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Original
From mode choice to modal diversion: A new behavioural paradigm and an application to the study of the demand for innovative transport services / Diana, Marco. - In: TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE. - ISSN 0040-1625. - STAMPA. - 77(3):(2010), pp. 429-441. [10.1016/j.techfore.2009.10.005]

Availability:
This version is available at: 11583/2317645 since:

Publisher:
Elsevier

Published
DOI:10.1016/j.techfore.2009.10.005

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Marco Diana, 8th September 2009

Diana, M. (2010) From mode choice to modal diversion: a new behavioural paradigm and an application to the study of the demand for innovative transport services, *Technological Forecasting & Social Change*, vol. 77(3), pp. 429-441.

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Abstract

We analyse past research efforts that focus on modal diversion in the transport sector, as opposed to the classical mode choice concept, showing the added value of this alternative framework that emerges from the existing scientific literature. The modal diversion paradigm is then used to assess the relative importance of the technical performances of transport services on one hand and of subjective factors of its potential users on the other, when forecasting the use of a new means among a group of white-collars working in a French research institute. We quantitatively show that multimodal habits and cognitive attitudes have an importance that is in general not negligible for this group, compared to that of the transport services performances, even if only these latter are routinely considered by engineers and planners. Beyond this, we find that the role of self-related factors further increased when the group was less familiar with the technological background and the subsequent operation of the new system, such as in the case of demand responsive transport services.

Keywords: Transport modal diversion; transport habits; cognitive attitudes; affective attitudes; structural equation modelling

1 Introduction

Modal diversion strategies play a key role in many transport management policies around the world. However inducing switches from the use of cars to the use of more environmentally benign modes such as transit or non-motorized means represents a true challenge. Classical transport engineering theoretical approaches have been developed with massive research efforts. These are generally based on the consideration of quantitative variables within a utility maximization framework to represent the alternatives, and they can now model many consumer choices in the transport sector with a high degree of refinement and appreciable predictive power. However the issue of how to elicit behavioural changes in the individuals through the use of new technology options should probably be considered by integrating different research perspectives in order to adequately take into account the related complexities of this problem.

The standard practice in the study of the use of different transport means makes use of the mode choice concept. According to this, the individual is seen as a consumer acting in a transport market by evaluating the available alternatives and selecting the "best one", whenever it decides to make a trip, in strict analogy with any purchasing behaviour of goods and services as studied in the marketing literature. The whole of these choices (including mode choice) then describes his/her mobility behaviour. Massive research efforts over the decades have continuously improved mode choice models on an analytical viewpoint, for example by widening the range of factors under consideration, progressively removing some limiting assumptions or setting up better estimation procedures. Yet this theoretical framework from the marketing literature is almost unchanged from the pioneering epoch of transport planning.

It is important to note that, historically speaking, the above scheme was developed when the rapid expansion of car ownership and use in the Western Hemisphere caused a radical overhaul of mobility patterns, which needed to be studied and possibly managed. Nowadays, we observe in those countries some structural trends at the macroscopic level, for example related to economic growth, but mobility behaviours and modal market shares are quite consolidated. Within such a rather static scenario, a set of new technologies such as Intelligent Transport Systems (ITS) are being introduced in an effort to improve safety, increase the systems efficiency and reduce environmental impacts [1, 2]. Even if new technologies can improve existing transport modes or even enable new services such as carpools, car-sharing or demand responsive buses, habits are still likely to have a predominant role compared to that of deliberate choice processes. Therefore, the key point seems to be more the study of changing behaviours and less that of the choices among alternatives, in order to effectively forecast the impacts of ITS.

In the following we consider demand responsive transport systems (DRT) as an example of new mobility service that is enabled by ITS. DRT is a service on demand where a fleet of vehicles can serve trip requests between any origin/destination pair without predefined paths or schedules, while allowing ride sharing. These services are traditionally dedicated to specific population segments such as elderly or disabled, but the diffusion of ITS is making them competitive with other transport means in terms of performances, thus making them appealing also for the general public. For example, according to a recent survey at least 615 DRT are in operation in France, where our later described experiment took place, 73% of which are for the general public [3]. In many other countries, such as in the Netherlands or in Sweden, large DRT systems are already in place. The problem of forecasting the demand of such services is then going up in research priorities agendas.

One theoretical premise of this study is that shifting paradigm from mode choice to modal diversion allows to better tackle the problem of forecasting the demand for new transport services. The present paper pays then some attention to review a number of rather disperse research efforts which propelled the evolution of the classical mode choice concept towards the behavioural change issue. The lessons that we learn provide guidance for further research developments and show the advantages of the modal diversion concept over the conventional mode choice approach. In particular, self-related factors such as attitudes, lifestyles or personality traits seem to play and even greater role in a decision making context where information on the new alternatives is incomplete.

As an illustrative example of this latter point, we present then an exploratory study of the demand for a new mobility service option and the subsequent market equilibrium change whose analytical methodology stems from the modal diversion paradigm. In similar cases, the mode choice scheme is particularly challenged because we simply cannot collect Revealed Preferences (RP) data from the field if the service is not existing, so that traditional model estimation and calibration processes could be jeopardized. An even greater concern can arise when the new service itself is not well known by potential users because of its technological content, so that usual theoretical assumptions concerning the knowledge of the alternatives in the choice set are hardly met and methods such as Stated Preferences (SP) experiments may prove ineffective.

In the following we present a method to investigate the importance of the above mentioned self-related factors in relation with the characteristics of the services, with an application to a pilot group of clerical workers. Examples from different epochs of research in the transport sector that is confronted with the problem of forecasting the demand of a non-existent transport service are described in [4-8]. However the present study is unique in its attempt to assess the relative importance of self related versus instrumental factors in this decision making process, thus trying to fill the gap between the different disciplinary ambits that will be reviewed in the following section.

2 From mode choice to modal diversion

It is theoretically possible and practically fruitful to study modal diversion with the same method normally used for mode choice models, i.e. the random utility approach within an econometric context where the attributes of the alternative modes are the independent variables. The commonest improvement of such models to study modal behaviours changes is the joint use of both revealed preferences and stated intentions data [9-14].

The above represents the framework of most analyses made by economists, planners and transport engineers. However different research perspectives related to modal diversion, stemming from other disciplines, have emerged over the years and correspondingly also other methodologies of analysis have been proposed. The new insights which have been thus gained are of capital importance to better understand the underlying theoretical mechanisms of transport mode choice processes [15] and to try to improve our forecasting tools when new technologies enter in this market. In this latter cases, the behavioural reactions of the individuals need to be carefully assessed.

Starting from the outset, one of the earliest contributions came from behavioural and social psychology. Soon after the development of the classical economics and engineering approach to study mode choice, which as we said focuses on the characteristics of the system, models that embedded measures of subjective constructs such as reliability [16], convenience [17] and comfort [18, 19] were developed. More in general, attitudinal theories started being used in the mode choice research field. Although the concept itself has been rather loosely defined in many studies, a more or less direct link with the contemporary expectancy-value theory of attitude [20] is often detectable. Attitudes were thus initially measured through attribute-related ratings of preference [21], satisfaction [22], satisfaction and importance [23-27] or satisfaction, importance and preference [28]. The relative importance of different attributes changes across individuals has also been examined [29], along with the different role of cognitive and affective attitudes in determining travel behaviours [30-32]. The latter distinction is also adopted in the application we present in the following section, so that we better describe it later.

Papers specifically focusing on modal diversion rather than mode choice are much more recent but are intrinsically connected with the above reviewed research, eventually considering more advanced social psychology constructs. In fact, while some authors stress the importance of rational processes in mode switch decisions [33, 34], others have investigated the role of social and affective motivations [35] and of personality traits [36]. Other psychological mechanisms such as social dilemmas [37-41] or cognitive dissonance and reactance [42, 43] have been widely observed in modal diversion studies and it has been shown that they can greatly affect the switching potential. We incidentally note that similar research has also been developed in the related field of the study of car use, see for example [44, 45]. Interestingly enough, the above mechanisms often contradict the assumptions underlying rational decision-making processes. For example, cognitive dissonance can explain why increasing the amount of information on some transport options (such as the “true” costs of running a car) could lead more to changes in the personal evaluation of the different attributes than to different choices.

The cognitive dissonance argument is just an example of a much wider issue concerning the direction of causation (if any) between attitudes and modal behaviours. Letting aside the underlying theoretical debates, we find in the modal diversion literature variegate positions [46]. Some authors [22] claim that modal selection decisions influence attitudes and not vice-versa, whereas others [30] found empirical evidence of a bi-directional relationship or study the mediating role of other constructs such as behavioural intentions [6] and preferences [31]. A strong attitude-behaviour relationship is conversely postulated by those works [33, 34] grounded on more recent versions of the above mentioned expectancy-value theory, namely the theory of reasoned action and the theory of planned behaviour [47].

Concerning the attitude-behaviour relationship, we mentioned in the introduction the important role of habit for the modal diversion research perspective as opposed to classical mode choice, which has been in fact extensively studied by social psychologists since the Seventies [48]. Related works show that repetitive choices tend to become script-based, so that the corresponding behaviours are more and more an automatism (see [49, p. 68-69] for a recent review of the literature on habit in travel behaviour). From a transport engineering perspective, habit can partly explain the observed predictive importance of situational variables such as socioeconomic characteristics and car ownership [e.g. 27, 50, 51], household activities and land-use patterns (from the seminal works [24, 25] down to the activity-based approach literature), or even transit passes availability [52]. The role of socioeconomic variables is also investigated by several market segmentation studies (see their review in [53]). Looking more specifically inside the habit formation mechanism, it was shown that the effect of ordinary policy tools such as economic disincentives can be greatly attenuated in presence of an increase of the cognitive burden needed to override an habit [54]. Moreover, this effect is also transitory if the “stimulus” does not last enough, so that a new habit has not a chance of being formed.

The latter research is also a good example of the importance of the dynamic dimension of the transport behaviour when studying the switching potential [55]. Temporal evolutions are also explicitly considered for example in longitudinal analyses [56, 57] or when determining how temporary policy measures such as free transit tickets or freeway closures impact the modal behaviour both in the short and in the long term [58-60]. Along the same lines, other works study how long does it take before people start using a new transport service offered near their house [61].

We can sum up this review by noting that modal diversion studies have in general terms investigated the role of three classes of factors: instrumental elements such as the characteristics and performances of the competing modes, subjective factors such as attitudes and personality traits and situational variables such as habits and socioeconomic characteristics. Some papers put together some of these points of view, showing the added value of jointly considering them [62]. However, a more comprehensive assessment of the relative importance of the different mechanisms which are involved in a modal diversion process is still missing. Concerning the available partial results, situational factors were found to be more influential than attitudes [27], whereas methods to integrate instrumental and attitudinal elements in a mode choice model have been developed [21, 63]. More ambitious works [64] compare the effects of attitudes, sociodemographic factors and time and cost attributes on modal choice.

Along the same lines, in more recent years we record studies on the importance of attitudes related to environmental awareness in the prediction of decision making processes concerning car use, as opposed to the exclusive consideration of standard socioeconomic variables [45]. Instrumental and affective factors were proven to be of comparable importance for the users of different modes, moreover for leisure travel [35]. Moreover, the consideration of attitudes, habits and affective constructs from the theory of interpersonal behaviour [65] can greatly improve simple econometric mode choice models [32]. A decisive role is finally played by lifestyle and life situations [66]. This prompts the more general study of the dynamic interactions of attitudes or motivations, habits and situational variables such as car ownership, and the presence of alternative transport services concerning the use of different transport modes [67].

A qualitative study on transport modes was recently proposed, which compares models that study behavioural changes in response to changes in the transport supply with models that can explain behaviours on the basis of personal characteristics [68]. We note that this explicitly addresses the above mentioned dichotomy between transport engineering and social psychology approaches. Different approaches to tackle the modal diversion issue are often developed in parallel in separate contexts, because each discipline tends to consistently propose working methodologies to study possible actions that are effective above all within its exclusive field of competence. Thus, policy makers and engineers concentrate on the attributes and performances of the different modes because they have the possibility to shape the supply of transport through their planning activities. On the other hand, sociologists and psychologists are more keen to consider personal characteristics, since they can contribute for example in marketing and educational campaigns.

In the following we try to overcome such disciplinary barrier. The application which we present in the remainder of the paper takes a point of view that fits the transport engineering practice in the study of the use of different transport modes, thus considering at the outset the characteristics and levels of service of the different options. Then our objective is to assess the relative importance of the attributes of the alternatives on one hand, and of three self-related factors on the other. The factors we consider in the present research are the multimodal habits of the respondent, his/her cognitive attitudes and his/her affective attitudes, which are quantified through appropriate measurement techniques on the basis of past research results.

Compared to the above state of the art, our experiment has been designed to investigate three aspects of the modal diversion issue that have not been previously considered. First of all, we explicitly consider the different role of cognitive and affective attitudes. Then we would like to examine the influence of being differently acquainted with the different means, which can be seen as a partial way to capture the above discussed concept of habit in a relatively easy way. Finally, we carry out a study that is focused on a specific trip rather than on general mobility behaviours. Beyond these three points, original contributions on a more methodological point of view, which allow us to better tackle the modal diversion concept, are presented in the following section.

3 Experimental study on modal diversion

3.1 Methodology and data collection

The data that we analyse come from an online attitudinal survey administered to the staff working at INRETS, The French National Institute for Transport and Safety Research, at the end of 2004 [69]. The purpose of the study was to assess the multimodal practices of the respondents and to perform an in-depth analysis of a randomly selected trip among those being completed the day before the interview. The characteristics of the selected trip have been completely investigated, as in standard mobility surveys, and a number of questions concerning attitudes and perceptions of the respondents in relation with this trip have also been asked. This allows us to match factual experiences with personal views concerning the same study object (i.e. the trip under investigation). 164 observation have been gathered, which are clearly not representative of any general population, but the focus was to test a method rather than to obtain results with general validity. Our highly skilled sample is likely to give a greater importance to the transport means performances when making a decision, so that our approach is probably rather conservative concerning the assessment of the role of self-related factors.

As noted in the preceding section, one distinguishing feature of the study consists in analysing mobility behaviours not in general terms or for a whole category of trips, as done in most of the above reviewed studies, but to focus on a specific trip. We believe that performing the analysis at this more disaggregate level (trips and not persons), and referring to something that has been really experienced more than to generic attitudinal statements, can greatly facilitate the inclusion of our results in a transport modelling process. The drawback is that situation-specific factors which are not controlled may inflate the error terms of the model and attenuate the relationships that we would like to study. In any case, trip-level analysis should represent a real chance to build a unified framework, where standard transport modelling practices can be improved through the contribution of different disciplines. We have already shown the benefits of this methodology in a somewhat related work, dealing with the intrinsic utility that people have from the travelling activity [70].

Another innovative characteristic of the survey was the set up of a variant of a Stated Choice experiment, in which respondents were asked to rate their propensity to perform the same trip with a non-existing transport service in the future. The proposed transport services were the following five: a cheap bus service of low quality and another of high quality and more expensive, a cheap demand responsive service of low quality and another of high quality and more expensive, and a taxi service. These services have been chosen considering a classification of the transport means that is not based on construction engineering aspects (road, rail, …). Following previous research

[71, p. 44-46], we rather observe that people are differently acquainted with different transport services, and an alternative classification of the transport modes can then be defined on the basis of this element. This perspective allow us to better put into evidence the difference of importance between service performances and self-related factors across the considered transport means.

We note that we study the modal diversion issue under both the more conservative and the more radical interpretation of the expression “new service”. In fact, we both consider a service not existing in reality, but which can be easily figured out by the respondents (the bus line), and another service that is more innovative on a technological point of view and that has little chance of having been experienced in the past by the survey respondents (the demand-responsive service). The taxi service can be seen as an intermediate case (not a new concept on one hand but relatively little used on the other). Then we assess the corresponding variations in the relative importance of transport services performances, multimodal habits, cognitive and affective attitudes as regards the stated propensity to try out the new service, if the specific trip under investigation had to be done again. As noted above, the issue of the “not yet experienced” means is timely, since the more and more widespread use of ITS is pushing the implementation of many services such as carpools, demand responsive transit or car shares which have little penetration in the market, and are therefore almost unknown by the general public. The related supply-side technological issues are the object of intensive research, but it is historically proved that failures are generally due to the lack of tools to adequately forecast the behaviour of the potential customers. This generally induces a poor knowledge of the demand for the new service and a subsequent difficulty in designing an economically sustainable system.

The choice task in our survey was different from a classical Stated Choice, or Stated Preferences (SP) experiment in two major points, which reflect the above discussion on the differences between mode choice and modal diversion. These points are well illustrated by the questionnaire screen snapshot reported in figure 1, which shows the two SP questions related to the two bus services. First of all, we did not present the alternatives together with their attributes in a symmetric way through two SP cards, as it is customarily done. In fact, our choice task is not “cognitively symmetric”, since people had to consider switching from an option which they know to something new. Consequently, only the attributes of the new option were presented to the respondent, who had then to compare these attributes with his/her past travelling experience. We believe that this methodology can mimic much better the mental process of the respondent in this case, which is quite different from a classical consumer choice scenario, where the different brands are equally considered before the purchase.

The second major difference is that the respondents did not have to make a clear choice between the two alternatives, but rather to express their propensity to change mode on an ordinal scale. Note that this is different from the “rating task” as described in SP textbooks, where the subject has to rate every option, but without explicitly expressing a choice. Expressing a propensity is consistent with the above mentioned “asymmetric design” of the experiment, since it would be difficult for the respondents to express a clear choice between an experienced alternative and something unknown, which is only described through some performance indicators. Our scale should then help decreasing the measurement error of the response. The resulting variable SWITCH is then an ordinal variable with an 11-point bipolar, scale where not all the points are explicitly labelled, as shown in figure 1. SWITCH will be the only endogenous variable of our modelling effort. A translation into English of the texts is displayed in figure 1 for the reader’s convenience. We incidentally note that this translation is very literal to preserve the original meaning as much as possible, so that the original text in French sounded much more natural to respondents than the one here presented.

Figure 1.

3.2 Exogenous variables definition

The exogenous variables that we use are listed in table 1. Variables that are present in the dataset or that are directly built from them are written in normal characters, whereas the unobserved latent constructs are italicised and the indented rows below them report the corresponding observed variables. The last column of the table reports the range of values given by the respondents for each observed variable. Latent constructs are quantified through a later presented structural equation modelling technique. These exogenous variables overall pertain to the following aspects: the performances of the competing transport modes, the multimodal habits of the respondent, their cognitive as well their affective attitudes concerning the trip under investigation. Both observed variables and latent constructs are defined as follows.

3.2.1. Relative performances of the competing transport modes

At the outset, we consider the following four indicators to describe the performances of the competing systems: waiting time, walking time, travel time and cost of the trip. These quantities, referred to the mode that has been actually used, are directly asked to the respondents in the first part of the survey. During the SP experiment, the corresponding four quantities for the proposed services are then computed solely on the basis of the reported trip distance, according to the analytical derivation detailed in [69], and are then displayed in bold characters in SP cards like the one in figure 1 (please note that the values here displayed are just for illustration, the correct ones are shown only when the interview actually takes place).

The final step is to compute the performances of the new mode as regards the performances of the mode that has been used, thus obtaining the *relative* performances of the new mode. For example, the relative performance of the new bus service in terms of waiting time is given by the waiting time which is computed and shown by the system during the SP interview minus the waiting time which has been reported by the respondent when performing the trip (again, see [69] for the detailed procedure to compute all the four relative performance indicators). These relative performances allow us to consider through single indicators the influence of both modes on the switching propensity. We determine in this way the four variables REL_COST, REL_TIME, REL_WAIT and REL_WALK, which are listed in the first four rows of table 1. We note that the range of values of these variables is quite wide, negative values indicating a better performance of the new mode and positive values a better performance of the experienced mode. Therefore our assumption is that these four variables have a negative effect on SWITCH.

3.2.2. Multimodal habits

The importance of “multimodal” beyond “monomodal” habits within the study of mobility behaviours has been shown in previous research [53, 72, 73]. In section 2, we reviewed the massive research efforts aimed at determining the influence of the repetitive use of a given transportation means (usually the car) on mobility behaviours. In the following, instead, we consider the “transport habit” concept in a complementary way, by taking into account the reported changes in modal uses when repeatedly performing the same trip and the stated propensity to use different transport means in the future. Multimodal habits are then assessed by looking at the number of different transport modes that the respondent indicated having used to complete the same trip in the past (PAST_MEANS), and the number of transport modes that the respondent is considering to use in the future to complete the same trip (FUT_MEANS). We see from table 1 that respondents indicated respectively up to 6 and 4 different means, chosen among the following 15: foot, roller/skate, bicycle, car, moped, motorbike, urban bus, tramway, subway, commuter train, long-distance train, long-distance bus, taxi, boat and plane.

In the following we do not directly define PAST_MEANS and FUT_MEANS as exogenous variables of our model, because it is the multimodal habit that is postulated to influence the switching behaviour, rather than these two variables that only partly capture the habit concept. It is then more appropriate to define a MULTIM construct on the basis of PAST_MEANS and FUT_MEANS, as shown in lines 6 to 8 of table 1, through the below specified measurement model. Our hypothesis is that MULTIM has a positive effect on SWITCH.

3.2.3. Cognitive and affective modal attitudes

Attitudes are considered here by introducing the theoretical distinction between cognitive and affective ones, a standard practice in the social psychology literature dating back the Sixties [74]. In our framework, cognitive attitudes, referring to perceptions, can be seen as the evaluations expressed by the respondents concerning specific attributes of the trip they have made, whereas affective attitudes refer to the emotional states that were induced by the trip itself. The interested reader is referred to [75] for a review on cognitive and affective attitudinal data applications in transport research. Here we only incidentally note that other authors [76] introduce also a third category of attitudes, called conative or behavioural, referring to the tendency to act in a certain way in a given framework or under the influence of specific environmental conditions. We believe that the above introduced MULTIM construct could actually capture some aspects of this latter component.

Cognitive and affective attitudes are therefore represented by the two latent variables COGNIT and AFFECT. Our questionnaire asked to evaluate several items related to cognitive and affective attitudes through 11 points bipolar ordinal scales. We report in figure 2 two excerpts from questionnaire screen snapshots, again literally translated from French as for figure 1, that show how respondents rated items for the two different categories of attitudes. Statistical analyses that allowed for the selection of the best items and the definition of these two constructs are reported elsewhere [70]. COGNIT and AFFECT were respectively indicated with the symbols η_3 and η_5 in that work. Here we directly build on those results, keeping the same definitions but considering only three indicators for each construct to improve the model parsimony. These six indicators are reported in the indented lines at the bottom of table 1. As for the SWITCH variable, we see from figure 2 that graphical devices (smileys for items related to cognitive attitudes and coloured bars for items related to affective attitudes) were used to label the points of the scales, so that we report scores from -5 to +5 in table 1 for ease of presentation, even if these scores were not shown to the respondents. Figure 2 reports the six items that are considered here, although in the original questionnaire they were not presented in this order and other items were interposed.

We finally note that in the present research we consider the reliability and flexibility of a transport means through the user perspective, thus including them in the cognitive attitudes construct, even if they could also be seen as attributes of the transport means itself, like travel times and costs. However it should be noted that the direct measurement of modal reliability and moreover flexibility is not so immediate or univocal as when considering times and costs. The analyst could then define some indicators, for example based on notions of punctuality or frequency, that well capture the concept but that might not well represent the user's point of view. This could lead to some attenuation or bias in the study of the relationship between reliability or flexibility and modal diversion. For this, we preferred to privilege to the maximum possible extent the user's perspective and consider these two aspects through the cognitive attitude concept. Statistical analyses presented in [70] support this assumption.

In the following we test the hypothesis that more positive attitudes concerning the experienced trip would result in a lesser propensity to change transport mode, so that the relationships between COGNIT or AFFECT and SWITCH should have a negative sign.

Table 1 and Figure 2.

3.3 Mode switch models

We estimate mode switch models by using the structural equations modelling (SEM) technique with the LISREL 8.72 software. Our models assess the relative influence of the above defined exogenous variables on the switching propensity, according to the experimental plan described in the following section. The structural model defining the relationship between the exogenous variables and SWITCH and the measurement model that defines the latent constructs MULTIM, COGNIT and AFFECT were jointly estimated through maximum likelihood, with correlation matrices as inputs. Polychoric correlations have been considered for the ordinal variables related to attitudes, whereas Pearson product-moment correlations have been used for metric variables representing the relative performances and the multimodal habits, and polyserial correlations have been considered when one variable was ordinal and the other was metric.

The initial dataset used for the estimation was obtained by pooling together the 164 observations from the survey that are relative to the five different transport services. Hence we obtained a sample size of 720, after listwise deletion of the missing cases. We acknowledge that one potential problem in doing so is to overlook that repeated observations from the same subject could not be independent, thus leading to potential biases in estimates, particularly concerning standard errors. However this approach still represents the state of practice in SP transport studies [77, p. 296]. Only in more recent years some works have specifically addressed this issue, but it is noteworthy that nobody recommends to avoid pooling repeated SP observations from the same subject, to the best of the author’s knowledge. Seminal research is instead elaborating corrective procedures through resampling techniques [78], mixed logit formulations with lagged dependent variables [79, p. 149-151] or error component decompositions [80]. We refer the interested reader to [81] for an extensive discussion of this problem. In the present work we do not take into account such research developments, also considering that we are not in a discrete choice modelling framework based on random utility theory as the above mentioned researches, so that the proposed corrective procedures would not easily be applicable in our case.

4 Results

In the following we present the estimation results of switch models that separately evaluate the relative importance of multimodal habits, cognitive and affective attitudes compared to that of the service characteristics and performances. The goal was then not so much to achieve the maximum predictive power, which would probably have led to a more complex model to jointly consider all these factors. This should be kept in mind when interpreting the following results. Beyond this, these results are only valid for our sample and cannot be generalized; they are presented here only to show the potential of the method of analysis that we propose. Significance levels concerning the estimated coefficients have been computed considering that our theoretical framework allowed us to specify the expected signs of the relationships, as mentioned in the previous section. One-tailed *t*-tests are thus appropriate in our case, so that for example we consider a *t* value of 1.645 for the 5% significance level.

For the sake of briefness we do not present the detailed fit assessment discussion for all the proposed models, simply reporting the most widely used goodness-of-fit measures in a table later in this section, when presenting the models estimation results. We only observe that fit statistics of the considered models meet the thresholds that are customarily considered acceptable in exploratory research, according to common practice [82]. For example, the root mean square error of approximation (RMSEA) is in fact smaller that 0.08 and the critical N value greater than 200, with one exception (namely, for model 3) that will be discussed in section 4.2.

4.1 Model 1: service attributes versus multimodal habits

In model 1 we match the importance of the four service attributes against that of the multimodal habits of the respondent to predict SWITCH. Therefore the five exogenous variables of this model are REL_COST, REL_TIME, REL_WAIT, REL_WALK and MULTIM. Figure 3 shows the path diagram for this model, together with the standardised estimates of the considered structural relationships and the corresponding t-statistics in parenthesis. These structural relationships are represented by the five arrows pointing to the endogenous variable SWITCH. Standardised estimates allow us to immediately appraise the relative importance of the different independent variables on the switch propensity. In the same figure, the two arrows pointing to PAST_MEANS and FUT_MEANS represent the measurement model for MULTIM and the corresponding coefficients are their factor loadings. Following standard conventions, the latent variable MULTIM is represented by an oval and all the remaining manifest variables by rectangles.

Figure 3.

With one-tailed t-tests, all the structural relations of the model are significant at the .05 level. As expected, a greater attitude to use different transport means positively relates to an increased propensity to try out the new service in our group. It can be seen that the influence of multimodal habit on the endogenous variable is appreciable, even if it is about half than that of the relative cost and of the relative travel time and about one third less than that of the other two relative performances of the service. This result is in any case rather remarkable, since our multimodal habit construct heavily loads on the number of means that the respondents have actually taken in the past. It is in other words a confirmation of the importance of habit conceived not only in monomodal but also in multimodal terms.

4.2 Models 2 and 3: service attributes versus cognitive and affective attitudes

Models 2 and 3 respectively assess the influence of cognitive and of affective attitudes on the switching propensity, compared to that of the transport system performances. The corresponding path diagrams are respectively reported in figures 4 and 5. Also in this case, both figures report standardised estimates and t-statistics of the coefficients to ease a comparative assessment of the influence of different factors. Beyond these results, we note that the correlations of the measurement errors of the three items pertaining to the COGNIT construct are highly significant. This represents a confirmation on the timeliness of using a structural equation modelling approach to study the problem.

Figures 4 and 5

We see from the structural coefficients of figure 4 that the effect of cognitive attitudes is smaller than that of the first three attributes but comparable to that of the relative walking time of the two competing services. The influence of affective attitudes on the other hand could not clearly be assessed within our framework. This can be inferred by the fact that the relative structural relationship is highly not significant (p = 0.25), so that it is indicated with a dotted line in figure 4, but moreover by the fact that the model does not fit the data, as shown by the measures in the fourth column of table 3, and therefore has to be rejected.

On the basis of these findings one might conclude that cognitive attitudes are more linked to the experience of travelling by a given transport means for our group of respondents, whereas affective attitudes express an evaluation of the travelling activity itself, so that they could have a limited influence on the switch propensity. However this latter interpretation is somewhat puzzling, since at least two of the items which load on the affective attitudes construct (namely, the sensation of freedom and the sensation of well-being) have been widely acknowledged by past research as inherent the use of private cars, and about one third of the reported trips is done by car in our sample. A possible explanation is that the measurement of affective attitudes is affected by a greater error, so that the relationship we would like to study is attenuated. Beyond this, the Stated Choices experimental context elicits a rather rational decision-making process, in which affective attitudes could be less considered. Nevertheless it is possible that they would still have an influence in a real choice situation, where individuals possibly tend to simplify their cognitive tasks by recalling past emotional states. This in turn would be the indicator of a decisive difference between stated intentions and behaviours. However, to the best of the author’s knowledge, studies on modal diversion that analyze this difference [6, 7] do not consider affective attitudes as we do, so that further investigation is needed on this point before one can conclude that affective attitudes are not relevant for modal diversion.

4.3 Submodels 1A, 1B, 2A, 2B: known versus unknown transport services concepts

In this section we present some results coming from the estimation of the above presented models 1 and 2 on specific subsets of the observations. In this way, we would like to assess if the determinants of the switching propensity play a different role when considering the “cognitive differences” among new transport services, i.e. services that can be somewhat imagined by its potential customers versus services whose concept itself is little known because of its “technology contents”. We consider bus services and demand responsive transit as examples of these two categories, according to the Stated Choice experiments described in section 3. We do not perform a separate analysis for the switching propensities to taxi services, since as we noted these latter can be considered as an intermediate case. Therefore, we estimated the above models 1 and 2 when the stated switching propensities to (A) bus and (B) demand responsive services are separately considered, thus respectively originating the new submodels 1A, 1B, 2A and 2B. The sample size after listwise deletion of missing observations becomes thus 288 for “A” models and 289 for “B” models, since we recall that in our experimental plan we have two observations for buses and two for DRT for each respondent.

We present in table 2 the estimation results of the structural relations to the SWITCH variable for models 1 and 2 again on the whole sample (second column), on the switching propensities for buses (third column) and for DRT (last column). Unlike the results shown in figures 2 and 3 and earlier commented, unstandardised estimates are now considered, since the focus is to draw comparisons of the role of each exogenous variable across different subsamples, i.e. to compare the numbers that are on the same line. Therefore the second column of the table shows the estimates of the same structural coefficients that are reported in figures 3 and 4, but the values are of course different since the figures report standardised estimates.

The fit of these four submodels did not significantly change compared to that of the model estimated on the whole sample, keeping into account the smaller sample sizes that produce lower chi-square statistics (see table 3). On the other hand, significance levels of the estimated coefficients is also sensitive to sample size, and this partly explains why some structural relations in table 2 are now not significant at the 5% level; comparing significance levels across samples of different sizes would in fact be incorrect.

Tables 2 and 3.

Data from table 2 give indications on the changing role of the determinants of the switching propensity across different transport means. We preliminarily point out that the signs of the coefficients do not change with these new estimates, thus confirming our assumptions, with the partial exception of the variable REL_WALK in submodel 1A whose effect is however highly not significant. Considering submodel 1A against model 1, the most evident result is that the role of REL_TIME and REL_WAIT becomes predominant in determining the attractiveness of the new bus service, whereas REL_WALK is less of a matter. This is a clear indication of the importance of the performances that a bus service should reach to be considered attractive, perhaps to counterbalance the negative image which is usually associated with this transport mode. The variable MULTIM is now not significant at the 5% level, but comparing the relative unstandardised coefficients its influence seems accrued. This is only an apparent contradiction, due to the aforementioned sensitivity of t-tests to sample size and having 2.5 times fewer observations in submodel 1A than in model 1. Keeping this fact in mind, we can conclude that multimodal habits play an important role in determining the attractiveness of a not yet existing bus service.

A comparison of models 1 and 1B shows the difficulty of forecasting the demand of a service which is not readily figured out by its potential users. The influence of 4 out of 5 variables is attenuated, and it is particularly striking the decreased role of REL_COST. It is possible that when considering a service for which the respondents do not have sufficient information we are moving further away from a classical rational decision-making context. Evaluating the alternatives through some key variables usually considered in econometrics (travel times and costs) is more difficult for customers and other elements might be considered. We come back to this point when commenting the results of models 2, 2A and 2B. On the other hand, the influence of MULTIM is lessened but still detectable. This is quite interesting and reinforces the parallel conclusion drawn when comparing models 1 and 1A, since it is unlikely that the multimodal habits of the respondents include demand responsive services. Recalling the definition of the MULTIM construct, we can say that the fact of having used a greater variety of transport modes in the past or considering using it in the future can be in any case an indicator of the willingness to try a new means, even if the latter does not belong to the originally considered set of transport modes.

Estimation results of models 2, 2A and 2B largely confirm the above findings concerning the role of the four variables REL_COST, REL_TIME, REL_WAIT and REL_WALK. Concerning the influence of cognitive attitudes, it can be seen that they become irrelevant when switching propensities to a bus service are considered (submodel 2A), whereas on the contrary their importance sharply increases when the focus is on demand responsive services (submodel 2B). We see then a positive correlation between the degree of acquaintance with the concept of a transport mode and the importance of more objective and quantifiable elements such as costs and travel times over qualitative ideas such as reliability, flexibility and comfort. As a general policy guideline, it is therefore evident that both the implementation of new transport services and its related marketing strategies should focus on different aspects, according to the degree of innovation of the service.

5 Conclusions

This paper reviewed past research in the mode choice and modal diversion fields and applied the modal diversion paradigm to study the relative importance of transport means performances and of more subjective factors concerning the propensity to use a new transport mode. Analyses have been carried out at the trip level, looking at the possibility of diverting trips that where actually done by a group of clerical workers, rather than investigating in general terms the availability to try out the new service. Conclusions of a study carried out in this way should then be more readily interpretable in terms of policy guidelines. Our results are of course only valid for the specific group of clerical workers that we interviewed, since it can not be considered as statistically representative of any general population. Nevertheless, in the following we comment them also in terms of policy implications, since it is important to assess the usefulness and the power of the proposed method of analysis as a policy decision support tool.

Findings from sections 4.1 and 4.2 show that both multimodal habits and cognitive attitudes turned to be important elements in determining the propensity to switch mode, whereas the influence of affective attitudes has not been shown in our experimental context. The latter result might partially depend on the experimental framework, which somewhat elicited a rational decision-making process concerning the switch propensity, as it is often the case in SP experiments. It is possible that in real-life choice situations people more consistently rely on affective attitudes to instinctively decrease their cognitive burden.

Not considering multimodal habits and cognitive attitudes could lead to biases in the estimation of the demand for new transport services in our sample, even if the influence of self-related factors is less relevant than the influence of the performances of the new system. The policy implications of such finding depend on the specific study context. For example, the potential demand for a new transport service in a context where car use is predominant should not be estimated on the basis of the demand for the same service in a different area, where modal market shares are more equilibrated, in order to avoid an overestimation of the demand. The methodology that we presented shows how to explicitly take into account this factor.

A more disaggregated analysis was carried out in section 4.3, in order to assess if the determinants of the switch propensity change according to the kind of new transport service. The degree of innovation of the service in relation with past experiences of its potential users turned out to be an important factor. Services whose concept is (presumably) well-know by their potential users have to be competitive on the classical economic ground, i.e. costs and travel times, in order to divert passengers from other modes, and they will be more successful with customers with more multimodal behaviours. These elements are still important when an innovative concept comes on the transport market, but switching propensity will also be greatly affected by the degree of satisfaction with current modes in terms of more qualitative factors such as reliability and comfort. These latter could partially offset any consideration of this new opportunity solely based on more objective and measurable elements.

Also in this case, some policy implications can be drawn on the basis of these results, whose validity cannot of course be extended beyond our group of clerical workers. Marketing mobility services that are unknown by the users is essential to attract customers, solely relying on their competitiveness in terms of performances could be insufficient. Information campaigns should then be targeted at lowering the cognitive burden undertaken by potential customers, willing to figure out how the innovating service works. Past multimodality behaviours are instead a driving force in the widespread use of a new mobility service whose concept is not unknown. In this case, policy actions aimed at increasing a more variegate use of different modes (for example, discouraging the use of the predominant mode) could increase the patronage of the new system.

A more complex behavioural model which puts together those aspects that here have been separately considered in models 1, 2 and 3 is currently under consideration. It is in fact possible to fully take advantage of the capabilities of the SEM technique to explore the intertwined relationships among competing services performances, personal attitudes and habits in order to gain further insights on the modal switch mechanism. This will probably require a new dataset coming from a larger survey, compared to the exploratory one which has been presented here, that of course should involve a random sample from a general population in order to obtain findings of general validity.

Acknowledgements

We acknowledge INRETS (The French National Institute for Transport and Safety Research) for its financial and logistical support in the data collection phase of this research.

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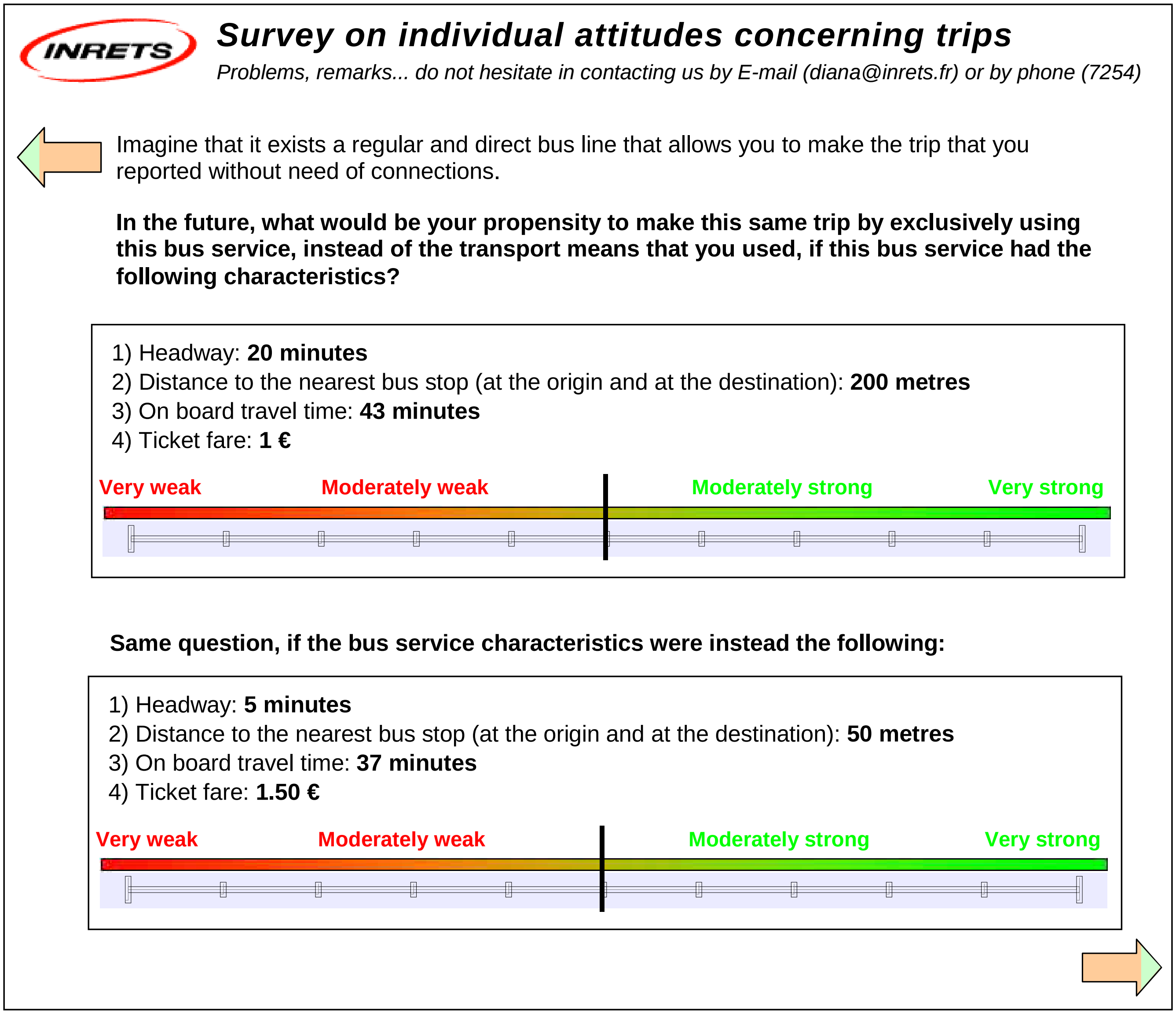

Figure 1. English translation of the questionnaire screen snapshot showing one modified SP experiment

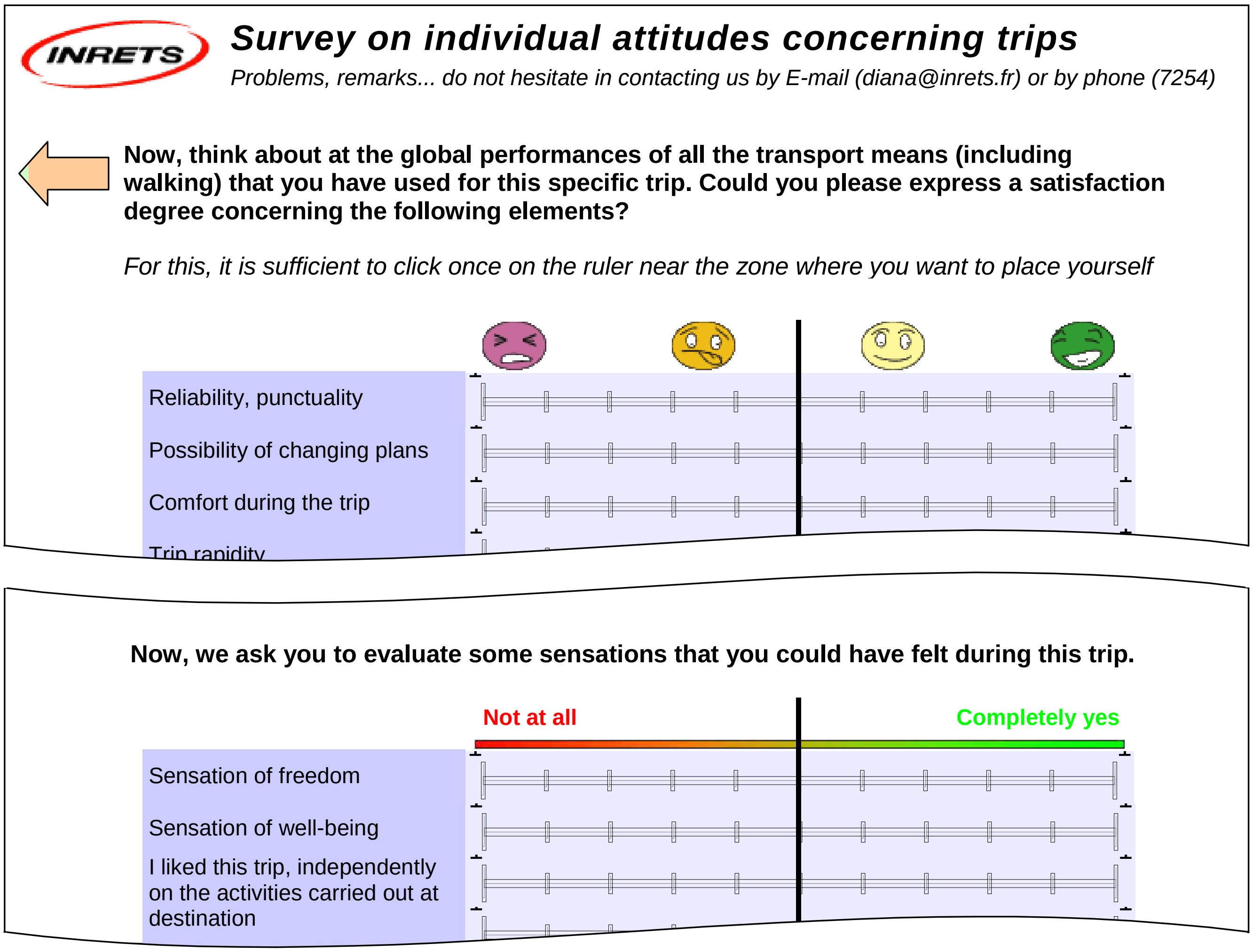

Figure 2. English translation of two questionnaire screen snapshots showing the three retained measurement items for COGNIT (top) and AFFECT (bottom) constructs

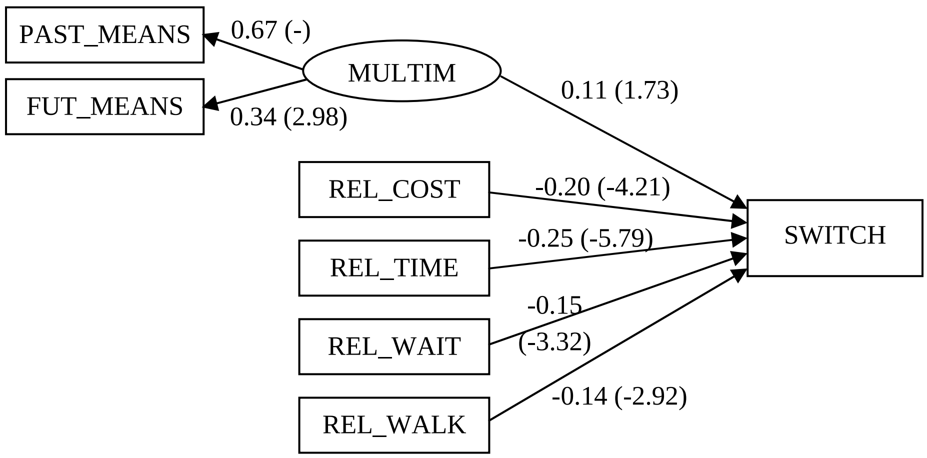

Figure 3. Path diagram of model 1 with standardised estimates and the corresponding t-statistics (in parenthesis)

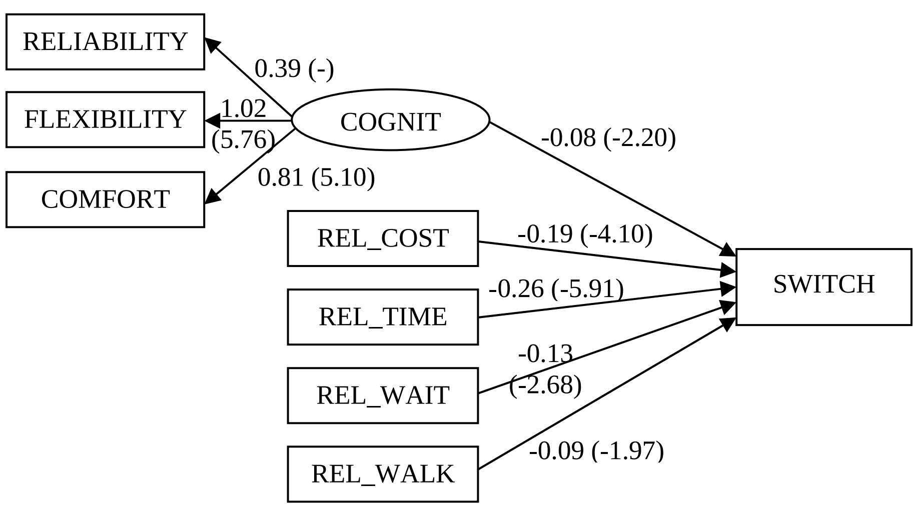

Figure 4. Path diagram of model 2 with standardised estimates and the corresponding t-statistics (in parenthesis)

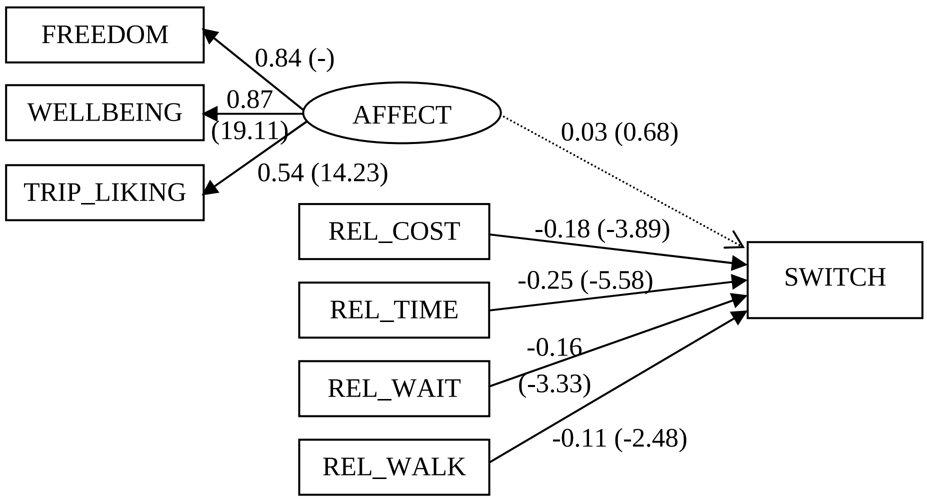

Figure 5. Path diagram of model 3 with standardised estimates and the corresponding t-statistics (in parenthesis)

Table 1

Observed and latent variables which are considered in the model

Label	Description	Observed values
REL_COST	Cost of the trip with the new service - Cost with the used means	-31.1 to +25.6 €
REL_TIME	Travel time with the new service - Experienced travel time	-465 to +152 min.
REL_WAIT	Waiting time with the new service - Experienced waiting time	-50 to +4.8 min.
REL_WALK	Walking time with the new service - Experienced walking time	-40 to +10 min.
MULTIM	*Multimodal habits concerning the specific trip*	
PAST_MEANS	Number of different transport means used in the past for this trip	From 0 to 6 means
FUT_MEANS	Number of different transport means planned for use for this trip	From 0 to 4 means
COGNIT	*Cognitive attitudes concerning the specific trip*	
RELIABILITY	Reliability of the transport mode which has been used	Scores from -5 to 5
FLEXIBILITY	Flexibility of the transport mode which has been used	Scores from -5 to 5
COMFORT	Comfort during the trip	Scores from -5 to 5
AFFECT	*Affective attitudes concerning the specific trip*	
FREEDOM	Sensation of freedom during the trip	Scores from -5 to 5
WELLBEING	Sensation of wellbeing during the trip	Scores from -5 to 5
TRIP_LIKING	Overall trip liking	Scores from -5 to 5

Table 2

Unstandardised estimates of the structural relations to SWITCH

Scenario	All observations	Buses (submodel A)	DRT (submodel B)
Model 1			
REL_COST	-0.20	-0.11 *	-0.07 *
REL_TIME	-0.25	-0.39	-0.21
REL_WAIT	-0.15	-0.29	-0.14
REL_WALK	-0.14	-0.05 **	-0.15
MULTIM	*0.17*	*0.29* *	*0.15* *
Model 2			
REL_COST	-0.19	-0.08 *	-0.07 *
REL_TIME	-0.26	-0.38	-0.21
REL_WAIT	-0.13	-0.27	-0.11 *
REL_WALK	-0.09	0.01	-0.10 *
COGNIT	*-0.20*	*-0.08* **	*-0.29*

NB: * = not significant at the 5% level
** = not significant at the 20% level

Table 3

Goodness-of-fit measures for the proposed models

Fit measure	Model 1	Model 2	Model 3	Submodel 1A	Submodel 1B	Submodel 2A	Submodel 2B
Likelihood-ratio chi-square	20.75	25.65	85.28	11.33	7.54	17.02	12.43
Root mean sq. err. of approxim. (RMSEA)	0.076	0.055	0.099	0.079	0.055	0.061	0.043
Goodness-of-fit index (GFI)	0.99	0.99	0.97	0.99	0.99	0.99	0.99
Adjusted goodness-of-fit index (AGFI)	0.94	0.96	0.90	0.92	0.95	0.94	0.95
Critical N	461	564	196	337	508	339	466