Use and Effects of Advanced Traveller Information Services (ATIS): A Review of the Literature

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(Received 27 April 2005; revised 26 July 2005; accepted 1 September 2005)

ABSTRACT Rapid technological developments in the field of personal communication services probe visions of a next generation in Advanced Traveller Information Services (ATIS). These technological developments provoke a renewed interest in the use and effect of such next-generation ATIS among academia as well as practitioners. To understand better the potential use and effects of such next-generation ATIS, a thorough review is warranted of contemporary conceptual ideas and empirical findings on the use of travel information (services) and their effects on travellers’ choices. This paper presents such a review and integrates behavioural determinants such as the role of decision strategies with manifest determinants such as trip contexts and socio-economic variables into a coherent framework of information acquisition and its effect on travellers’ perceptions.

Introduction

Providing travellers with relevant information on travel options is generally acknowledged as having the potential to change their behaviour in ways that are beneficial to the efficiency of the use of the transport system (e.g. Koppelman and Pas, 1980; Kanninen, 1996). Services providing such information (Advanced Traveller Information Services, ATISs) are widely available nowadays for travellers, and are becoming more advanced every year. Recently, rapid technological developments in mobile communications have provided a vision among telecommunication companies, transport agencies, governments and academia of a technological revolution in ATIS towards what can be called the next-generation ATIS (e.g. Adler and Blue, 1998; TRAIL Research School, 2002). Such ATISs are envisaged to be able to provide at anytime a traveller with all the travel information, asked for and unasked for, that is relevant given his time and place in the multimodal transport network and his personal characteristics. Currently, policymakers in many Western countries have high expectations of the potential effects of such information services on, for example, network efficiency (e.g. European Commission, 2001a, b; Ministry of Transport, 2002; Transportation Research
These expectations provide an interesting momentum for research and development efforts aimed at designing this next-generation in ATISs as well as policy initiatives that aim at optimal use and effects of such ATISs.

This momentum provides opportunities for many players in the field of personal mobility and information provision. First, public transport companies may consider the provision of next-generation ATISs as a means to retain or attract customers. A comparable argumentation goes for the automotive industry, where built-in information services become increasingly more common. Second, providers of personal telecommunication services in general or travel information in particular may find the development and implementation of next-generation ATISs an interesting business case, depending on the traveller’s willingness to pay for these services. Third, policy-makers that in some way wish to induce changes in travellers’ choices for departure times, routes and travel modes may hope that the introduction of next-generation ATISs will, more than current ATISs, cause such adaptations to occur. Finally, as academia has been greatly interested in the role of travel information and services in traveller decision-making, it is expected that this interest will most certainly apply for the next generation in travel information services. Central to all these perspectives, two categories of questions arise: What will be the level of use of next-generation ATISs? And what will be the effect of information provided through next-generation ATISs, once used, on a traveller’s choices?

Although next-generation ATISs’ functionality reaches beyond that of most currently available ATISs, a conscious interpretation of the abundant body of the literature concerning ATIS use and effects that has been established over the last 15 years may provide an important first step in the understanding of its potential usage and effect. This body of the literature takes the form of either empirical results, such as notable contributions by Polak and Jones (1993), Emmerink et al. (1996), Khattak et al. (1996), Polydoropoulou and Ben-Akiva (1998), Hato et al. (1999) and Denant-Boèmont and Petiot (2003) or conceptual frameworks such as those presented by Bovy and Stern (1990), Ben-Akiva et al. (1991), Schofer et al. (1993), Walker and Ben-Akiva (1996) and Kenyon and Lyons (2003). Where the empirical work mostly focuses on the study of the use and effects of current information services given all sorts of manifest determinants such as trip purpose and socio-economic characteristics, the conceptual contributions predominantly take a rather behavioural perspective, identifying the role of latent determinants such as decision styles and knowledge levels in the process of information use and effects. On the threshold of an area in which a new generation of travel information services is introduced, a review of academia’s recent empirical and conceptual contributions to one’s understanding of travellers’ decision-making in the presence of information is warranted, in order to learn lessons concerning the potential of future ATISs.

This paper presents such a review of both the empirical and the conceptual literature concerning the use and effects of travel information. It contributes to the literature by integrating the conceptual and empirical findings of more than 15 years of research regarding ATIS use and effects and summarizing these in coherent frameworks that appear to be consistent with several dominant theories on traveller behaviour. Designers of next-generation ATISs as well as transport policy-makers might apply some of these findings in order to derive technical or functional requirements of optimal services or to help them estimate the potential levels of use and effects of services that are being developed. Note, however, that
this paper itself does not aim to present a state of the practice regarding technical development and the implementation of next-generation ATISs and their prototypes, or at deriving implications for the design of ATISs or related transport policy. Rather, a behavioural focus is adopted that aims to identify important determinants of the levels of use and effects of next-generation ATISs in general.

Although throughout most of this paper the general term of ‘travel choices’ has been applied, the focus is on literature regarding an important subgroup of travel choices: departure time, route and mode choice. It is expected that as well as these choices, next-generation ATISs might also have an impact on a traveller’s destination choices and activity patterns, and that the framework developed here might assist in an understanding of those impacts. Furthermore, note that this paper has been concerned with day-to-day pre- and in-trip information use and effects. The acquisition of next-generation ATISs as a device or service, however, would also be an interesting subject of research. Finally, note that the short-term or direct effect of next-generation ATISs on a traveller’s behaviour is studied. Through primary learning there may also be an indirect effect that may in the long-term influence next-generation ATISs’ use and effects. Such effects may be analysed using extensions of the framework presented here.

The paper is organized as follows. The second section reviews theoretical and empirical literature concerning information acquisition among travellers and integrates them into a conceptual framework. The third section reviews studies concerning travellers’ perception-updating as a direct effect of travel information and it presents a framework that depicts travel information acquisition and effects as an iterative process. The fourth section draws conclusions and points towards further research efforts needed in order to understand more fully travel choice-making in the presence of next-generation ATISs.

Information Acquisition

The paper will focus on pre-decisional acquisition of travel information, defined here as information acquisition that is performed before a travel choice is made, with the purpose of supporting the making of this travel choice. It is this type of information acquisition that is of most interest to policy-makers, as the expected impact of acquired information for the purpose of making travel decisions is likely to be higher than that of information acquired for other purposes, such as post-decision information use. A traveller, after having decided to travel by train, may still need information in order to find out the exact time, and on what platform, to board the train. Note that pre-decisional as such does not necessarily imply pre-trip. The paper will also distinguish here between active information acquisition (information search) and passive information acquisition (the use of information provided). This way, two combinations of these forms of information acquisition may be identified: first, a traveller may first decide to search for information (active acquisition). After he has found it, he must subsequently decide whether or not to use the information he provided himself (passive acquisition). Second, an information service may provide a traveller with information unasked for. A traveller must then only decide whether to use the information he is provided with (passive acquisition). Pre-decisional information acquisition can either aim at the generation of alternatives, i.e. adding alternatives to the traveller’s choice-set, or at assessing the alternatives that are already in his choice-set. Understanding an individual’s pre-decisional information acquisition therefore
follows from understanding the strategy he uses to generate and assess alternatives: this will be called his decision strategy. Arguing the other way around, the decision strategy an individual has adopted is often manifested through his search for and use of available information. Note that the term ‘decision strategy’ is used here with a somewhat different meaning than decision-making. The latter refers to the entire process that the individual follows when choosing between alternatives, while the former refers to the assumed goal of this process and the amount of effort that the individual puts into trying to achieve this goal. It is clear that when discussing the acquisition of travel information, this must be done in the light of dominant theories of traveller decision strategies. This section will therefore commence by presenting an overview of theories that have proven to be useful and important in current travel demand literature (for a more extensive overview, see Gärling et al., 1998; Svenson, 1998; and Stern and Richardson, 2005), and by discussing the role of information acquisition in each of them. Subsequently, empirical findings concerning actual information acquisition among travellers are presented and discussed. Together, this leads to the formation of a behavioural framework of travel information acquisition.

Dominant Theories on Travellers’ Decision Strategies and Information Use

Maximization. The dominant perspective on travellers’ decision strategies is that of microeconomic consumer theory (e.g. Samuelson, 1947). The individual is assumed to be an instrumentally rational agent who performs an exhaustive assessment of alternatives, exploring each alternative’s relevant attributes and trading off the utilities derived from them. The decision strategy serves to generate a choice from a choice-set for the alternative that provides the individual with a maximum pay-off. When choices are made under uncertainty, this pay-off is mostly defined through the concept of maximum expected utility (Von Neumann and Morgenstern, 1947), although other preference measures are also applicable. This view is often extended by including so-called transaction costs (Coase, 1937, 1960), representing the often intangible costs of decision-making and information acquisition preceding the actual moment of choice. Today, practically every study on travel demand that does not explicitly adopt another perspective on decision-making implicitly adopts principles of utility maximization. Note that this utility maximization framework only deals with the assessment of already available or specified alternatives and not with alternative generation. Often, it is simply assumed that the decision-maker knows all the alternatives from which he can choose. Microeconomic search theory, however, applies the principles of utility maximization to the situation where an individual performs a sequential search for alternatives as well as an assessment of the alternatives generated, and can provide one with insights regarding this alternative generation process (e.g. Manski, 1977; Weibull, 1978; Richardson, 1982). In such a sequential search process, apart from transaction costs, the cost of rejecting the most recently searched-for alternative can also be included. Such costs may be traded-off against the expected utility to be derived from the next found alternative. The alternatives found are mostly assumed to be subsequently assessed following the principles of utility maximization. Several notions of microeconomic search theory can be found in travel demand studies (e.g. Richardson, 1982; Williams and Ortuzar, 1982; Lerman and Mahmassani, 1985; Swait and Ben-Akiva, 1987; Polak and Jones, 1993; Ben-Akiva and Boccara, 1995; Arentze and Timmermans, 2005a, b). There is one important difference between the application of utility
maximization principles for alternative assessment and for alternative generation: utility maximization for alternative assessment deals with choosing from alternatives, while its application on alternative generation in addition to this also deals with choosing from decision strategies (should one proceed or stop searching?). Choosing a search strategy by applying utility maximization principles, the individual may well end up with an alternative with suboptimal utility because the costs of searching are also taken into account in the decision strategy. Utility maximization principles are thus applied at different levels.

Although the application of principles of utility maximization has provided many valuable contributions to the research on individual choice (e.g. McFadden, 1974), as well as travel choice (e.g. Ben-Akiva and Lerman, 1985), researchers in general agree that its assumption of trade-off and maximization behaviour may form a less realistic representation of the actual behavioural process the individual performs (e.g. Edwards, 1954; Simon, 1955, 1978a, b; Kahneman and Tversky, 1979, 1992; Hargreaves Heap et al., 1992; McFadden, 1999). This agreement is shared with many researchers of travel demand (e.g. De Palma, 1998; Gärling and Young, 2001).

Satisficing. A dominant critique on the validity of utility maximization principles as a base for individual decision-making was formulated by Herbert Simon, who introduced the perspective of bounded rationality (Simon, 1955, 1978a, b). According to Simon, people cannot be assumed to have either the wish or the capability to perform extensive search processes and thoroughly assess the alternatives found. A perspective on decision strategies that does not make such strict assumptions is that of satisficing behaviour (Simon, 1955); the individual is assumed to be searching for the first alternative that is good enough, i.e. he has certain aspiration levels for relevant attributes of alternatives – these levels may change over time – and searches for an alternative that meets these standards (Olander, 1973). Bounded rationality is often called procedural rationality, representing the idea that most decision-making is performed using simple ‘rules of thumb’ (e.g. Hey, 1982; Johnson and Raab, 2003). An essential consequence of this perspective is that choice between alternatives, and with this choice also the generation and assessment of alternatives, is generally not driven by a determination of the agent to use information in order to maximize some form of pay-off. Instead, a pre-decisional information search is performed to end up with an alternative of which relevant attributes meet the aspiration level set for that attribute. Notions of bounded rationality and satisficing behaviour can be found in several travel demand studies (e.g. Foerster, 1978; Mahmassani and Chang, 1987; Mahmassani and Jayakrishnan, 1991; Schofer et al., 1993; Van Berkum and Van der Mede, 1993; Emmerink et al., 1995, 1996, Gärling et al., 2002).

Habit execution. As a third perspective, parallel to the ones describing decision-making as a more or less conscious process, it is often argued and shown that many of the choices individuals repeatedly make are a consequence of the execution of a habit (e.g. Triandis, 1977; Hodgson, 2004), being defined as a repetition of past behaviour without deliberating or forming an intention. Since no actual decision is made in the sense of generating and assessing alternatives, habitual behaviour is often not regarded as decision-making. Although the past behaviour on which habitual behaviour is based was an actual decision, and could well have been optimal when it was first performed, a suboptimal situation may arise as changes concerning alternatives and situations are not observed by the individual because
he does not consciously make his decisions. Pre-decisional information acquisition is virtually non-existent in habitual behaviour (Aarts et al., 1997; Verplanken et al., 1997). Ample recent empirical studies on travel demand have pointed towards the role of habitual travel behaviour in the making of travel choices, especially mode choices (e.g. Aarts et al., 1997, 1998; Aarts and Dijksterhuis, 2000; Fujii et al., 2001; Fujii and Gärling, 2003; Fujii and Kitamura, 2003; Schlich and Axhausen, 2003).

Effort–accuracy trade-off. From the field of behavioural decision theory a perspective on decision-making originated that is often seen as an extension of bounded rationality, but that in fact incorporates several perspectives on choice-behaviour: the individual is assumed to select a decision strategy based on an effort/accuracy framework (Payne et al., 1993, 1996). When choosing between alternatives, an individual first chooses a decision-strategy based on a trade-off of both the perceived effort and perceived accuracy of different decision strategies ‘available’ to him (Chu and Spires, 2003). Often, making decisions based on a careful trade-off of utility derived from attributes of alternatives (i.e. compensatory strategies) is not the selected decision strategy, and non-compensatory strategies such as satisficing (Simon, 1955) or some variant of lexicographic choice1 (Tversky, 1972) are performed instead. Only when there exists a need for and a possibility of achieving highly accurate choice-outcomes will the costs of extensive search for and use of information be accepted by the decision-maker (for a study on the effects of accountability on information search, see Huneke et al., 2004). In other cases, it is more likely that decision strategies are used that are only boundedly rational, including less extensive information search and use. Furthermore, different individuals facing the same choice-situation may perform different strategies. In recent travel demand research, explicit notions of this framework are not very widespread (for examples of the application of this framework, see, for example, Gärling et al., 1998, 2001, 2002; Svenson, 1998; Fujii and Gärling, 2003). Note that this effort–accuracy framework implicitly deals only with the assessment of already available or specified alternatives (Swait and Adamowicz, 2001) and not with alternative generation, while both processes should be taken into account when studying decision-making and information acquisition (Smith, 1991; Posavac et al., 2003).

A central notion: pre-decisional information acquisition as a cost–benefit decision. In our opinion, all the theories above, although they differ widely in their description of choice-strategies, have in common that the use of information, be it for alternative generation or assessment, is framed as a cost–benefit decision.2 The costs of information acquisition are a function of price and usability of the information service and characteristics of the travel situation at hand. They may include a number of tangible and intangible costs, such as monetary costs, time (for a study concerning travel choice-making under time pressure, see Stern, 1999), effort, irritation, attention and the risk of foregoing any already found alternative (Simon, 1978a; Weibull, 1978; Shugan, 1980; Richardson, 1982). The benefits of information acquisition result from the fact that information may help a traveller achieve his goal, as manifested in the decision strategy he applies. For maximizers, benefits may thus lie in the potential of information to help them choose the alternative with maximum pay-off. Satisficers may derive benefits of information acquisition as it may help them choose a ‘good enough’ alternative. Habitual travellers may find some benefits in information when they want to have their habitual option confirmed in changing travel circumstances, although such will be not be the case
very often. Obviously, this cost–benefit perspective is congruent with the general idea of an individual’s trade-off of effort and accuracy.

Generally, information benefits are a function of the decision strategy followed by the individual together with his perceived knowledge level, the availability of attractive alternatives and the quality of the information service. More specifically, information is beneficial to the traveller only to the extent that he feels that his current knowledge is insufficient to make the right choice. Note that two travellers with the same levels of knowledge but different decision strategies may have completely different perceptions of their lack of knowledge (Huneke et al., 2004). Further conditions for information acquisition to be perceived as beneficial are that the alternatives about which information is available are perceived as potentially attractive and that the service is perceived to be resourceful and delivers relevant and reliable messages. A number of studies in the field of travel demand analysis have, in one way or another, adopted the idea of information acquisition as a cost–benefit analysis (e.g. Ben-Akiva et al., 1991; Polak and Jones, 1993; Schofer et al., 1993; Bonsall, 2001; Yang and Meng, 2001; Golledge, 2002; Denant-Boèmont and Petiot, 2003; Khattak et al., 2003; Arentze and Timmermans, 2005b; Sun et al., 2005). Given this view on information acquisition, it appears logical that travellers sometimes do not engage at all in a search for travel information in response to uncertainty they face, but rather use another tactic to deal with their lack of knowledge (Gemünden, 1985; Lipshitz and Strauss, 1997; Bonsall, 2004). For example, a traveller may decide simply to acknowledge his lack of knowledge when choosing, instead of trying to reduce it, by taking a guess and knowing he may guess ‘wrong’ (for the case of alternative generation, see, for example, Johnson and Raab, 2003; for the case of alternative assessment, see Bonsall, 2004). Also, he might decide to lower his aspiration level so that the unreliability of estimates or absence of attractive alternatives does not affect him, or apply a number of other tactics when confronted with a lack of knowledge.

In order to test and concretize the idea of information acquisition as a cost–benefit trade-off within the boundaries of a traveller’s decision strategy, the following subsection considers against findings of studies that tried to identify manifest determinants of ATIS use.

Empirical Findings on Manifest Determinants of ATIS Use

Over the last 15 years, a number of studies have tried to identify what kind of traveller would be relatively likely to search for and use travel information, in what kind of trip context, and facing what kind of travel alternatives and information services. The focus of this literature is on a variety of ATISs, such as the Internet, telephone services including mobile and Short Message Service (SMS), in-car guidance systems, Variable Message Signs, etc. It will be shown that the insights generated from these empirical studies are fully consistent with the theoretical notions on information acquisition developed above. It is also argued that the identified manifest determinants of ATIS use are in fact determinants of the behavioural factors that really drive information acquisition.

Who Uses ATIS?

What kind of traveller is relatively prone to acquire information? Literature on ATIS use in this regard mainly focuses on socio-economic characteristics. These
characteristics of the individual, however, as can easily be seen, are nothing more than indicators or proxies for the actual, behavioural determining factors of ATIS use. The literature states that male, highly educated, high-income travellers (e.g. Petrella and Lappin, 2004) are more likely than others to use travel information, as well as professionals (Emmerink et al., 1996), as groups these appear to attach greater importance to making an accurate choice (Hato et al., 1999). Travellers who have mobile phones (Polydoropoulou and Ben-Akiva, 1998; Yim and Khattak, 2002) and are connected to and make use of the Internet are relatively prone to using ATIS. These individuals can be expected to have more experience in handling information technology and therefore are likely to perceive less difficulty in using ATIS and to be more aware of the potential of ATIS, increasing its perceived usefulness. Regarding the awareness of ATIS services (Goulias et al., 2004), it was found that professionals in general, higher income and younger persons are more likely to be aware of all kinds of ATIS, as are car owners and owners of a bus pass. Chatterjee and McDonald (2004), however, found that even messages on large Variable Message Signs (VMS) above roads may only achieve awareness rates among passing car drivers of about 33%. Polak and Jones (1993) and Petrella and Lappin (2004) found that ATIS use may differ significantly across regions and countries, partly due to differences in transport systems. It has also been found that ATIS acquisition can be explained by attitudinal factors: individuals who can be characterized as control seekers and those who are technologically astute are relatively aware of (Polydoropoulou and Ben-Akiva, 1998) and prone to use (Lappin, 2000) ATIS.

Influence of Trip Purpose and Context

What trip purpose induces a pre-decisional search for and use of information? Commuter trips (Petrella and Lappin, 2004) and especially business trips (Emmerink et al., 1996; Hato et al., 1999) appear to induce the search for and use of ATIS, mainly because these are generally arrival time-sensitive trips (Polydoropoulou and Ben-Akiva, 1998; Srinivisan et al., 1999). These insights show that trip purposes that cause a highly negative attitude towards uncertainty (a lack of knowledge) induce a high willingness to engage in an information acquisition process. Expected congestion or expected volatility in travel times induces a search for and use of ATIS (Hato et al., 1999; Yim and Khattak, 2002; Targa et al., 2003; Petrella and Lappin, 2004). Travelling during peak hours in general also increases the likelihood of ATIS use (Peirce and Lappin, 2004). Longer trips also increase a traveller’s need for travel information, pre- as well as in-trip (Emmerink et al., 1996; Lappin, 2000; Yim and Khattak, 2002, Targa et al., 2003). Furthermore, the expectation of bad weather during the trip causes an increase in ATIS use (Polydoropoulou and Ben-Akiva, 1998; Peirce and Lappin, 2004). These insights show that a traveller’s willingness to engage in a pre-decisional information search indeed increases when the trip context induces a relatively high degree of perceived lack of knowledge regarding current characteristics of travel alternatives.

Travel Alternatives and Their Characteristics

How does the perceived availability and quality of travel alternatives of which the traveller is aware influence the search for and use of ATIS? Referring to the alternative the traveller plans to take, Polak and Jones (1993), Srinivisan et al. (1999) and Van der Horst and Ettema (2005) show that travellers are more likely
to search for information regarding alternatives of which they are aware, prefer or often use, than for other alternatives. Second, Denant-Boèmont and Petiot (2003), Peirce and Lappin (2004) and Van der Horst and Ettema (2005) notice that the availability of viable travel alternatives to a planned alternative was crucial to pre-decisional information acquisition. However, Chatterjee and McDonald (2004) find that still about one-half of car drivers found VMS information on incidents useful even though they considered that there were no alternative route options. Note that this latter case does not concern pre-decisional information acquisition and therefore falls outside the scope of this paper. Taken together, these findings suggest that information is actively acquired mostly for those alternatives the traveller plans to use, and is actively acquired for other alternatives to the degree they are found viable or promising for the trip to be made.

Concerning the characteristics about which information might be acquired, it has recently been found that besides travel time and travel costs, travellers are interested in many other, often less tangible, characteristics of travel alternatives such as convenience, privacy and comfort (Hague Consulting Group, 1991; Steg et al., 2001; Thogersen, 2001; Ellaway et al., 2003; Bos et al., 2004; Anable and Gatersleben, 2005; Steg, 2005). Although it did not explicitly focus on information acquisition, this empirical literature does suggest that travellers might want ATISs to provide them with information concerning such ‘soft’ characteristics of travel alternatives.

**Influence of Characteristics of the Information Service**

Finally, what information service induces use? That is, how should an information service be designed in order to encourage use by travellers? In general, almost every study on ATIS use stresses the importance of information quality. More specifically, reliability, timeliness and coverage of the information provided is key to ATIS use (Polydoropoulou and Ben-Akiva, 1998; Hato et al., 1999; Fayish and Jovanis, 2004). Also, travellers appear to have a need for personal (Adler and Blue, 1998) and multimodal information (Polak and Jones, 1993; Kenyon and Lyons, 2003). Just as is the case for all high-tech applications (Davis et al., 1989), easy accessibility and use of the information service and good graphical design also induce greater use of ATIS (e.g. Fayish and Jovanis, 2004).3 Concerning the issue of willingness to pay, the literature generally states that there is among travellers in general a low willingness to pay for information provided through current advanced travel information services (e.g. Polydoropoulou et al., 1997; Khattak et al., 2003; Wolinetz et al., 2004), and for public transport (PT)-information among PT users specifically (Vance and Balcombe, 1997; Neuherz et al., 2000; Molin and Chorus, 2004; Molin et al., 2005), as PT users mostly feel they have already paid for information provision by buying their ticket. From a business case perspective, this is a somewhat worrying finding. Nonetheless, these findings clearly state that the expected benefits of ATIS use – as in the potential to improve the quality of choices – must outweigh the expected costs resulting from the high prices for information or difficulty using the information service, in order for the ATIS to be used.

It appears that the empirical findings on manifest determinants of information acquisition are fully compatible with the theoretical notions on behavioural drivers. Therefore, combining the theoretical ideas with the empirical findings presented above, a general framework of pre-decisional information acquisition may be constructed (Figure 1).
Figure 1. Framework on pre-decisional information acquisition
After having reviewed the contributions to the literature in the field of information acquisition, the paper will now shift attention to an adjacent field of study: that of the effect of acquired information on travellers’ perceptions.

Information Effect

It is generally acknowledged that travellers base their choices on their perception of, or beliefs regarding, reality instead of on the objectively measurable reality itself (e.g. Recker and Golob, 1976; Koppelman and Pas, 1980; Ben-Akiva et al., 1998; Golledge, 2002; Bonsall et al., 2004). It is obvious that information will not change the objective reality, but rather may affect a traveller’s perception of this reality (e.g. Bovy and Stern, 1990; Ben-Akiva et al., 1991; Khattak et al., 1993). This section will explore how travel information can update a traveller’s perceptions. When a traveller has decided to search for information and/or use the information with which he is provided, the question arises as to how he will combine this information with already existing beliefs to create new beliefs. In other words, how might travel information update a traveller’s initial perceptions of travel alternatives? A first notion to be taken into account here is that perception updating occurs only to a certain extent: a traveller may be provided with information, either through his own active search or because an information service has provided him with information unasked for. At that moment, he decides whether or not to use this information (i.e. passive information acquisition). This decision is not assumed to be a binary one: a traveller may subconsciously decide to pay attention to the information with which he is provided to a certain extent, the decision itself being determined by the traveller’s weighed expectations regarding the costs and benefits of information use (see above). The extent to which he decides to use the information forms an upper limit to the degree of updating that may possibly be achieved, based on the information provided. An upper limit, since also his mental processing ability and his perception of information unreliability may induce a further decrease in the degree to which perceptions are updated through information. There are two paths along which perceptions can be updated: first, information on travel possibilities may serve in the process of generation of travel alternatives by updating a traveller’s perception of availability (i.e. awareness) of travel alternatives, or, in other words, his choice-set. Second, information on travel costs may serve in the process of assessing the travel alternatives a traveller is aware of by updating his perception of characteristics of travel alternatives.

Awareness of Travel Alternatives and the Effect of Information

Usually, a traveller has several options from which to choose when performing a trip. Different combinations of departure time, route and travel mode may bring him from the origin to the destination within boundaries set regarding monetary costs, time and other constraints. For trips within urbanized regions, often with a dense multimodal transport system, the number of available travel options may even be very large (Ramming, 2002; Hoogendoorn-Lanser and Van Nes, 2004). Nevertheless, a traveller is usually only aware of a handful of travel options, and only considers some of those alternatives when making a choice (Bovy and Stern, 1990; Fiorenzo-Catalano et al., 2003; Last and Manz, 2003). In the case of the existence and execution of a travel habit, often only one alternative is known and
considered by the traveller (e.g. Aarts et al., 1997, 1998). Furthermore, knowledge, in the sense of the number of travel alternatives of which a traveller is aware may differ widely between individuals (Williams and Ortuzar, 1982; Cascetta and Papola, 2001). Recent studies have shown that it is therefore useful when analysing travel demand explicitly to take into account a traveller’s choice-set (e.g. Swait and Ben-Akiva, 1987; Thill, 1992; Ben-Akiva and Boccara, 1995; Swait, 2001; Ramming 2002; Hoogendoorn-Lanser and Van Nes, 2004, Cantillo and Ortuzar, 2005). Cascetta and Papola (2001) suggest the behaviouralistic idea of regarding a traveller’s choice-set as having fuzzy boundaries: travel alternatives belong to the set of perceived available alternatives to some extent.

What might be the effect of the information with which a traveller is provided and then decides to use? There seems to be, to the authors’ knowledge, no empirical study that deals with the effect that ATISs may have on a traveller’s perceptions and choices through generating travel alternatives and bringing them to the traveller’s attention. This lack of empirical literature is surprising given the potential impact of this type of information provision. However, it seems reasonable to assume that information might contribute to a traveller’s awareness in two ways. First, an alternative can be brought to his attention of which he was completely unaware. In fuzzy terminology, the degree of membership of the alternative to the set of known alternatives is increased from zero to a value larger than zero. For example, a traveller might be told that he can reach his destination by intercity bus, while he was unaware that such a service existed for a given origin–destination pair. Second, information might inform the traveller in a more detailed way about an alternative of which he was already partly aware, but did not know well enough actually to consider for choice. This is done by providing him with what might be called a ‘user manual’ for the alternative. That way, the degree of membership of that alternative to the set of known alternatives is increased from a non-zero value to a larger value. For example, a traveller that knew of the existence of an intercity bus service, but did not know where to find the nearest bus stop, might be told where he can find that stop, making the intercity bus a more viable member of his choice-set.

**Perceived Characteristics of Travel Alternatives and the Effect of Information**

The travel demand literature, as well as more generic microeconomic literature, has provided convincing evidence that an individual’s perceptions of characteristics of alternatives might differ greatly from the actual values of those characteristics (e.g. McFadden, 1999, 2001; Lyons, 2001; Zhao and Harata, 2001; Avineri and Prashker, 2003a, b; Li, 2003; Bonsall et al., 2004). Mostly, individuals overestimate positive features of chosen alternatives compared with non-chosen alternatives. Van der Steen (2004) argues that this not only can be explained through psychological insights (such as cognitive dissonance; Festinger, 1957), but also that it is highly consistent with micro-economic theory. As alternatives that are overestimated in terms of the utility that may be derived from them are more attractive on average than those that are underestimated, the overestimated ones are per definition more likely to be chosen. Furthermore, just like awareness, perceptions of characteristics appear to differ widely across the population of travellers (e.g. Jha et al., 1998; Bonsall et al., 2004). Together with the facts that perceptions of reality are forceful drivers of choices and that information may affect these perceptions rather than reality itself, this makes the formation and adaptation of
perceptions a non-neglectable issue to be dealt with in the analysis of choice-
behaviour, especially under conditions of uncertainty (Delavande, 2003; Manski,
2004) and in the presence of information.

In studies on ATIS use and effects, however, attribute perception updating is
generally not treated explicitly as a distinctive step in the decision-making
process. Rather, the effect of ATIS on travellers’ perceptions of travel times is
studied either indirectly through observing choice-adaptation (e.g. Adler and
McNally, 1994; Lotan, 1995; Jou et al., 2003; Bogers et al., 2005), or theoretically
using simulated data (e.g. Adler et al., 1993; Van Berkum and Van der Mede, 1993;
Emmerink et al., 1995; Jha et al., 1998; Chen and Mahmassani, 2004; Ettema et al.,
2004; Sun et al., 2005) or from a network perspective, where categories of
informed an uninformed travellers are created (e.g. Levinson, 2003; Lo and Szeto,
2004; De Palma and Picard, 2005). A notable exception is the study by Zhao and
Harata (2001), who found that travellers’ perceptions of actual travel times under
conditions of provision of travel times by ATIS may be represented by a linear
function of the ATIS’s message, with a positive intercept and $\beta$. This indicates that
travellers do not completely rely on messages received, but rather use them in a
conservative updating process. In the absence of other relevant empirical litera-
ture on the topic, the remainder of this section reviews studies on the updating of
perceptions through travel information mainly from a theoretical approach.
Although the main focus of recent theoretical studies on perception updating has
focused on the updating of perceived travel times, most of the basic ideas and
gained insights are applicable to a number of characteristics of travel alternatives
(costs, number of interchanges, departure times, etc.). These perceptions can be
argued to be stochastic variables, as the individual has limited confidence in his
estimates regarding the characteristics of travel alternatives. However, most
theory concerning the updating of travellers’ perceptions treats them as determin-
istic variables, applying views consistent with information integration theory (e.g.
Anderson, 1981; Einhorn and Hogarth, 1981). For example, Horowitz (1984) and
Ben-Akiva et al. (1991) consider perception updating as a process of weighted
averaging of initial perceptions and a new experience/the uptake of travel
information. Although such a view has provided valuable insights regarding
information potential (e.g. Adler et al., 1993; Van Berkum and Van der Mede,
1993; Emmerink et al., 1995), it remains incomplete by not reflecting the stochastic
nature of perceptions.

A perspective that does treat perceptions as stochastic variables is that of the
decision-maker as a Bayesian updater (Raiffa and Schlaifer, 1961; Edwards et al.,
1963): an individual has a prior perception of a characteristic, represented by a
probability distribution. Using Bayes’ rule, he uses new information to update
this prior distribution into a posterior distribution that becomes his updated
perception. The degree to which the prior perception is updated depends on the
individual’s perceived unreliability of his initial estimates and the perceived reli-
ability of the new information. Recently, this perspective has been adopted in
activity–travel studies. First suggested by Kaysi (1991) as a potentially fruitful
perspective to analyse travellers’ updating of travel–time perceptions, Bayesian
travel–time perception updating was empirically introduced by Jha et al. (1998)
and Chen and Mahmassani (2004). The updating of the attributes of travel
destinations using a Bayesian Belief Network was introduced by Arentze and
Timmermans (2005a, b). As the attributes of a destination represent the possible
activities that can be performed at that destination, this latter application can also
be seen as the updating or extension of choice-sets. Note that the assumption of the individual being a Bayesian updater, although extensively used in microeconomics, has a limited behavioural validity in some situations due to the assumed high degree of information processing capability, in particular an individual’s way of dealing with conditional probabilities (e.g. Phillips and Edwards, 1966; Tversky and Kahneman, 1974; El-Gamal and Grether, 1995; Avineri and Prashker, 2003b). However, the authors feel that the application of Bayes’ law of conditional probabilities concerning variables that may be represented as continuous, rather than discrete, stochasts reduces to such elegant and intuitive formulations that these may provide behavioural realistic representations of human behaviour. It may therefore be expected that notions of Bayesian updating will better represent the effect that travel information may have on a traveller’s perceptions of characteristics of travel alternatives than treating these perceptions as deterministic variables.

Information Acquisition and Perception Updating as an Iterative Process

As discussed above, travel information may increase a traveller’s awareness of alternatives by introducing them to the traveller or by explaining them. Also, it may alter a traveller’s perception of the characteristics of travel alternatives. Next to these two main updating mechanisms, travel information potentially has two secondary impacts on a traveller’s perceptions. First, it may influence a traveller’s perception of the trip context, more specifically his perception of the complexity of the choice-situation, as good information may explain and compare travel alternatives, and present them in an understandable format. Such a reformatting of the choice-situation may substantially reduce its complexity in the eyes of a traveller, especially in the case where a traveller faces a dense multimodal transport network.4 Second, travel information may influence a traveller’s perception of the degree of incompleteness of his knowledge by providing him with travel alternatives and estimates of their characteristics.

Given these four mechanisms, it can be seen that the acquisition of travel information may lead to further information acquisition. First, alternatives brought to the attention of a traveller might be evaluated as promising, which will increase the perceived benefits of further information acquisition concerning their characteristics. Second, the updating of perceptions regarding the characteristics of those alternatives of which the traveller was aware might make these alternatives more (or less) promising in the eyes of the traveller. This change in the degrees to which a traveller finds alternatives promising also influences the benefits he may expect to derive from further information search concerning their and other alternatives’ attributes. Third, as good information might reduce the complexity of the choice-situation a traveller perceives, the expected costs of further information acquisition will decrease. Such might, for example, be the case when a complex multimodal network is reduced by an information service to two attractive alternatives. Fourth, relevant and reliable travel information will reduce the incompleteness of knowledge a traveller perceives, reducing the benefits he expects to derive from repeated pre-decisional information acquisition. These four mechanisms together determine whether additional pre-decisional information will be acquired.

Given these ideas, the following iterative decision scheme can be presented for a traveller’s acquisition of travel information (Figure 2). Facing a travel situation,
a traveller forms perceptions of the trip context, the information services available, his own knowledge, and the availability and characteristics of travel alternatives. Based on these perceptions, he subsequently forms expectations regarding the costs and benefits of pre-decisional information acquisition in order to decide whether or not to engage in pre-decisional information search or use. If he decides to do so, the information might lead to an updating of perceptions. As discussed above, this update may possibly trigger a repeated search for or use of information. This loop continues until the moment where a traveller finds that based on his expectations of costs and benefits of information acquisition, further information acquisition will not be beneficial to him. At that moment, he will make his choice for a travel alternative, choosing from the alternatives of which he is aware, based on their perceived characteristics and using the type of evaluation mechanisms that fit the decision-making strategy he has adopted.

Between the moment of making the travel choice and executing the choice, additional information might be acquired, called here ‘post-decisional information acquisition’. This information may serve to help the traveller execute his choice or plan his activity schedule. Take, for example, the situation where a traveller who has decided to go by train needs to know on what platform his train is standing, or the situation where a traveller who has decided to go by car may want to estimate his travel time in order to tell his family at what time he will be home and whether or not he will have time to do shopping on his way home. At least theoretically the information provided to a traveller after he has made his choice might again update his perceptions in such a way that he subsequently feels the need to engage in a pre-decisional information search or even to change his choice. After this potential loop is iterated until the moment where no pre- or post-decisional information is needed by the traveller, he will execute his choice.
From that moment on, the transport system may show its dynamic nature, e.g. by the occurrence of unexpected delays or congestion. Also, a traveller’s perception of travel alternatives may alter as he notices, for example, underway that the road on which he is situated is blocked. These changes in the transport system or in a traveller’s perceptions potentially lead to a new process of pre-decisional information acquisition.

Conclusions

This paper signals the development of a next generation in ATISs potentially resulting in mobile, multimodal, dynamic and personal travel information services. It is argued that a review of current conceptual frameworks and empirical findings regarding information use and effects is warranted to gain insights into the potential use and effects of this next-generation ATIS. This paper presents such a review, and therefore provides insights concerning the determinants of optimal levels of use and effects of next-generation ATISs for ATIS designers and transport policy-makers.

Based on a review of general theories of individual decision-making and information acquisition, a framework was first developed that can be used to explain the acquisition of travel information. This framework regards pre-decisional information acquisition as a direct derivative of the decision strategy a traveller uses, which makes the framework consistent with a multitude of perspectives on travel behaviour. It states that the decision to acquire information is based on a traveller’s weighed expectations of costs (in terms of, among other things, time, effort and money) and benefits (in terms of the information’s potential to help the traveller make the ‘right’ choice given his strategy) of acquiring the information.

A review of the empirical literature concerning ATIS use makes concrete this theoretical notion of information acquisition as a cost–benefit decision. Several interesting findings concerning the manifest determinants of ATIS use are identified. Concerning socio-demographics, there appears to be a consensus that male, highly educated, high-income professional travellers that frequently use Internet and mobile phones are particularly likely to engage in information acquisition using all sorts of ATISs. Concerning trip purpose and context, it appears that, consistent with intuition, business trips and commuter trips and arrival-time-sensitive trips in general induce higher usage levels of ATISs. The variability in the performance of travel alternatives, due to, for example, peak traffic, bad weather or long trip duration, also positively affects a traveller’s inclination to use ATISs. The literature is also in agreement with the suggestion that travellers are particularly using ATISs to be informed about their favoured mode of transport. On the other hand, the availability of viable travel alternatives other than the preferred mode also has a positive effect on ATIS use. There is indirect empirical evidence that travellers wish to be informed not only about travel times and costs of alternatives, but also about more ‘soft’ characteristics such as convenience, comfort and privacy. Besides all this, there is consensus in the empirical literature that travellers use ATISs to the extent that they perceive them to deliver reliable, resourceful and relevant information. There does exist a clear need for multimodal, personalized ATIS applications. However, the willingness to pay for travel information is generally very low and also the usability of ATISs plays an important role, which signals that travellers are generally willing only to bear very few costs in terms of effort, time and money in order to receive travel information
through ATISs. Finally, it is argued that all these empirical findings are fully consistent with the idea of information acquisition as a cost–benefit decision: the manifest determinants are in fact nothing more than proxies for the true, behavioural determinants of information acquisition through ATISs.

This paper also presents a review of the literature on the potential effect of travel information on travellers’ choices. It is argued how, once acquired, information may update a traveller’s perceptions of travel alternatives: it may make a traveller aware of alternatives and their true characteristics. Information acquisition and perception updating appear to be an iterative process. Eventually, travel information may, through the updating of perceptions, influence a traveller’s choice-behaviour. Due to the scarcity of empirical literature on the topic of the effect of travel information on travellers’ perceptions of alternatives, the developed framework on information effect is based only on theoretical work.

Based on the literature review performed, several knowledge gaps can be identified. First, it appears there is a need for theoretical and empirical studies and research tools that investigate the behavioural, rather than the manifest, determinants of information acquisition under uncertainty. For example, a rigorous mathematical formalization of conceptual ideas regarding travellers’ acquisition of information may help increase the understanding of the complex behavioural mechanisms that drive this process. Such mathematical representations are recently developed by Arentze and Timmermans (2005a, b), Chorus et al. (2005a, b) and Sun et al. (2005). Furthermore, concerning the direct effect of information on the updating of travellers’ perceptions, a serious lack of empirical knowledge exists. Insights on this issue are, however, critical in order to understand fully in what ways travel information may effect a traveller’s choices for departure time, routes and modes. The authors acknowledge the need for empirical data concerning the behavioural mechanisms behind information acquisition and perception updating in general and are currently obtaining such data through the application of advanced survey instruments, such as the travel simulator laboratories presented by Hoogendoorn (2003) and Chorus et al. (2005c), that facilitate interactive choice-experiments in a controlled but realistic transport network. It is expected that data derived from such experiments will help in obtaining some of the insights so badly needed in order to understand fully the potential of next-generation ATISs.

Acknowledgements

The authors acknowledge the valuable insights gained from discussions with Theo Arentze and Harry Timmermans. Remarks by David Banister and two anonymous referees also substantially improved the focus and contents of the paper. The paper was written in the context of the PITA programme, which is a collaboration between the Delft University of Technology and the Eindhoven University of Technology, and which is sponsored by NWO/Connekt.

Notes

1. In a lexicographic choice, the performance of alternatives concerning their most important attribute is evaluated, and the alternative with the highest score is chosen.
2. Framing elements of habitual behaviour as a cost–benefit decision may appear somewhat counter-intuitive at first. However, it may be argued that when relevant past behaviour exists, executing a habit is in a sense an economizing mode of decision-making as the costs of decision-making are practically non-existent (Gärling et al., 2001; Golledge, 2002; Gärling and Axhausen, 2003). Argued
this way, habit may be regarded as an application in extremis of the cost–benefit perspective: given both unchanged situational factors and the availability of alternative options, repeating successful past behaviour without acquiring any information is very cost-effective.

3. It may be expected, although no empirical evidence in that regard is known, that an important determinant of the usability of an information service (and therefore its effectiveness) is that it provides the traveller with information in his/her own language, especially in situations where complex information is provided, and time pressure plays a role.

4. On the other hand, the introduction of new alternatives may also increase a traveller’s perceived complexity of the situation.

References


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