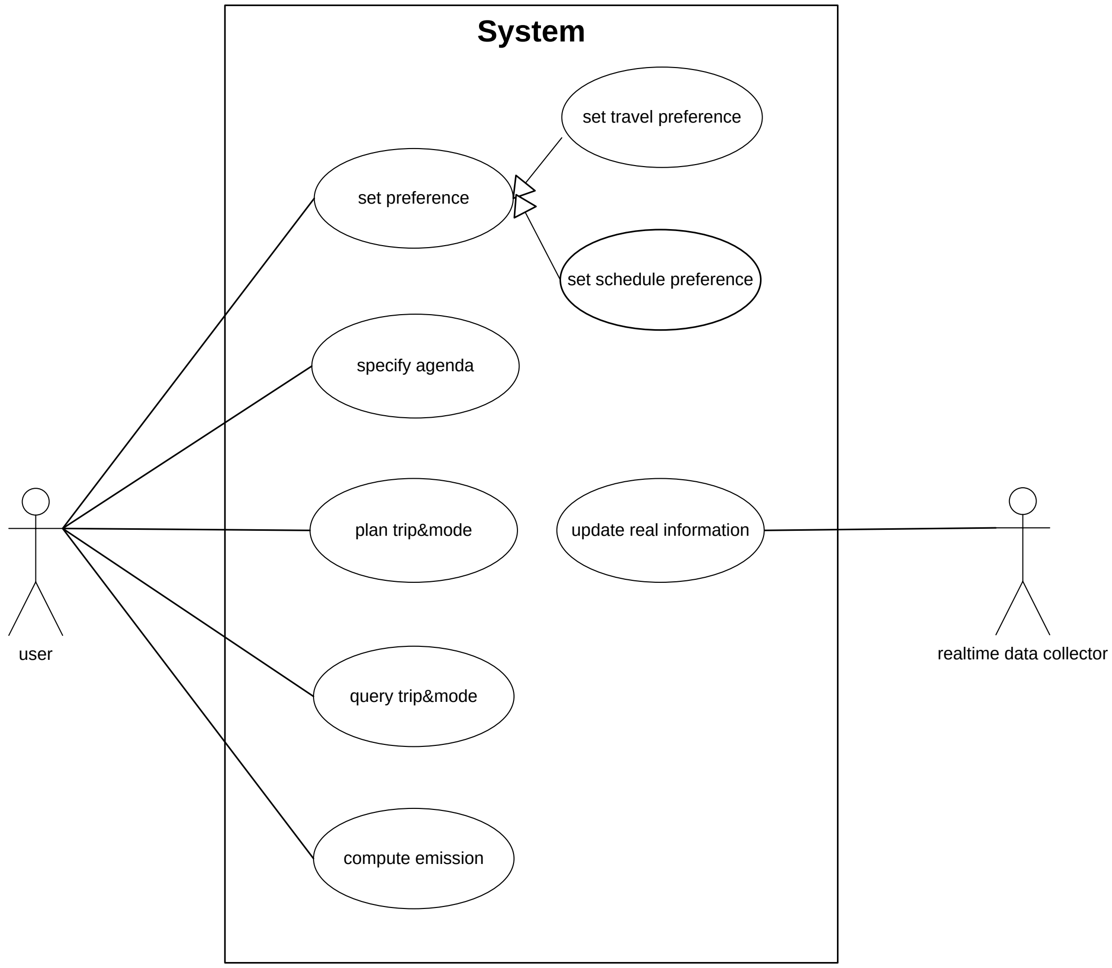

Figure 1 –Use case diagram of system

In the activity diagram of Figure 2, the system first has to initialize the user's preference. Then, the system will update real-time information on traffic and weather conditions and executes activity scheduling and travel planning. Each time choice alternatives are presented to the user and the user indicates a choice, the system will update preference weights according to the user's response. The system will automatically update real-time information and decide whether to re-schedule or re-plan during the execution of the schedule.

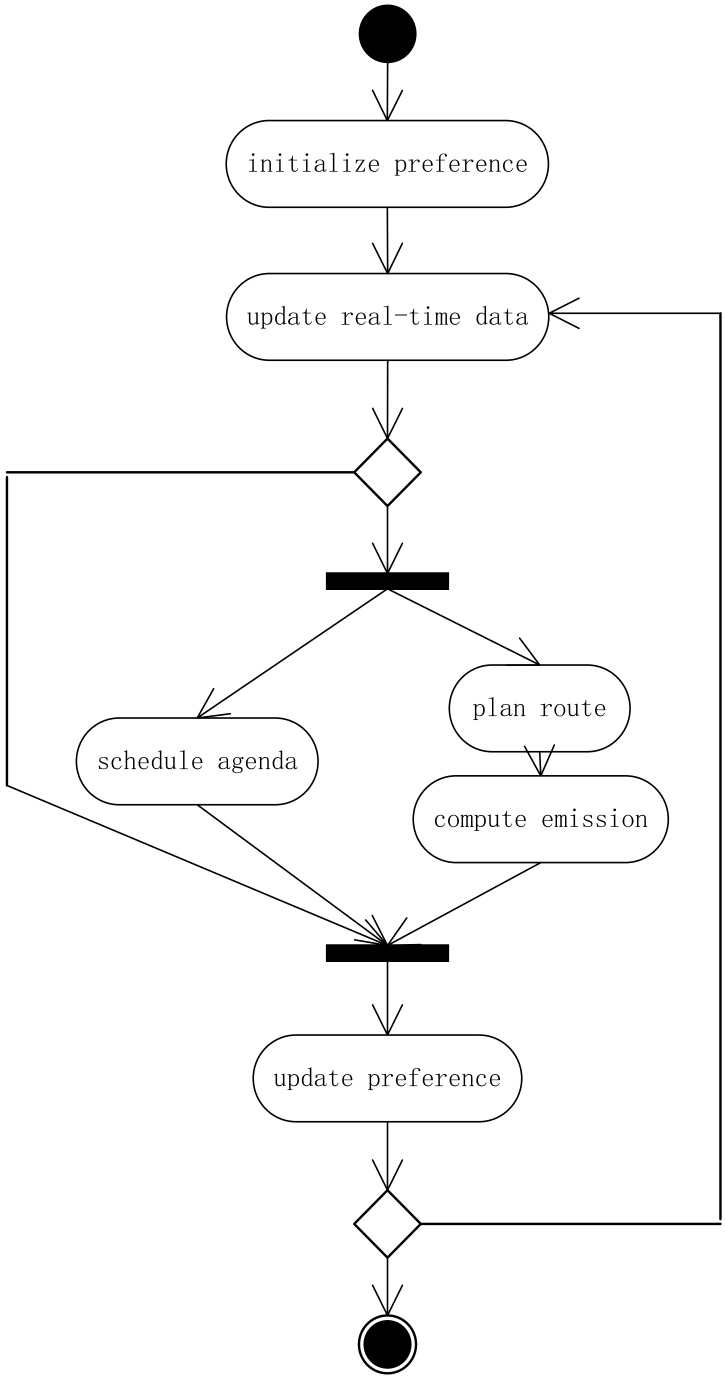

Figure 2 –Activity diagram of system

The routing component – where 'routing' is taken in the broadest sense to be a complete activity-travel schedule – is just one of the recommender systems of i-Tour. In addition, there is a recommender and trust system that is concerned with location-based services (points of interest) of the user. In this paper, we focus on the routing component. In the deployment and component diagram of Figure 3, the routing component together with other components is deployed at an application server. The traveller can access the application server through a PC or a mobile device (such as mobile phone or PDA). The data collector will update the real-time information in the database.

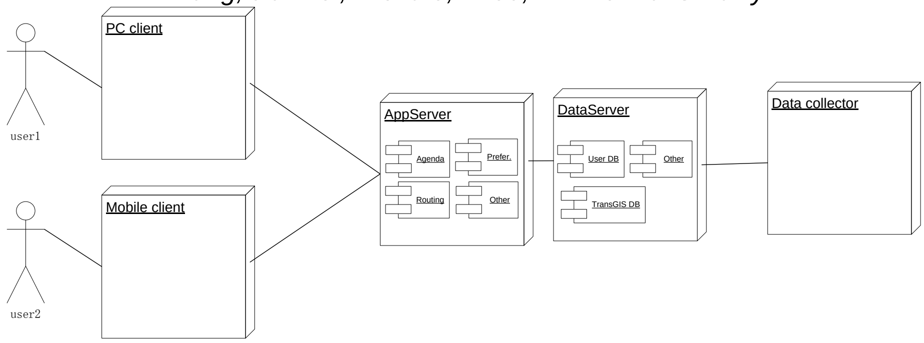

Figure 3 –Deployment and component diagram of system

In the following subsections, we will introduce the characteristics and primary functions of four components separately, which are the routing component (in a narrower sense of the term), preference component, activity scheduling component and system consequences.

Routing component

There are two main characteristics of this component: the first one is supporting multimodal travel where various combinations of modes could be taken into account; another is supporting the use of real-time information that is received from the sensors via middleware in generating routes.

The main functions of the routing component can be classified into route planning and navigation, where the former is considered as static and the latter is considered as dynamic. The route planning part can be further categorized into full-information routing and partial-information routing. In full-information planning, the user gives definite specifications of origin and destination, whereas in partial-information planning, the user may tell the system by natural language where he or she wants to go or what he she wants to do. The user can indicate particular preferences by selecting one label (e.g., time, cost, convenience) or leave it to the system in which case all labels are integrated in the evaluation with appropriate weighting according to the beliefs the system has on preferences of the user (see preference component). In the navigation part, the system shows the real-time position of the user based on GPS and provides directions for further steps. Whenever schedule conflicts or opportunities arise or are to be expected, the system gives alerts and guidance on that level.

Preference component

The preference component probably is the most distinctive feature of the system. Adopting a utility-based model of choice behaviour, essentially, user preferences are internally represented as weights of attributes of trips and activity patterns. The preferences are incorporated in generalised link costs functions for transport networks so that standard least-costs algorithms can be applied to find an optimal path through the network. Since the network is generally represented as a supernetwork of different modalities, link costs functions are also specified for transfer links (see below). The generalized cost functions are dynamic and are updated each time a change in the state of the traveller causes a change in his/her preferences for travel options (e.g., carrying bags after a shopping activity increases perceived costs of walking/ transferring). The cost functions are personalised based on the system's estimates (beliefs) of personal preferences. Dynamic information such as waiting times, effort and inconvenience involved in transfers can be represented in the generalised cost functions associated with transfer links and, hence, can be taken into account when searching for an optimal path for a multimodal trip.

On a more fundamental level, preferences are dynamic in the sense that they are conceptualized as beliefs the system has of the user at a current moment in time. These beliefs are updated each time the user makes a choice regarding travel options or schedule adaptations by using belief updating in the context of the Bayesian Belief Network.

Scheduling component

It is important to emphasize that adequate travel information and advice should be consistent with scheduled daily activities and should fit a set of general constraints underlying such scheduling behaviour. Thus, a personalised information system should give suggestions regarding the sequence of activities and the locations where they are conducted, consistent with the personal perceptions and needs of the traveller.

During execution of an activity schedule, unforeseen travel times (e.g., delays) or activity durations (e.g., a meeting went on longer than expected) or unplanned activities (e.g., bumping into a friend and go to a café) may necessitate or evoke a wish to revise an existing activity schedule. The anticipated system will identify time conflicts, brings them to the awareness of the user and presents suggestions for schedule adaptations taking into account user preferences and constraints imposed by the current space-time environment and activity program. Furthermore, the system will monitor opportunities for re-scheduling whenever they arise given real-time information or changes in a route or activity plan.

System consequences

One of the motivations for developing personalized travel information systems is to induce travel behaviour that is environmentally friendly. By using such systems travellers may become increasingly aware of the environmental impacts of their behaviour and therefore act more responsibly. Another functionality of the system therefore is that the environmental impact of their behaviour is calculated and fed back to the user. Recommendations are also cast in these terms. The system consistently provides feedback on environmental friendliness of travel behaviour of the user. Key pollutants assessed by the system for each trip made are the amounts of CO_2 and PM produced. Using general standards for emissions the quantitative information will be complemented with a quality label. Whilst it is considered essential that environmentally sensitive behaviour is a reward in itself it is considered that as a short term incentive that an award system is offered to encourage such behaviour where there is evidence of sustained effort to reduce the environmental footprint made by choice of transport, this may be offered in a number of forms including concert tickets. A consequence of a reward scheme is that the user's give consent to the system maintaining a record of the user's behaviour in terms of these pollutants..

Another key functionality in this section is that the system takes into consideration the possible influence of route guidance itself to users. To avoid frustration of in particular public transport users, the system anticipates on traffic conditions under influence of route guidance that users will or are expected to receive (from i-Tour or other systems). It is key therefore to develop and include a validated model of compliance behaviour that takes into account possible strategic behaviour of a traveller (e.g., declining an advice because everyone else may follow the same advice and the location/route will be crowded).

AVAILABLE KNOWLEDGE

The new generation of ITS – Intelligent Transport Systems and Services – allow the integration of information and communication technologies with transport infrastructures, vehicles and users. By sharing vital information, ITS allow people to get more advantages from transport networks in terms of greater safety and with reduced impact on the environment. Progress made in this area of research and development can be used as the knowledge base of such systems.

1. Modelling of multi transport system

Over the years, the methodology for modelling multimodal transport systems and planning multi-modal routes has been well-developed. As indicated, a supernetwork approach has been suggested to integrate different physical networks. Arentze and Timmermans (2004) have developed a methodology to specify generalized costs of links in a supernetwork as a function of an individual traveller's state which changes as execution of an activity schedule progresses. Liao et al. (2009) have extended this approach and more importantly have demonstrated the possibility of fast algorithms to find optimal paths in these complex networks. A specialized supernetwork will be employed as a method to construct integrated transport networks. Multi-criteria cost functions of links will reflect users' evaluation of different trip and route attributes.

2. Stated choice and adaptation experimental design methods

Personalized systems require information about personal preferences. Stated choice experiments, which have a long tradition in transportation and consumer research, can be elaborated to provide such information in the context of multimodal systems. Although this specific application will increase the complexity of the approach and require creativity and sophistication, it is to be expected that methodologies to optimize experimental designs, to (visually) present choice alternatives and to estimate discrete choice models based on recorded choices that are well-developed can be elaborated and applied for the present purpose. Challenges relate to the questions how the choice task can be designed such that it is entertaining for users and which attributes of travel alternatives and situational conditions are relevant to attain the objectives of the mobility system. Travel simulators developed in this context (e.g., Chorus et al. 2006, Sun et al. 2005 and Arentze et al. 2008) offer interesting possibilities and have been used to reveal behaviour of travellers in artificial space-time settings. Stated adaptation experiments have a shorter tradition but are receiving increasing interest recently in travel behaviour research (e.g. Arentze et al. 2003, Nijland et al. 2006, Roorda et al. 2007). These studies also show how data collected can be analyzed in the framework of a utility-based activity re-scheduling model.

3. Bayesian estimation and incremental learning methods .

Bayesian techniques of parameter estimation and incremental learning are well-established and have been applied in the context of information systems to improve a system's ability to provide tailored information to individual users. A good example is MUSE developed by Orzechowski et al. (2008). This system allows lay users to design their own residential house. Using principles of Bayesian learning, the system learns about the user's preferences while he or she makes choices in the process of designing the house and, hence, is increasingly better able to provide tailored design-support information and advice.

4. Modelling of activity schedule generation and adaptation

The scheduling of daily activities - including travel - has been extensively studied in travel behaviour research since the introduction of the activity-based approach to travel demand modelling. Existing approaches, however, focus primarily on the analysis and prediction of individuals travel behaviour (descriptive) and, in that sense are not necessarily suitable for an information service that is more concerned with optimizing activity-travel choices (prescriptive). Nevertheless, several approaches described in the literature are of interest for prescriptive purposes as well. Charypal et al. (2005), Meister et al. (2005) and Balmer et al. (2007) developed the MATSIM model. This model uses a genetic algorithm to generate daily activity schedules of travellers in a simulation, given a fitness function representing the travel and activity preferences of these agents. Timmermans et al. (2001), Joh et al. (2004) and Arentze et al. (2005) developed the Aurora model which uses a more dedicated heuristic to generate daily activity schedules of travellers. Their approach is particularly interesting here for several reasons. First, their heuristic is computationally very efficient and, hence, would meet user and system constraints of a mobility system. Second, the model is able to generate solutions for re-scheduling problems (i.e., adaptations of an existing schedule) as well as for scheduling problems. Third, the model assumes utility functions that can represent subjective preferences for schedule adaptations as well as for travel and activity alternatives.

CONCLUSIONS

Although travel information system have been advocated as contributing to the alleviation of congestion and other environmental problems, the overall interest of the industry and the public at large has been very limited. For long, the travel industry has not look positively at such systems as a business case. However, this scene is gradually changing. Although one may speculate about the reasons for such change, it seems that discussions on climate change and energy have articulated the need for more forcefully try of new technologies. Moreover, now that standard navigation tools have started to reach their satiation levels in many countries, there is a natural need for these companies to add value and expand their services. Finally, modern information and communication technology, moving to ubiquitous environments, allow the shift in principle from static information provision to interactive, dynamic recommendation systems.

Ultimately, the acceptance and use of this new generation of travel information services depends on the value it offers to consumers. It is argued that value in this context depends on (i) the contents, (ii) the accuracy and (iii) the personalization of the services. While some of this functionality is primarily a matter of organization and logistics (e.g. dynamic data warehousing and exchange protocols), other components depend on our ability to successfully model consumer response to new technology and compliance to recommendation, combined with model destination and route choice or even comprehensive (re-)scheduling of activity-travel behaviour in uncertain multi-model transportation environments.

The academic literature on these issues is still relatively scarce and it seems a long way from such basic research to the implementation of related technology in daily life. However, we have briefly argued in this paper that the basic tools and models have been developed over the last couple of years and can be integrated and tested in real-world settings. The project discussed in this paper is an attempt to bring the pieces together. Time will learn whether these components can be successfully developed into a personalized learning system and whether such system will help in alleviating environmental problems caused by transport.

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