Travel information as an instrument to change car-drivers' travel choices: a literature review

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This paper aims to provide insights that help transport academics and policy makers appreciate the potentials and limitations of information provision as a means to changing car-drivers' travel choices. The focus is on a modal shift from private car to public transport and changes in car-drivers' choices for departure times and routes towards a more even distribution of traffic within the available road network. These insights are gained through a review of more than 15 years of literature concerning the use and effects of travel information among car-drivers. Based on the performed review, a number of generic, integrative insights are derived, including the following: it appears that our expectations with respect to the effects of information provision on travel choices in general may be mildly optimistic, particularly for behavioural changes not involving changes in mode-choice. In the longer term, the effects of information provision, when presented to travelers in suitable formats, are likely to be somewhat stronger than the short term effects, due to learning dynamics.

Keywords: travel information, transport policy instruments, behavioural adaptation, literature review

1. Introduction

Fairly high expectations exist among transport policy-makers concerning the potential of travel information to alter car-drivers' behaviour in ways that would reduce passenger transport externalities such as congestion, fossil fuel exhaustion, noise, etc. The most often cited examples of such expected changes are modal shifts towards transit and adaptations of departure time and route choices (e.g. Commission of the European Communities, 2001; Dutch Department of Transport, 2002; UK Department of Transport, 2004; US Federal Transit Administration, 2003). Generally, this expected behavioural change, and the ultimate reduction of transport externalities caused by car-drivers, are put forward as an important motivation for governments to financially support the development and deployment of travel information services, which require enormous investments in terms of money, time and energy. Not surprisingly, a large body of academic literature has, over the last 15 years or so, investigated these expectations of behavioural change due to the provision of information. These studies provide us with a wide variety of valuable insights into the impact of the provision of specific types of information (route guidance, descriptive information, etc.) delivered through specific types of media (internet, text-messages, Variable Message Signs, etc.) on specific types of choices (departure time, route, or mode, etc.), made under specific types of contexts (habitual trips, business trips, recreational trips, etc.) in specific types of travel situations (pre- or in-trip, normal or accident conditions, etc.). One thing the separate papers in this body of literature do not do is provide an integrative, generic insight into the overall potential and limitations of travel information as a means to change car-drivers' travel choices. It is the opinion of the authors that such integrative, generic insights are needed in the arenas of transport academics and transport policy alike, as a fundament for i) academic research into the potential effects of ever more advanced travel information services and ii) transport policy initiatives involving the provision of travel information to car-drivers.

This paper aims to help provide these insights by providing a literature review of studies into the effect of providing travel information on car-drivers' choices for modes, routes and departure times. Based on this literature review, we will draw up a list of ten integrative, generic insights which may aid transport academics and policy makers to appreciate the potentials and limitations of information provision as a means to change car-drivers' travel choices along the dimensions considered here.

Due to the potential vagueness associated with terminology like 'travel information' and 'changes in travel choices', a rather extensive research specification is needed and presented here, before starting the actual review in section 2. The scope of research is specified along nine dimensions: firstly, let us define what types of travel information are considered here. Following the bulk of available literature, we consider all types of information that have been, or may be, provided to travelers pre- or in-trip, on either the performance of their current or intended travel alternative (i.e. mode-route-departure time combination) as well as on the availability and performance of other travel alternatives. Such information may for example take the form of travel time information or route-advisories displayed on Variable Message Signs, dynamic transit timetables provided through the internet, congestion warnings provided through text-messages on mobile phones, etc. We do not consider commercials. Secondly, we particularly consider information provision by a transportation agent (e.g. road authority, local or national departments of transport) with the aim of helping induce a change of travel choices in ways that are beneficial to the transport system. That is, we do not consider travel information that is provided by other actors, having different aims

(such as information provided by newspapers as a form of service to their readers). Thirdly, we focus on the choice adaptations of car-drivers in particular. Although it has been appreciated that travel information might play an important role in transit too, e.g. to retain customers or increase the efficiency of their choices in transit networks (e.g. Hickman and Wilson, 1995; Gentile et al., 2005), the majority of research and transport policy documents regarding the effect of travel information on choice behaviour focuses on car-drivers' choices, and so do we. A fourth dimension along which this research is specified is the following: we focus on three types of potential behavioural changes that are generally expected to reduce passenger transport externalities: i) a modal shift from private car to public transport and changes in ii) departure times and iii) routes among car-drivers that lead to a more even distribution of traffic within the available road network. Notwithstanding this, many of the findings presented here might also be of interest to readers interested in the effect of information on other choice dimensions such as activity schedules or destination choices. Furthermore, this paper's research is based on the notion that behavioral changes among car-drivers in terms of their mode, route and departure time-choices are often claimed to be a means towards reducing passenger transport externalities. That is, we do not focus on investigating this claim of reduction in externalities itself. Furthermore, we look into those effects of information provision that follow travelers' use of the available information. That is, we do not cover here the potential effect of information *availability per se* on travelers' choice for routes and modes, as discussed in Zhang and Levinson (2006) and Abdel-Aty et al. (1997) for the case of route choice and Abdel-Aty et al. (1996), Reed et al. (1997), Ouwersloot et al. (1997), Abdel-Aty (2001) and Benjamin (2006) for the case of mode-choice. Another specification in research scope is that we consider *empirical* literature on the *outcomes* of traveler decision-making. That is, we do not consider *theoretical* work on the topic, nor do we discuss *process*-oriented research efforts, predominantly from the field of psychology, that focus on issues like information processing and persuasion. This is not to say that we consider theoretical and process-oriented work to be of little value; rather that this choice is made for the clarity of the discussion and for reasons of space limitations. This research is also specified in terms of the sources considered: with a few exceptions, we selected, due to quality considerations, material from reviewed international scholarly journals and reviewed international conference proceedings. Finally, although the research presented in this paper may serve as an input for policy-makers who consider the provision of information as a TDM-tool towards car-drivers, it should be acknowledged that the successful development and deployment of travel information services as TDMs involves a variety of other (mainly organizational and technological) challenges that are not addressed here: we do not provide guidelines towards such a successful development and deployment of travel information strategies.

The outline of the rest of this paper is as follows: section 2 reviews the abundant body of literature available on the topic of travelers' use of provided travel information and its impact on their choices. Subsequently, section 3 provides ten integrative, generic insights that may be derived from the literature review and which may aid transport academics and policy makers appreciate the potentials and limitations of information provision as a means to change car-drivers' travel choices. Section 4 draws conclusions and gives pointers for further research.

2. Potential impact of information provision on travel choices: a literature review

2.1 Providing a conceptual framework for literature review

Let us assume that some transportation agent provides travelers with information that she hopes or thinks may help induce a change of travel choices in ways that are beneficial to the transport system. In order for such a change to occur, travelers must 1) acquire the information and 2) the acquired information must lead to the wanted behavioral change. Many travel demand studies either explicitly or implicitly frame a traveler's decision to acquire travel information and/or to change behaviour as a result of acquired information as a cost-benefit decision (e.g. Schofer et al., 1993; Bonsall, 2001; Yang and Meng, 2001; Golledge, 2002; Khattak et al., 2003; Denant-Boèmont and Petiot, 2003, Srinivasan and Mahmassani, 2003; Sun et al., 2005; Arentze and Timmermans, 2005a; Chorus et al., 2006a). We feel that this is an intuitively appealing approach, and will use it as a means to structure our literature review. Let us adopt the following notation: T represents the traveler's current chosen alternative (i.e. a mode-route-departure time combination), or an alternative that she intends to choose. T^+ stands for the goal alternative, i.e. a travel alternative which is considered by the transportation agent to have a less negative impact on the performance of the transport system than the traveler's current or currently intended choice. In our study, T^+ may differ from T in terms of the chosen mode and/or route and/or departure time. The wanted behavioral change from T to T^+ is denoted by Δ^+. Finally, I stands for the information that the transportation agent hopes or thinks will help realize the wanted choice adaptation Δ^+. Using the concept of utility as the ultimate driver of choices made by a traveler, we may conceptualize the utility of acquiring the relevant information (1) and the utility of choice adaptation after having acquired the information (2), as follows:

$$U(I) = f\left(U(T^+) - U(T); Q/K; C(\Delta^+) + C(I)\right) \quad (1)$$

$$U(\Delta^+) = f\left(U(T^+) - U(T); C(\Delta^+)\right) \quad (2)$$

Where $U(I)$ stands for the traveler's utility of acquiring the relevant information[1], $U(\Delta^+)$ stands for her perception of the utility to be derived from the behavioural change that is wanted by the transportation agent, after having acquired the information. $U(T)$ represents the utility, perceived by the traveler, of executing the intended or current travel option, $U(T^+)$ stands for her perceived utility of the transportation agent's goal alternative. The quality of the information or information service, in terms of its potential to identify the utility difference between T and T^+, is represented by Q, and the traveler's perception of her own knowledge needed to identify this utility difference is given by K. Furthermore, $C(\Delta^+)$ stands for the perceived costs of choice adaptation towards T^+, $C(I)$ represents the generalized costs of acquiring information, including monetary as well as non-monetary

[1] By *acquiring* information we mean here that the information is *searched for* (or paid attention to) by the traveler and *processed* by her, including a potential update of her perceptions.

costs[2]. The above formulations imply that the potential of information *provision* for wanted choice adaptation, i.e. its potential to fulfill conditions 1) and 2) presented above, is mainly determined through the interplay of $U(T)$, $U(T^+)$, *Q*, *K*, $C(\Delta^+)$ and $C(I)$. In words, equation (1) and (2) imply that the extent to which travel information provision may invoke behavioural adaptation in ways that are beneficial to the transport system depends on (see table 1 and 2 for a schematic representation):

a) the perceived utility of the intended or currently chosen travel option $U(T)$ and the perceived utility of alternative options (including the goal alternative $U(T^+)$);
b) the perceived own knowledge-level *K* and perceived information quality-level *Q*;
c) the perceived costs of choice adaptation $C(\Delta^+)$ and of acquiring information $C(I)$;

Table 1. Conceptualized determinants of the utility of information acquisition

$U(I)$		$C(\Delta^+)+C(I)$			
		Low		**High**	
		Q / K			
		Low	**High**	**Low**	**High**
$U(T^+)$-$U(T)$	**Low**	-	+	--	-
	High	+	++	-	+

Table 2. Conceptualized determinants of the utility of choice adaptation

$U(\Delta^+)$		$C(\Delta^+)$	
		Low	**High**
$U(T^+)$-$U(T)$	**Low**	+/-	-
	High	+	+/-

In this paper we will use these three sets of theoretical determinants of the impact of travel information provision as a framework within which findings from academic literature on the topic are presented and discussed, as it is felt that this categorization based on behavioural determinants allows for a generic, integrative review of literature. Note however, that the use and effects of travel information are acknowledged to be the result of a complex interplay between a number of determinants, including, but not limited to, the ones mentioned here. A systematic discussion like the one we propose is therefore bound to sometimes oversimplify how things work in reality. Where relevant, we will discuss findings from literature in the light of this complex interplay. Those findings from literature that in reality may relate to multiple sets of determinants are discussed under the heading of the determinant with which the relation is most obvious, those for which correspondence with none of these three determinants is directly apparent are discussed separately afterwards.

[2] Note that the utilities evaluated in equation 2 are in fact conditional on the received message. However, it may be assumed that information-providers do not want to present travelers with untrue information on purpose, making the content of messages not suitable as a policy-variable. We will thus ignore the conditionality on the content of received messages. This does not mean to say that the *format* and *type* of information are outside the scope of this study.

2.2 A review of the literature

2.2.1 Perceived utility of the intended or currently chosen travel option $\boldsymbol{U(T)}$ and of alternative options, including the goal alternative $\boldsymbol{U(T^+)}$

Let us start with discussing findings from the literature concerning the role of the performance or utility of the currently chosen or intended travel option: abundant evidence is found for the proposition that expected or actual bad performance of the current or intended alternative induces the acquisition of travel information (Khattak et al., 1996; Polydoropoulou and Ben-Akiva, 1998; Chatterjee et al., 1999; Lappin, 2000; Targa et al., 2003; Pierce and Lappin, 2004; Petrella and Lappin, 2004). Furthermore, it appears that travelers are relatively prone to change to other alternatives when information is received concerning poor performance of the intended or currently chosen alternative[3] (Mannering, 1989; Khattak et al., 1993b; Adler and McNally, 1994; Polydoropoulou et al., 1996; Polydoropoulou and Ben-Akiva, 1998; Mahmassani and Liu, 1999; Srinivasan and Mahmassani, 2003; Chatterjee and McDonald, 2004; Abdel-Aty and Abdalla, 2004; Van der Horst and Ettema, 2005; Chorus et al., 2006b). Poor performance is expected especially during peak hours, bad weather or incident conditions. Information acquisition and changing to an alternative other than the chosen or intended one is especially likely when travelers face a potential deviation from a preferred arrival time (Emmerink et al., 1996; Srinivasan et al., 1999; Pierce and Lappin, 2004), particularly the prospect of a late arrival (Mahmassani and Liu, 1999; Srinivasan and Mahmassani, 2003). Complementary to these insights, it might be expected that when travelers perceive their current or intended alternative as satisfactory, information acquisition (and the potential resulting choice adaptation) becomes unlikely. This expectation is indeed underpinned for the case of mode-choices by studies concerning the impact of providing transit information to car-drivers: Chorus et al. (2006c) found that, even when transit is considered by car-drivers as a feasible mode, satisfactory performance of the car-option is a serious barrier to transit information acquisition. Polak and Jones (1993) found that the availability of free parking reduces information enquiries by car-drivers into the bus as an alternative . In combination with the suggestion by Bonsall et al. (2004) that car-drivers are likely to underestimate the cost of driving (and overestimate the costs of riding transit), this would imply that information acquisition among car-drivers about other modes is lower than it might be given more realistic perceptions among car-drivers concerning the actual performance of their preferred mode.

Moving to the perceived utility of other travel options, it is found that, although travelers generally search for information concerning their currently chosen or preferred travel alternative in the first instance (Polak and Jones, 1993; Van der Horst and Ettema, 2005; Chorus et al., 2006c), there appears to be a need to be informed about other alternatives, e.g. through multimodal information (Polak and Jones, 1993; Srinivasan et al., 1999; Yim and Khattak, 2002; Chorus et al., 2006d). Complementary to these findings, many studies suggest that information provision on alternative routes and modes to the currently chosen or

[3] The mentioned studies focus on *travel time and reliability aspects* of performance. Note however, that Tertoolen et al. (1998) found that repeatedly and extensively mentioning to car-drivers the poor performance of the car in terms of *environmental costs* had virtually no effect on their travel behaviour. Instead of altering behaviour, car-drivers rather changed their attitudes as environmental aspects became less important to them than they were initially, which forms a classic example of dissonance theory (Festinger, 1957).

intended one does lead to more changes to these alternatives (see Khattak et al. (1993a), Polydoropoulou et al. (1996), Srinivasan and Mahmassani (2003), Dia (2003), Bogers et al. (2005) for the case of route choice and Khattak et al. (1996) and Abdel-Aty (1996, 2001) for the case of mode-choice). The perceived availability (Emmerink et al., 1996; Lappin, 2000; Chatterjee and McDonald, 2004; Peirce and Lappin, 2004; Van der Horst and Ettema, 2005) and perceived or reported quality (Khattak et al., 1993b; Hato et al., 1999; Chen et al., 1999; Srinivasan and Mahmassani, 2000; Abdel-Aty and Abdalla, 2004; Jou et al., 2005) of these alternative routes or modes is found to be a main determinant of the use and effect of travel information concerning these alternative options. Consistent with this insight is the finding that delays caused by bad weather conditions or recurrent congestion induce less route change than comparable delays due to incident congestion. The former congestion types are likely to affect the network as a whole, so the quality of alternative routes is deemed to be not much better than that of the currently chosen or intended route (Khattak et al., 1993b; Polydoropoulou et al., 1996). Note that travelers' availability-perceptions of alternative travel options may be considered a relative notion: Peirce and Lappin (2004) found that the number of times that travelers report that they could not change due to the unavailability of alternatives decreases as the delay on the current route increases.

Information acquisition concerning other than the usual mode-route-departure time combination, as well as changes to these alternatives, appears to be more likely for travelers with schedule flexibility than for those with fixed arrival times (Lappin, 2000; Targa et al., 2003). This finding can be explained as follows: greater schedule flexibility implies that alternative travel options that are attractive in terms of attributes other than time-related ones but less satisfactory than the normally chosen option from a travel time point of view become more feasible choice options. Take the situation where a tight schedule would induce a traveler to take the fast and reliable (but expensive) toll road, whereas the same traveler facing a flexible schedule might decide to acquire information about and subsequently travel over a toll-free road with longer or more variable travel time. Petrella and Lappin (2004) argue that such differences in schedule flexibility partly account for the often[4] noticed phenomenon that information acquisition and diversion to other than the usual travel alternative is more likely to occur in the evening than in the morning commute (Jou and Mahmassani, 1996; Polydoropoulou et al., 1996; Lappin, 2000; Petrella and Lappin, 2004). These findings might appear paradoxical in relation to the earlier reported increase in information use and diversion probability when schedule delays are expected. It may be interesting to note here though, that both behaviours can be considered to be driven by completely different aims: the latter type of behaviour (fixed schedule) can be seen as driven by the aim of damage control, the former (flexible schedule) more by the aim of searching for interesting opportunities.

It should also be noted that many agree upon the fact that the utility of alternative routes, and especially modes, that are suggested by travel information services depends on many more factors than their travel times and costs alone (e.g. Golledge, 1995, 2002; Abdel-Aty et al., 1996; Abdel-Aty, 2001; Chorus et al., 2006c): information concerning factors such as convenience (Lyons, 2001), accessibility (Van der Horst and Ettema, 2005) and perhaps even image (Kenyon and Lyons, 2003; Bonsall et al., 2004) is important to travelers as well. These notions are in congruence with a growing body of literature on mode-choice determinants that stresses the importance of such 'soft' modal attributes (Hague Consulting Group, 1991;

[4] Khattak et al. (1993b) and Mehndiratta et al. (2000) however, find the opposite.

Tertoolen et al., 1998; Steg et al., 2001; Thogersen, 2001; Ellaway et al., 2003; Bos et al., 2004; Steg, 2005; Anable and Gatersleben, 2005). Together, these findings provide the following picture concerning the potential of travel information as a means to induce a modal shift from private car-use to transit use: for many car-drivers, transit is perceived as a low-quality alternative, based on a mix of 'hard' (travel times and costs) and 'soft' (image, convenience) factors. It is known that the perceptions of 'hard' factors among car-drivers may be negatively biased towards transit, and positively towards the car (e.g. Bonsall et al., 2004), which might create a role for travel information services to correct these misperceptions and induce greater use of transit, as suggested by e.g. Watling and van Vuren (1993). However, as travelers are unlikely to seek for or pay attention to information concerning alternatives they perceive as low-quality, such transit information might not be acquired by car-drivers in the first place. Furthermore, as travel information predominantly concerns the 'hard' characteristics of car and transit (travel information services are hardly the ideal tool to convey image-related messages)[5], the effect of acquired information on mode choices is bound to be limited.

As a final note on the role of the perceived utility of alternative travel options on information use and effects, note that it is well recognized that information acquisition and diversion from intended or current alternatives is found to be especially likely pre-trip (Abdel-Aty et al., 1997; Lyons, 2001; Srinivasan and Mahmassani, 2003; Abdel-Aty and Abdalla, 2004; Mahmassani and Srinivisan, 2004; Geweke and Zumkeller, 2006), or in-trip near the origin (Chatterjee et al., 1999; Jou et al., 2005), or for longer trips in general (Emmerink et al., 1996; Abdel-Aty et al., 1997; Mehndiratta et al., 2000; Khattak et al., 2003; Peirce and Lappin, 2004). An explanation for these findings can be found in the notion that, on average, more feasible travel alternatives are available pre- than in-trip, more at the beginning of the trip than near the end of it, and more during long than short trips: the window of opportunity to change to feasible departure time-, route- and modal options becomes smaller as the traveler approaches her destination (e.g. Polak and Jones, 1993). Note that these findings can also be explained by pointing at the role of travelers' knowledge limitations: as the destination is approached, and for short trips in general, there is generally less expected variation in the performance of chosen travel alternatives (for the remainder of the trip) than there is before or at the beginning of a (long) trip.

2.2.2 Perceived own knowledge-level K and perceived information quality-level Q

As mentioned in footnote 1, we regard here information acquisition as the combination of the search for and processing of information. As we will see, perceived knowledge levels and information quality play a role during both these two processes.

Starting with a traveler's search for information, it is generally acknowledged that the making of complex trips induces a relatively high need for detailed information (e.g. Srinivasan et al., 1999; Mehndiratta et al., 2000), as do trips that are made for the first time (Chorus et al., 2006d). These findings are in line with what would be expected, as these latter situations imply a relatively low level of knowledge on the side of the traveler, which might be increased through information acquisition. The expectation of unpredictable traffic or travel times (Lappin, 2000; Chorus et al., 2006d) is also found to induce a higher level of need for

[5] Although it should be mentioned here that car advertisements do appear to be quite successful in conveying 'soft' factors such as image and status.

information. It should be noted however that it is the expected variability in, or lack of knowledge concerning, *pay-offs* that drives information acquisition, rather than just a variability of travel times or other attributes. That is, variability in the attributes of alternatives only leads to information acquisition to the extent this variation leads to a variation in the utilities or *pay-offs* derived from choosing the alternatives. For arrival-time insensitive trips, travel time-variability might not lead to information acquisition as this variability does not lead to a substantial *pay-off* variability. This nuance is incorporated in recent behavioral models of information acquisition and effect (e.g. Denant-Boemont and Petiot, 2003; Arentze and Timmermans, 2005a; Chorus et al., 2006e). Therefore it should be noted that the distinction we make between low expected utility of the current alternative and low knowledge levels is to some extent artificial. In order to be perceived as able to fill a traveler's knowledge gap, information must be perceived as accurate: it appears that indeed, reliability is found by travelers to be of paramount importance in their decisions to search for, or pay attention to, the available information (e.g. Polydoropoulou and Ben-Akiva, 1998; Lyons, 2001; Jou et al., 2004; Fayish and Jovanis, 2004; Bogers et al., 2005; Sun et al., 2005). As Petrella and Lappin (2004) state, it is more important to travelers that the information received is precise than that the information service has advanced features. In this light, it is somewhat worrying to see that, as found by Yim and Khattak (2002) and Chorus et al. (2006d), it is exactly in those situations where travelers perceive their own knowledge to be particularly unreliable, e.g. in the case of an accident or other incident, that information is also perceived to be particularly unreliable. Finally, there appears to be a relation between perceived knowledge levels and the type of information needed (Adler and McNally, 1994): as travelers become more experienced in a road network, their needs shift from prescriptive info ("take route A") towards descriptive info ("route A's travel time equals x, route B's equals y").

We will now move our attention to the second part of the information acquisition process, being the actual processing of received information - possibly leading to perception updating. Intuitively, it would be expected that the less knowledge a traveler thinks she has, the more susceptible she will be to update her perceptions with received information, and to potentially adapt her current or intended choice. This intuitive notion of weighed perception updating, often theoretically underpinned by applying Bayes' law of perception updating, is increasingly used in traveler behavior research (e.g. Horowitz, 1984; Kaysi, 1991; Ben-Akiva et al., 1991; Jha et al., 1998; Chen and Mahmassani, 2005; Arentze and Timmermans, 2005a, b; Sun et al., 2005; Chorus et al., 2006e). Indeed, empirical evidence is available to support this intuition. To start with, as mentioned above, the widely established fact that diversion from intended or current alternatives, after having received information, is found to be especially likely pre-trip, or in-trip near the origin can be at least partly explained by pointing to the fact that in those situations there is a relatively strong perceived variation in the performance of the chosen or intended travel alternatives than there is near the end of a trip. Due to these high levels of perceived variation, travelers appear to be relatively susceptible to updating their perceptions using received information. Furthermore, it is argued by Petrella and Lappin (2004) that greater variability of travel times during the evening commute is one of the reasons why travelers are relatively prone to switch routes after having received information (compared to the morning commute). Abdel-Aty et al. (1997) found that a high perceived reliability of the route normally taken induces a low willingness to switch to other routes under information provision. This inclination to follow received information particularly when the traveler's own knowledge is perceived as insufficient, such as in the

middle of a trip (Bovy and Stern, 1990), or in the context of trips towards destinations never visited before (Chorus et al., 2006d), implies the potential for providing information on other alternatives in these situations.

However, care should always be exercised when providing information on alternative travel options. It has been found that reporting to travelers the high performance of routes or modes other than the chosen ones when the facts don't support such information, e.g. in order to induce high short term deviations, is not a good idea. Bonsall et al. (2004), concerning mode-choice, and Chen et al. (1999), Srinivasan and Mahmassani (2000) and Jou et al. (2005), concerning route choice, all present evidence that bad experiences with choice adaptation due to inaccurate travel information on alternative options may seriously affect a traveler's propensity to adapt their choices based on received information in the future. The latter three studies found that especially underestimation of travel times appears to negatively affect this propensity. Good experiences however, do lead to a greater propensity to use travel information (Emmerink et al., 1996; Polydoropoulou and Ben-Akiva, 1998) and to comply with its suggestions (Chen et al., 1999). These findings again strongly suggest the paramount importance of information reliability, not only for the information to be searched for (as discussed above), but particularly for found information to be used in a process of perception (and choice) updating: there is abundant empirical underpinning for the suggestion that received information leads to perception and choice updates only to the extent that it is considered reliable (Van Berkum and van der Mede, 1991; Khattak et al., 1993a; Wardman et al., 1997; Fox and Boehm-Davis, 1998; Chen et al., 1999; Jou et al., 2004; Mahmassani and Srinivasan, 2004; Bogers et al., 2005). Another indication of the often suggested notion that travelers use received information and their prior knowledge of network dynamics in some form of a weighed updating process, is the empirical insight that travelers appear to be sensitive to the cause of delays reported by travel information: simply explaining the cause of a delay induces higher rates of route-switching, especially when the delays are caused by incidents (Khattak et al., 1993b; Wardman et al., 1997; Chatterjee et al., 2002). Thus, it appears that more elaborate information may lead to a higher rate of route change (Polydoropoulou and Ben-Akiva, 1998). There is a trade-off to be made here however, as travelers may not be able to comprehend long messages presented while travelling, especially when driving a car. This may hold particularly when elaborate text-messages are displayed on cell-phone displays (Dicke and de Groot, 2005). Finally, the importance of reliability is also reflected by the finding that travelers that are confronted with *ex-post* information on their chosen alternative as well as on the performance of other alternatives, are quite prone to switching in subsequent trips (Chen et al., 1999; Srinivasan and Mahmassani, 2003; Mahmassani and Srinivasan, 2004; Bogers et al., 2005): this *ex-post* information may be considered by travelers as much more reliable than information provided pre- or in-trip.

Another insight that follows from the above finding that bad experiences lead to less information use is that in the longer term travelers actually *learn* during the process of information acquisition and subsequent travel choice making. This learning concerns getting to know the dynamic nature of the transport network with the help of information services, as well as learning the potential of these information services to support choices in this network. For theoretical models of how the dynamics behind such a learning process can be described, see Avineri and Prashker (2003) and Sun et al. (2005). Where most agree that information provision *induces* learning (e.g. Van Berkum and van der Mede, 1991; Watling and van Vuren, 1993; Emmerink et al., 1996; Polydoropouluo and Ben-Akiva, 1998; Chatterjee et al., 1999; Adler, 2001; Kreitz et al., 2002; Kenyon and Lyons, 2003; Avineri and Prashker, 2003,

2006; Viti et al., 2005), some argue that travel information provision, particularly the provision of advice, may actually *hinder* aspects of long term transport network learning, such as a traveler's cognitive representation of the spatial environment (Jackson, 1996). We will return to this issue below.

Note that it is increasingly acknowledged (Katsikopoulos et al., 2000, 2002; Avineri and Prashker, 2003; Arentze and Timmermans, 2005a) that a traveler's learning from information may involve principles from Prospect Theory (Kahneman and Tversky, 1979, 1992), such as framing- and reference-effects. Katsikopoulos et al. (2000, 2002) strongly suggest that such effects should be taken into account when information is presented to travelers (e.g. the framing of uncertain travel time estimates as either gains or losses, in order to induce risk-averse or risk-seeking behaviour).

2.2.3 Perceived costs of choice adaptation $\boldsymbol{C}(\Delta^{+})$ and information acquisition $\boldsymbol{C}(\boldsymbol{I})$

Starting with the issue of choice adaptation costs, intuition says that no matter how attractive an alternative other than the one currently (intended to be) chosen may be perceived to be, if the perceived costs of adaptation towards that alternative are too high, travelers will limit their information acquisition concerning the other alternative and stick to their current or intended travel option. These adaptation costs may take the form of monetary costs or costs in terms of time. However, also more intangible costs such as time, effort and attention may be important components of these adaptation costs (as Haselkorn et al. (1989) point out, diversion causes stress). Literature on this topic predominantly considers the role of adaptation costs implicitly[6]: a number of studies, predominantly based on the stated or revealed preferences of car-drivers, found that choice adaptation is relatively likely towards a route or departure time other than the normal one, and unlikely towards other than the normal mode, be it pre-trip or in-trip using Park&Ride facilities (Kitamura et al., 1995; Tertoolen, 1998; Chatterjee et al., 1999; Mehndiratta et al., 2000; Neuhertz et al., 2000; Yim and Khattak, 2002; Chatterjee and McDonald, 2004; Loukopoulos et al., 2004; van der Horst and Ettema, 2005)[7]. There is no consensus about whether route (Neuhertz et al., 2000; Petrella and Lappin, 2004) or departure time (Jou and Mahmassani, 1996) switching is the most likely adaptation due to information provision. Furthermore, it is suggested that travelers simultaneously consider both route and departure time switching as one package choice (Caplice and Mahmassani, 1992; Mahmassani and Liu, 1999). Although many factors may co-determine differences in these diversion likelihoods, it may be safely assumed that these differences are partly attributable to differences in adaptation costs (e.g. Garling et al., 2002; 2004; Loukopoulos et al., 2004): changing from one (intended) mode to another, say an en-route change from private car to transit, may involve costly actions such as parking the car at a Park&Ride facility, walking towards the train platform (possibly while carrying luggage), buying a ticket and waiting at the platform. As Bos et al. (2003, 2004) argue, these tangible and intangible costs are important elements in a traveler's decision whether or not to use Park&Ride facilities. Furthermore, it should be noted here that by changing modes (either pre- or in-trip) a traveler loses flexibility with respect to mode-use for the next trip: e.g.,

[6] Some studies use the concept of inertia to describe how travelers prefer to stick to a chosen or intended travel alternative (e.g. Srinivasan and Mahmassani, 2000; 2003; Bogers et al., 2005).

[7] Although Khattak et al. (1996) find that mode shares did change substantially in favor of transit as a result of information provision, particularly under incident conditions.

changing from car to transit halfway through the morning commute means that the private car is not available for the first part of the evening commute. This loss in flexibility should be considered as an adaptation cost as well.

Complementary to these findings, it is often suggested that when travel information leads to an increase in transit ridership, this increase is due mainly to an increase in transit-use among current transit-users, rather than to a modal shift among car-drivers (Chatterjee et al., 1999; Bonsall et al., 2004). Furthermore note that diversion rates to alternative routes are negatively correlated with the distance between the current and the alternative route (Chen et al., 1999; Srinivasan and Mahmassani, 2000; 2003). Another finding that appears consistent with the importance of adaptation costs is that travelers appear to be more prone to switch pre-trip from an intended alternative, than in-trip from an already chosen alternative (Mahmassani and Srinivasan, 2004), as the former type of adaptation generally induces lower adaptation costs. Trip cancellation appears to be a very unlikely adaptation due to travel information acquisition (Khattak et al., 2003), probably due to the fact that such cancellation induces high levels of tangible and intangible costs. Another adaptation possibility with relatively low adaptation costs attached (and a relatively high adaptation benefit) is to make additional stops underway when high congestion levels are encountered, e.g. to do groceries (Mehndiratta et al., 2000; Petrella and Lappin, 2004). The inclination, mentioned earlier, of travelers to initially search for information concerning the travel alternative they currently (intend to) use can also be partly explained by the adaptation costs: if the information signals that the current alternative will perform satisfactorily, no adaptation is needed – and the traveler that acquires information anticipates this.

Another factor that appears to play a dominant role in travelers' information acquisition and choice adaptation processes, and that can be at least partly explained through the notion of adaptation costs, is the notion of network familiarity: several studies point out that travelers are more inclined to pay attention to information concerning, and subsequently switch to, travel alternatives that they consider to be familiar to them (Huchingson et al., 1979; Haselkorn et al., 1989; Khattak et al., 1993a; Adler and McNally, 1994; Lotan, 1997; Yang and Fricker, 2001). At first sight, this finding may appear to be paradoxical in relation to the earlier mentioned finding that low knowledge levels induce information search and perception updating. It may be interesting then to consider that the adaptation costs incurred by changing to other routes in familiar parts of the network are known more precisely, and are likely to be lower, than those incurred by changes towards unfamiliar routes. Choice adaptation towards unfamiliar routes may involve a costly wayfinding process and even the very costly possibility of getting lost; taking into account these differences in adaptation costs between diversion to familiar and unfamiliar routes, the important role of familiarity appears quite logical. Note that the finding that travelers who share a ride are relatively prone to divert to other routes (Khattak et al., 1993b) may also be considered a familiarity-effect, as two know more than one.

Moving to the topic of information acquisition costs, it is widely acknowledged throughout the social sciences that the non-monetary costs of acquiring information (in the sense of searching for and processing information) may be substantial in terms of effort, time, attention and the possibility to forego already found alternatives[8] (e.g. Simon, 1955, 1978; Weibull, 1978; Shugan, 1980; Smith, 1991; Payne et al., 1993; Hauser et al., 1993; Mehta et

[8] E.g. driving past a highway-exit during the process of trying to find information about whether it is a good idea or not to take this or a next exit.

al., 2003; Lu et al., 2005). Many traveler behaviour studies suggest that this general insight is particularly applicable to the context of travel choice making, where travelers dislike to engage in a lengthy search- and decision-process, and rather apply myopic or heuristic decision strategies (Foerster, 1978; Hey, 1982; Richardson, 1982; Polak and Jones, 1993; Stern, 1999; Fujiwara et al., 2004; Jou et al., 2005). The finding of Chorus et al. (2006d) that travelers appear to desire information that makes traveling easier (e.g. route guidance or early warning functions) rather than information that helps them optimize their decisions (e.g. personalized, multimodal information) is consistent with this insight. As a result, the usability of travel information services appears to be a crucial determinant of its usage among travelers (Golledge, 2002; Kenyon and Lyons, 2003; Fayish and Jovanis, 2004; Geweke and Zumkeller, 2006; Kihl, 2006). Furthermore, limited awareness of the availability and capabilities of travel information services is found to be a potentially substantial barrier to the propensity of travelers to search for the information (Kenyon and Lyons, 2003; Goulias et al., 2004; Peirce and Lappin, 2004): active marketing efforts are needed to help travelers find the information they might be looking for. Besides the non-monetary costs of information acquisition discussed above, travelers generally appear to have a very low willingness to pay for acquiring travel information[9] (e.g. Emmerink et al., 1996; Polydoropoulou et al., 1997; Zhao and Harata, 2001; Khattak et al., 2003; Zhang and Levinson, 2006), especially for transit information (Vance and Balcombe, 1997; Neuherz et al., 2000; Molin and Chorus, 2004; Molin et al., 2006). This latter finding can be explained by acknowledging that potential transit-users mostly feel that they have already paid for information provision by buying their ticket. Furthermore, it appears that there is a widespread dislike among travelers to pay for information about delayed trains. If information must be paid for, travelers prefer to pay per acquisition rather than paying a flat fee per month (Polydoropoulou et al., 1997; Khattak et al., 2003; Molin and Chorus, 2004; Wolinetz et al., 2004). It should be noted that willingness to incur (non-) monetary costs when acquiring information appears to differ widely between travelers (Denant-Boemont and Petiot, 2003; Chorus et al., 2006f). Given this average low willingness to pay for information among travelers, but depending on the market structure of information suppliers and the transport policy goals of government, subsidization of information supply could be considered a welfare enhancing policy (Zhang and Verhoef, 2006).

Another phenomenon that plays an important role in everyday traveler behavior and which can be explained by referring to the concept of information acquisition costs, is the notion of habitual travel behavior. It has recently been widely acknowledged (e.g. Lyons, 2001; Fujii et al., 2001; Fujii and Kitamura, 2003; Fujii and Gärling, 2003; Schlich and Axhausen, 2003; Bogers et al., 2005) that many travel choices are made out of habit: the same alternative is chosen repeatedly, without any conscious deliberation from the side of the traveler[10]. As found by Aarts et al. (1997) and Verplanken et al. (1997) in the context of mode choices, travel information acquisition is virtually non-existent during the execution of travel habits. Some might say that this lack of deliberation and information acquisition implies that habit

[9] Although estimates appear to differ quite widely between studies: for example, Tam and Lam (2005) find a rather high willingness to pay for travel information. Furthermore, although no empirical results were found in this regard, it appears that in-car route guidance systems are rapidly gaining in popularity among car-drivers, notwithstanding their relatively high prices. Willingness to pay for information (services) thus seems to depend on the type of information (service).

[10] However, as Chatterjee et al., (1999) argue, executing a habit may not always mean there is only one habitual alternative: depending on e.g. the departure time and en-route conditions, multiple habitual routes may exist.

execution should not be considered an actual 'decision'. 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 and information acquisition are practically non-existent (Gärling et al., 2001; Golledge, 2002; Gärling and Axhausen, 2003). The absence of information acquisition during habit execution does not mean that travelers that make most of their travel choices out of habit never use travel information. As habitual behaviour is mostly very dependent on the choice context (in terms of destination, time-of-day, trip purpose), choices that are made by the same traveler in (even slightly) different contexts are likely to be made in a less habitual fashion and may thus involve information acquisition. This information might indirectly help break down habits. Indirect evidence for this argument appears in Van der Horst and Ettema (2005) and Jou et al. (2004), where travel information use and effects is found to be higher during weekends than during weekdays, and also relatively high during non-daily recreational trips. Other studies point to the fact that habits may be broken in situations where the habitual alternative performs very badly, e.g. due to incidents or road works (Fujii et al., 2001). In these situations, travel information use and effects are likely to reach relatively high levels.

2.2.4 Cross-category and miscellaneous findings

As indicated in section 2.1, a number of findings from the literature concerning travel information use and effects do not clearly relate to one of the identified sets of determinants: there appears either to be a relation with all three sets of determinants, or with none. Two groups of findings are found to be especially difficult to categorize, and will therefore be discussed here separately: the first group refers to the role of sociodemographic and socioeconomic factors, the second group refers to the role of information format and the type of medium that is used for information provision. Note that while reviewing these two groups of findings we will only make limited attempts to find reasons behind the empirical relations found, as these are often simply not clear.

Sociodemographic and socioeconomic factors

In general, many studies point to the fact that there is a large variation in travelers' use of travel information, and its effect on their travel choices (e.g. Watling and van Vuren, 1993; Golledge, 2002; Denant-Boemont and Petiot, 2003; Chorus et al., 2006f). Generally, it is acknowledged that although a traveler's personality (Khattak et al., 1993a; Chatterjee et al., 1999; Golledge, 2002), the constraints they face (Golledge, 2002), the regional travel context[11] (Bonsall, 1992; Polak and Jones, 1993) and the various determinants discussed above play an important role as causes for this variation, sociodemographic or socioeconomic grounds can also explain a substantial part (e.g. Srinivasan et al., 1999; Geweke and Zumkeller, 2006). Concerning the acquisition of provided travel information, it is generally found that the following groups of travelers are relatively prone to search for (and pay for) available travel information: young, male[12] travelers and travelers with high education and income levels (Lappin, 2000; Mehndiratta et al., 2000; Targa et al., 2002; Yim and Khattak,

[11] It should be noted however, that Jou and Mahmassani (1996) and Petrella and Lappin (2004) find remarkable resemblances between information use and effects among travelers in different regions of the United States.

[12] Although Polydoropoulou et al. (1997) find that women perceive the benefits of the use of travel information services to be higher than men.

2002; Petrella and Lappin, 2004; van der Horst and Ettema, 2005). Given the reception of travel information, it is found that male travelers (Emmerink et al., 1996; Wardman et al., 1997; Mannering, 1998; Mahmassani and Liu, 1999; Dia, 2003; Mahmassani and Srinivasan, 2004; Jou et al., 2005), young travelers (Abdel-Aty et al., 1997; Mahmassani and Liu, 1999; Dia, 2003; Srinivasan and Mahmassani, 2003; Jou et al., 2005) and high-income travelers (Khattak et al., 1993b; Jou et al., 2005) are also relatively prone to change to other than the currently chosen or intended travel alternative. However, Wardman et al. (1997) found that younger travelers are less likely to comply with advice given by travel information services. Abdel-Aty and Abdalla (2004) found the same relation, but for higher educated travelers. Note that, as Chorus et al. (2006a) state, these sociodemographic and -economic determinants for travel information use and effects are in fact likely to be proxies for more fundamental behavioural determinants: for example, younger travelers are likely to be more technology-oriented, and are therefore likely to be more aware of available information services and to perceive their use as less costly in terms of effort and attention. This may explain their relative susceptibility to acquire travel information, when compared to older travelers.

Information format and medium type

Quite a lot of research has been done to identify which information format affects travelers' choices the most, in terms of diversion levels[13]. Format is here defined as the way in which some information content is translated into a message that is provided to the traveler. Such a message may for example take the form of advice or a travel time estimate, a qualitative or quantitative message, a one phrase message or an integral story, etc.

Many studies stress the relatively high potential of advice or prescriptive information (e.g. "take route A") to alter traveler behavior in the short run (Khattak et al., 1996; Chen et al., 1999; Mahmassani and Srinivasan, 2004; Abdel-Aty and Abdalla, 2004; Jou et al., 2005), as well as the provision of ex-post information on the current and best available alternative (Chen et al., 1999; Srinivasan and Mahmassani, 2003; Mahmassani and Srinivasan, 2004; Bogers et al., 2005). The provision of predictive and quantitative information ("due to an accident, the expected delay on route A equals 25 minutes") is found to have more effect on choices than historic and qualitative information ("due to an accident, there are delays on route A") (Khattak et al., 1996; Dia, 2003; Jou et al., 2005). Furthermore, increasing the level of detail is found to increase diversion levels (Khattak et al., 1993a; Polydoropoulou and Ben-Akiva, 1998; Yang and Fricker, 2001; Yim and Khattak, 2002). Note however again the trade-off with respect to readability and comprehensibility of the information (Dicke and de Groot, 2005; Kihl, 2006). Chatterjee and McDonald (2004) also argue that the use of arrows and the combination of fixed and variable elements are likely to confuse travelers, although learning might eliminate this confusion in the longer run. Bogers et al. (2005) found that travelers are well able to derive efficient travel choices from queue length information. In order to influence car-drivers' mode-choices (and persuade them to consider taking or actually take transit), it is generally acknowledged (e.g. Lyons, 2001; Abdel-Aty, 2001; Kenyon and Lyons, 2003) that information should be presented to them that compares both modes, and does so on a number of attributes - i.e. not on travel times only. Note however, that Polydoropoulou and Ben-Akiva (1998) find that prescriptive information to take transit has an effect on mode-choices, too. The findings of Polydoropoulou et al. (1996) may be used

[13] Research concerning how information format influences travelers' need for and acquisition of the information is relatively scarce, but see Chorus et al. (2006d, f) for examples.

here as a summary: highest (short run) diversion rates among car-drivers are established by prescriptive information, followed by quantitative/predictive information on multiple alternatives, followed by quantitative/predictive information on the usual alternative. Qualitative information on the usual alternative results in the lowest diversion rates.

Before concluding this section on the role of information format, we pay some more attention to the effect of advice, or prescriptive information. Let us first restate the argument made by Jackson (1996) that when longer term effects are taken into account, there is a case to be made against the provision of advice. Note that such a long-run perspective is rarely adopted in the studies encountered during our review. We agree with Jackson (ibid.) when he states that the provision of advice (in contrast with descriptive information such as the provision of travel time estimates or the presentation of previously unknown routes) prohibits learning and makes travelers dependent on the information service as it reduces a traveler's decision-making process from a true spatial choice to a binary choice of whether or not to follow the advice. We feel that it may even be argued that in the long run, through this choice-reduction process, providing advice may induce habitual behavior. Furthermore, we feel there is another reason to be cautious with the provision of advice: by giving advice, the information provider does part of the traveler's thinking, and by doing so, risks reaching other conclusions than the traveler would have reached. Take for example the case where one route is 2 minutes faster than another one, but where the other route is more attractive in terms of scenery, road conditions, etc. Based on travel time comparisons, the information provider is likely to prescribe the traveler to take the former route, whereas the traveler might have chosen the latter. In combination with the earlier mentioned finding that travelers are very sensitive to 'wrong' information, there are many thinkable situations where such advice is harmful to the use and effect of travel information in the long run. In general, giving advice becomes a hazardous thing to do when more than one attribute determines a traveler's preference (e.g. in situations where fast but expensive toll-roads are available). As Golledge (1995, 2002) states, the information provider should always acknowledge that travelers may have a multitude of criteria for the selection of travel alternatives.

Concerning the role of medium type as a determinant of information use and effects, it is found that the radio is a preferred information medium among car-drivers (e.g. Haselkorn et al., 1989; Yim and Khattak, 2002; Targa et al., 2002); Chatterjee et al. (1999) however find that radio-information is often ignored. Many researchers propose the use of graphical information as the format that is most easily understood by travelers, arguing that vision is the spatial sense par excellence, especially in unfamiliar parts of the network (Hato et al., 1999; Yang and Fricker, 2001; Golledge, 2002). Yang and Fricker (2001) found that auditory information is very effective when conveying less detailed information, whereas visual information may help conveying more extensive messages (e.g. in unfamiliar parts of the network). Consistent with this argument, it is suggested that the internet is the ideal medium to provide in-depth comparisons between different modal options (e.g. Kreitz et al., 1999; Kenyon and Lyons, 2003). Variable Message Signs are found to induce rather high route-diversion rates, too (e.g. Zhao and Harata, 2001), although other studies mention that they are often overlooked (Wardman et al., 1997; Chatterjee and McDonald, 2004). In a more general sense, Polydoropoulou and Ben-Akiva (1998) find that pre-trip information from electronic sources has a higher impact on travelers' choices than comparable information from non-electronic sources. This might be due to the fact that electronic information suggests dynamism (i.e. that it is regularly updated), whereas non-electronic sources such as timetables and newspapers by definition provide only static information. Jou et al. (2005)

find that travelers are generally most experienced with travel information provision through the radio and Variable Message Signs, and Emmerink et al. (1996) find that radio-information and Variable Message Signs induce comparable diversion levels. In conclusion, it is found that the medium to convey messages should be carefully chosen in accordance with the format and content of the information provided.

3. Ten summarizing insights into the potential and limitations of travel information

We will here present ten integrative, generic insights that may be derived from (combining elements from) the literature review and which may aid transport academics and policy makers appreciate the potentials and limitations of information provision as a means to change car-drivers' travel choices along the dimensions considered here. For clarity of presentation, no references will be made to literature underpinning these insights – they directly relate to findings presented in section 2.2.

1. *Our expectations with respect to the effects of information provision on travel choices in general may be mildly optimistic, particularly for behavioral adaptation not involving changes in mode choice.* Many empirical studies suggest that information provision on alternative routes and modes to the one currently chosen or intended does lead to more changes towards these alternatives. However, several potential barriers exist that may hamper the provided information being searched for and processed by travelers in general and car-drivers in specific, and the processed information leading to choice adaptation: travelers may perceive their currently chosen travel option as satisfactory and are likely to perceive the quality of proposed alternative options negatively; they are likely to feel that their own knowledge is sufficient or that provided information is irrelevant or unreliable; they are likely to perceive the (non)-monetary costs of information acquisition and choice-adaptation as too high in relation to the expected benefits. Only when given a favourable mindset of the traveler, the availability and high quality of the information service and alternative travel options, and a favorable travel context, will a traveler search for and process travel information, and adapt her choice towards a different mode, route or departure time. Mode choices are found to be harder to change than other travel choices, as the former are often made in an habitual way, and are driven by soft factors such as status, rather than hard factors such as travel time gains. In the longer run, the effects of information provision, when presented to travelers in suitable formats, are likely to be stronger than the short term effects. Travelers that are repeatedly exposed to high quality information at relevant moments pre- and in-trip are likely to learn the value of information and become more aware of the availability and quality of alternative travel options. However, the barriers mentioned directly above are also likely to prohibit the emergence of substantial information effects on car-drivers' travel behaviour, especially their mode-choices.
2. *Provided information is used among travelers to the extent that its (non-) monetary costs are low.* Travelers' perceptions of information benefits are generally low or moderate. This means travelers will generally only acquire information when its perceived costs are low. Concerning monetary costs, it is found that a traveler's willingness to pay for information is very low, although substantial differences exist among travelers.

Concerning non-monetary costs, it is found that travelers avoid spending time and attention on using information services. Those travel information services and devices that are easily usable, and that provide information in ways that are readable and comprehensible while traveling, are far more likely to be used among travelers. It may be expected that these non-monetary costs of information acquisition will become more and more relevant as mobility among older travelers is projected to grow strongly over the next decades (although it might also be expected that the elderly will become more and more familiar with the use of high-tech devices and services).

3. *Information provision on the performance of the currently chosen alternative, also under normal circumstances, may help change car-drivers' choices in the long run.* Travel information can play an important role in a traveler's learning process as it has the potential to redress misperceptions of a normally or habitually chosen alternative. As such misperceptions may also exist under normal conditions, information provision on the currently chosen option under normal circumstances is likely to have a reducing effect in the long run on travelers' misperceptions of normally chosen travel alternatives.
4. *The effect of information provision on other than the currently chosen or intended option is conditional on the performance of these alternative options and the extent to which the information takes into account information acquisition costs and the costs of adaptation towards these alternative options.* It is found throughout the literature that providing information (especially advice) about alternative options when adaptation towards them is likely to cause regret, is a highly non-effective strategy. Information provision is effective, at least from the viewpoint of behavioural adaptation, to the extent that adaptation towards the other alternative, including potentially substantial information acquisition and choice adaptation costs, is more attractive than executing the currently chosen alternative. Information concerning other than the currently chosen alternative may benefit from a higher level of detail than information concerning the currently chosen alternative. This level of detail may concern two dimensions: firstly, it should be acknowledged that travelers may not know the alternative option as well as their currently chosen one. Therefore, the traveler may want to be informed about all the relevant attributes of the alternative- not only expected travel times. Secondly, information containing directions concerning how to reach the alternative option may lower the costs associated with choice adaptation towards the alternative.
5. *The long term effect of giving advice is likely to be limited.* Confronting travelers with advice may reduce the longer term learning potential that information provision has, and may therefore be of limited value in the long run, notwithstanding the relatively high diversion rates that may be established in the short run. This is due to the fact that advice reduces the complex spatial environment into a binary choice environment. When giving advice, presenting the argument behind the advice may help avoiding complete dependency on the received information. In general, the provision of advice is intrinsically difficult when it is acknowledged that travelers take into account more than one attribute dimension of alternatives, since it remains unclear on what weighing of attributes the advice is based.
6. *Young male travelers with high education and income levels that make a trip that differs from trips normally made in terms of destination, departure time, day of the week (weekday versus weekend) are most likely to use information provided to them and divert to other travel alternatives.* In travel situations that differ from a traveler's normal trip along some dimension, travelers that exhibit habitual behaviour for their usual trips may

be expected to be more susceptible to the acquisition of travel information and to possible diversion to other than planned or intended travel alternatives. Furthermore, the mentioned socio-demographic group appears to be more prone than others to use information and possibly divert, possibly due to the fact that people from these segments travel more than others. However, before using this finding as an underpinning of an information provision strategy that explicitly targets this segment of travelers, it should be acknowledged that in many cases targeting specific segments of travelers with information may be costly and even ethically troublesome. One acceptable way of doing so is to tailor marketing campaigns concerning travel information services towards this segment.

7. *In situations where a high variability of conditions exists in parts of the network the traveler is familiar with, information use and effect is likely to be relatively high.* When traveling through familiar parts of the transport network, travelers will be relatively prone to acquire information on other than the currently chosen option and potentially divert. Furthermore, when the attributes of travel alternatives are perceived as unpredictable, travelers will be relatively prone to search for the information provided to them, and they will be relatively prone to update their perceptions with received information and to divert to other alternatives. In parts of the network the traveler is unfamiliar with, it is recommendable that the information not only focuses on the attributes of alternatives (e.g. expected travel times), but also brings alternative travel options to the traveler's attention and guides the traveler towards them. If not, the traveler may perceive the potential costs of behavioral adaptation as too high, e.g. due to the risk of getting lost when changing routes in-trip.
8. *The effect of information provision is relatively high during long trips, complex trips and trips made for an important purpose.* These trips are likely to induce optimizing-behaviour in the traveler, leading to a higher likelihood of information acquisition (concerning both the intended alternative and other options) and choice adaptation. Examples of such a trip are a journey towards a holiday destination or a multiple stop-trip (e.g. home – kindergarten - business meeting - work).
9. *Making information services work well under incident conditions is likely to be cost-effective.* Generally, travelers perceive travel information services to be particularly unreliable under incident conditions. However, it is during these conditions that a need exists for detailed reliable information. Furthermore, as travelers, including the ones that chose their current alternative out of habit, perceive their own knowledge levels as particularly insufficient during such conditions, they are particularly likely to update their knowledge with received information and adapt their choices when the information gives reason for it. Such a diversion may be a first step in breaking a traveler's habit. Although the cost of improving the performance of an information service's performance (particularly in terms of their reliability) under incident conditions is bound to be high, it would be a cost-effective strategy from a behavioral adaptation point of view. Note that a traveler's willingness to pay for information will be relatively high under these circumstances.
10. *Providing travelers with information as early as possible is likely to increase its effectiveness in terms of behavioral adaptation.* Travelers generally find information useful to the extent that it may help them improve their choices. Before a trip is started, or at the beginning of a trip, far more choice adaptation possibilities exist than near the end of it, where information is of limited value to travelers. Furthermore, near the end of a trip

a traveler's knowledge levels are much higher than at the beginning (e.g. regarding expected arrival times), so that information needs are lower and the inclination to update perceptions with received information decreases . When providing information to travelers just before a moment of choice may occur (e.g. advice to leave the highway, presented to travelers right before a highway exit), it should be kept in mind that travelers may need time to think before they want to make a choice to divert.

4. Conclusions and discussion

This paper set out to provide insights that help transport academics and policy makers appreciate the potentials and limitations of information provision as a means to induce a modal shift from private car to public transport and/or changes in car-drivers' choices for departure times and routes towards a more even distribution of traffic within the available road network. It does so by providing a review of more than 15 years of literature concerning the use and effects of travel information among car-drivers. Based on the performed review, a number of generic, integrative insights is derived which are listed directly above and will not be repeated here, except for two main findings: it appears that our expectations with respect to the effects of information provision on travel choices in general may be mildly optimistic, particularly for behavioural changes not involving changes in mode-choice. In the longer term, the effects of information provision, when presented to travelers in suitable formats, are likely to be somewhat stronger than the short term effects, due to learning dynamics.

It should be acknowledged that for policy-makers considering the provision of travel information as a travel demand tool among car-drivers, this paper has only tried to answer a subset of the wide variety of questions that are relevant to them. We will list some of the most crucial ones here, without answering them: which transport externalities should the government try to reduce? How do these externalities relate to traveler behaviour? What travel demand management tools exist that may help reduce particular externalities caused by particular traveler behaviour? How does the provision of travel information compare to other travel demand management tools in terms of cost-effectiveness? Besides these effects in terms of travel demand management, what other effects might the provision of travel information have on traveler behaviour? What role should the government play in the process of gathering, integrating and distributing relevant travel information? How does this role relate to the potential role of private parties, such as technology-providers or transportation companies? Clearly, the answers provided in this paper only solve part of the complex puzzle that is faced by transport policy makers who consider attacking the externalities of passenger transport and possibly doing so by means of travel information provision. A clear research need exists concerning the other questions raised here.

Furthermore, where this paper has tried to capture a wide variety of rather *specific empirical* studies concerning the use and effect of travel information by means of a literature review, this is certainly not the only way to gain the needed insights into the potential and limitations of travel information as a travel demand management tool among car-drivers. More particularly, a clear need exists for an *integrative empirical* study effort. Such a study effort should consider simultaneously the use and effects of a variety of types of travel information in the context of multimodal travel choices, and it should simultaneously focus on the role of travelers' knowledge levels, information reliability and trip purpose. Preferably, data on revealed information acquisition and travel choices should be collected. However, a useful

and less costly alternative data-collection method is to construct a multimodal travel simulator-experiment. Based on such an experiment, a forthcoming study has attempted to obtain some of these much needed integrative empirical insights (Chorus et al., 2006f). As a final reflection, it is felt by the authors that notwithstanding all our efforts in modeling the variation in behavioral response to information (and in reviewing the empirical application of these models), a substantial part of this variation will always remain unexplained: traveler behavior, and particular travelers' response to knowledge limitations and information provision, is too complex and nuanced to be fully understood by us analysts.

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