WHAT DO YOU DO WITH YOUR APP? A STUDY OF BUS RIDER DECISION-MAKING WITH REAL-TIME PASSENGER INFORMATION

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ABSTRACT

Provision of Real-Time Passenger Information (RTPI) is increasingly becoming a fundamental element of the service offered by transit agencies. RTPI changes the way in which travellers perceive public transport services and it can have remarkable consequences on travel choices and eventually on system performances. Such consequences depend on the objectives pursued by the riders and the characteristics of the transit service. We extend the existing knowledge on transit RTPI by studying the decision-making process of bus passengers in the presence of multichannel descriptive and prescriptive real-time information. We investigate use of different kinds of information, decision-making objectives, travel choices, and their associations (defining what we call classes of travel choice behaviour) through a survey of Lothian Buses passengers in Edinburgh. We observe that descriptive RTPI is largely accessed also before travelling and it influences above all the decisions concerning route choice. Our analysis demonstrates that RTPI is associated to more flexible behaviour, and that there are well-defined classes of behaviour. Our results emphasise the importance to transit agencies of providing RTPI tailored to their customers. We recommend the development of models including the effects of RTPI in order to assess its impact in terms of system performance.

INTRODUCTION

Public transport uses space more efficiently than other motorised modes, contributes to emission reduction, and encourages healthier life styles. Therefore within the current paradigm of sustainable mobility *(1)* transport policy aims at increasing the role of transit in answering the demand for passenger mobility, above all in urban contexts.

Nowadays Real-Time Passenger Information (RTPI) is increasingly available to and expected by transit riders. Designing, installing and operating the ITS required for the provision of RTPI can generate significant technology and staff costs for transport agencies and operators *(2, 3)*. Hence it is important to understand the demand for and the effects of RTPI to plan investments in passenger information wisely.

Human behaviour is determined by habits, motivations, opportunities and constraints. Route choice is a complex, multi-objective decision-making process, requiring different kinds of information. For example, besides reducing travel times and monetary costs, travellers may be interested in maximising the probability of getting to destination on time. In this case, they will consider not only the travel time expectation but also its variability. RTPI improves the visibility of transport services and thus it can widen the set of alternatives contemplated by travellers. For illustration purposes consider the simplified case of rational travellers aiming only at reducing travel time. Without RTPI such travel time minimisers choose always the option with the minimum *expected* travel time. With RTPI, they can consider also alternatives which are slower *on average* but *in specific cases* can be faster. In other words, RTPI makes more opportunities *actually* available. This could promote a beneficial shift from habitual to planned travel behaviour *(4)*.

Two consequences can be expected from RTPI diffusion: an increase in ridership and a different use of the service. It is known that transit ridership is linked to factors external to the public transport systems – such as regional geography, metropolitan economy, population features, and characteristics of the highway systems – as well as to public transport policies *(5)*. Evidence about the impact of RTPI provision on patronage is not conclusive, although some studies have found positive correlation *(6)*. The potential for RTPI to encourage the use of public transport seems to be greater where the level of transit services is higher *(7)*. In any case it is evident that, in a world ever more dominated by the Information and Communication Technology (ICT), a public transport system that did not offer RTPI would be doomed to experiencing decreasing modal shares in favour of the car mode, which can rely on information deriving from a large number of ICT applications.

How and how much travellers change their route choice depend on the characteristics of the RTPI itself and on the objectives of the decision maker, and are constrained by the transit supply features. The case of real-time information on occupancy at bus stops is useful to illustrate the interaction between RTPI and decision maker objectives (note that this kind of information is not largely available at the moment but it is in the development plans of major transit agencies). The content of the information (bus occupancy) and its characteristics (real-time, available only when the passenger reaches a stop) are such that travellers are enabled to select less crowded vehicles but not to decide to board a different vehicle because this way they will get to destination earlier. If the stop is served by more lines heading towards the passengers' destination, choosing different buses can induce different line loads, but if only one line is available then the same information will not change the line patronage. It has been shown that RTPI about crowdedness of incoming vehicles is relevant only for specific user groups and trip purposes *(8)*. Therefore RTPI makes the opportunity of changing available, but this opportunity becomes an actual change only for those passengers for whom riding less crowded vehicles is important. Normally travellers can access different kinds of information, have the possibility of defining several characteristics of their trip, and endeavour to achieve different objectives. Knowledge is still largely incomplete on the existence of patterns in how travellers use multi-source RTPI to pursue their goals by deciding the characteristics of their travel in complex transit networks *(9)*.

The paper is organised as follows: In Literature review, the existing research on the influence of RTPI on transit passenger decision-making is critically summarised and the contributions of our work are highlighted. Edinburgh and its system mobility, including a successful public transport system, are introduced in Public transport in Edinburgh to provide the background of the study. The survey, and the general features of the respondents and their trips are presented in Survey. Use of information, and decision-making objectives and dimensions are analysed individually and in relation to travel demand in Use of information and Decision-making respectively. Then TCBCs are defined using variable cluster analysis in Classes of travel choice behaviour. Results are summarised and discussed in Synthesis and conclusions.

LITERATURE REVIEW

In general decision makers can pursue two aims: maximising, i.e. selecting the best available option, or satisficing, i.e. selecting a sufficiently good alternative (which might be the least unsatisfactory one). The choice between maximising and satisficing can depend on the trade-off between the accuracy of the information and the effort to obtain it *(10)*. In both approaches information can be sought by travellers to discover unknown options (alternative generation) and/or to complete their knowledge regarding known options (alternative assessment). Chorus et al. *(11)* provide an interesting view of travel decision-making, and a thorough review of models for alternative generation (sometimes referred to as search models) and alternative assessment (developed applying expected utility theory, prospect theory, or regret theory) in the transport field.

The complexity and the variability of the transport service, and the age and the degree of “technological sophistication” of the passenger population determine the level of the demand for Advanced Traveller Information Systems (ATIS) *(12)*. The required information depends on the characteristics of both the traveller (safety concerns, lifestyle and demographics, familiarity with the transport system, comfort with complexity and technology, accessibility requirements) and the trip (nature or purpose of the trip, journey stage, trip frequency) *(13)*.

Information can become available to travellers in different forms: Descriptive information is an account of the current or predicted conditions of networks and services. Fujii and Kitamura *(14)* find that descriptive information can be more influential than experience in route choice. Currently the most commonly available real-time transit descriptive information concerns service disruptions, arrivals/departures and travel times. New services are becoming increasingly available which offer updates on vehicle crowding conditions, also in collaboration with users. Prescriptive information is an advice on the alternative to choose. Such recommendations are based on the computerised elaboration of descriptive information. The potential benefits of prescriptive routing information increases with the quality of the information used for the elaboration *(15)*. Feedback information is ex-post information concerning the chosen alternative and the foregone payoff.

As discussed, RTPI is credited with the potential to influence public transport passengers in several ways. Dziekan and Kottenhoff *(16)* identify seven categories of effects: reduced perceived wait time, adjusted travel behaviour, increased willingness-to-pay, different mode choice, higher satisfaction, better image of the system, other psychological effects. Utilisation of wait time, more efficient travelling (i.e. route choice leading to shorter travel times) and decisions such as letting more crowded vehicles go are examples of travel behaviour adjustments.

Empirical studies have looked at psychological and, to a lesser extent, behavioural effects of RTPI. A 20% reduction of the perceived wait time has been observed following the installation of displays at stops and stations *(17)*. A study of Dublin public transport system shows that bus users, who experience longer waiting times and a greater sense of frustration, are more likely to benefit from RTPI than train passengers *(18)*. The impact of RTPI can be amplified when the information is disseminated through different channels, including mobile technology. In one of the few studies of multichannel information systems Watkins et al. *(19)* find that information users have a more correct perception of wait time. Furthermore the possibility of knowing the bus arrival time before getting to the stop significantly reduces actual wait time from 11 to 9 min on average. Other measured psychological effects of multichannel RTPI are an increased feeling of security when riding a bus after dark and higher overall satisfaction levels *(20)*. *(19)* and *(20)* consider only descriptive information.

Travelling using complex multimodal transport systems entails multidimensional decisions: the traveller may have to choose whether to make a trip and the destination, the mode, the route and the departure time. Decisions concerning public transport are complicated by the nature of the transit service, which is discrete in time and sparse in space. For instance, in the simplest scenario – a single stop with a single line – prospective passengers have to choose which service they are going to use and their arrival time at the stop, on the basis of stochastic quantities such as the vehicle arrival time and the in-vehicle travel time. ATIS and in particular RTPI can assist travellers in taking better decisions in all these dimensions. Dziekan *(21)* analyses literature review and expert opinions and concludes that the behavioural effects of RTPI are to be fully understood yet. Despite ten years have passed since the study, the knowledge about the topic does not seem to have improved much. In the existing literature, no significant difference is found between the behaviour of passengers using only timetables and that of passengers relying only on experience, whereas RTPI is associated with longer duration of impacts and higher utility of decisions *(22)*. According to a survey reported by Multisystem *(13)*, in consequence of pre-trip information bus and ferry commuters are likely to change departure time, to switch mode, and to adapt their routes. Other insights on the likely impacts of RTPI can be drawn from the much more substantial body of literature on real-time information about car drivers. SP and RP experiments confirm that route choice is the outcome of the interaction of information with habits. In the case of prescriptive information, the outcome depends on the decision to comply with the suggestion. Information can determine route choice by changing the attitude towards risk of travellers. Both compliance and risk attitude are affected by the accuracy of information *(23)*.

Transit route choice models have been proposed considering RTPI under the assumption that the objective of decision-making is minimizing the overall travel time. They show that departure time information at stops can bring forth remarkable changes in line loads whereas the reduction of the average travel time and its variability are more modest.

Greater accuracy of information does not seem to affect travel times significantly *(24, 25)*. Simulation shows that en-route information on bus arrival increases the wait time but reduces the in-vehicle time. Interestingly when discomfort from crowding is considered together with information about bus occupancy, it does not change travel times but it does increase passenger utility *(26)*. The availability of RTPI allows choosing different alighting and transfer points. This has an impact on the expected travel time comparable with that of the line choice *(27, 28)*. Dissemination of information through mobile devices is predicted to yield significant reductions of travel time and again remarkable changes in the way travellers use the network *(29)*. Most recent research considers that RTPI enables route choice objectives more complex than minimising the expected travel time. The way in which the information is elaborated and communicated, and the combination of RTPI and route choice objectives can largely influence flows *(30)*.

We present a study of bus rider decision making with RTPI. In particular we determine the existence of Classes of Travel Choice Behaviour (TCBCs). By TCBC we mean any combination of different types of RTPI, travel choice and decision-making objective frequently considered together by travellers. The research is based on a survey among the passengers of Lothian Buses (LB) in Edinburgh. Our paper extends the current knowledge on the impact of RTPI in several ways. We contribute to the scarce literature about multichannel information and, different from previous research, we explore use and effects of real-time prescriptive information. We investigate the whole range of travel choices entailed in the traditional four-step approach to transport modelling *(31)* instead of focusing on single behavioural and/or psychological impacts of RTPI. Acknowledging that actual travel behaviour is determined by the interaction between information and attitudes, we study the objectives of the decisions of public transport users and their link with information and travel choices (TCBCs). Last but not least we deal with a successful public transport service, which can be useful to define best practices.

PUBLIC TRANSPORT IN EDINBURGH

Edinburgh, the capital of Scotland (UK), has 476,600 inhabitants, 51.2% of which are female. Half of the population is younger than 35 and 71% of working age. With a surface of 264 km^2 it has a density of about 1.8k residents per km^2. The annual average gross disposable income per resident is above £17k, a value second only to that of London in the UK. With almost 60k university students and 3.7m visitors per year, the city is very popular inside and outside the UK *(32)*.

At the moment of the survey, the only available transit option were LB buses. LB runs 73 lines, including 11 night and 7 express services. The bus network has a prevailingly hub-and-spoke topology, with many radial services and fewer orbital ones. In the proximity of the city centre there is a high incidence of common lines *(33)*. Day services are in operation from 4am to midnight. Frequencies range from 2 to 6 services per hour. A flat fare is charged. Travel cards are available. In 2013 LB buses transported 115.4m passengers, with a rise of 4.2% on the previous year.

The public transport service in Edinburgh is generally appreciated and largely used. 30.8% of employed residents travel to work by transit (23.0% by an active mode). The success of transit is confirmed by the fact that, despite the wealth of the city, 40% of households do not have a car. The mobility system of Edinburgh tends to evolve towards the adoption of more sustainable forms of transport, as demonstrated by the increase in the number of people going to work by bus and of households without car in the last decade *(34)*.

Real-time information is supplied by a fleet management tool called BusTracker (BT). All the 600 LB buses are equipped with the BT technology. RTPI is disseminated in several ways: arrival times can be retrieved at stops, from the LB website (http://www.lothianbuses.com) and through ad hoc mobile apps. LB offers a real-time transit journey planner, which can be used on-line or via a mobile app (the latter was not available at the time of the survey). The schedules of the LB services are available in Google Maps. Timetables and maps are present at every bus stop. The sources of information available to LB passengers are characterised in TABLE 1 according to their availability, up-to-dateness, content, and versatility.

SURVEY

A survey among LB passengers was carried out in some weekdays between 7 August and 27 September 2013. A questionnaire of 12 questions (TABLE 2) was administered by two surveyors at six central bus stops and on-board two orbital bus lines. A convenience sampling approach was adopted. The final sample includes 613 passengers, interviewed in different demand segments: 22.5% during the AM peak (7-10am), 40.0% in the central hours of the day (10am-12noon and 2-5pm), 24.5% during the PM peak (5pm-7pm), and 13.1% at night (9-10pm).

Passengers

Women and men are evenly represented in the sample (Q.X). Respondents are quite young (Q.XI). The vast majority of participants live or work in Edinburgh and so presumably they are able to figure out travel alternatives also without the help of journey planners (Q.XII). Only 8% of participants are occasional visitors despite 74.7% of responses were collected in August when the city hosts very popular festivals (the largest one, the Edinburgh Festival Fringe, sold almost 2m tickets in 2013). No significant association is found between demographic variables.

Trips

Most of the respondents are involved in regular trips (Q.I). The familiarity with the trips is confirmed by the destination, which is home or the work/study place in most cases. Buses are seldom used for personal or family business and even less for other activities, whereas they are more popular for leisure activities (Q.II). There is a significant association between regularity and destination, with trips towards home or the work/study place occurring several times a week. Most of respondents travel alone, groups of adult passengers are also relatively common, few respondents accompany children (Q.VIII). The trip characteristics change significantly along the day. AM and PM peak trips are typical of urban commuting travel patterns: ⅔ of AM and half of PM peak trips are made every weekday. ¾ of AM peak trips have the work/study place as destination, whereas about half of PM peaks and night trips head towards home. The difference in the proportions of regular trips between the morning and evening peaks might be due to our definition of the peak periods (7-10am and 5-7pm) and show that people start going home earlier than 5pm.

There is no publicly available statistic concerning LB usage so the representativeness of the sample cannot be evaluated. However the interviewers were instructed to avoid bias in stopping people. Despite the convenience approach to sampling, we are quite confident that the survey has produced a realistic picture of the LB riders and their trips.

USE OF INFORMATION

Although the majority of participants are familiar with the city and involved in regular trips, still information is largely sought (Q.III). Only 6.0% of respondents do not consult any information source. The most popular information source are the BT displays at stops. Mobile apps (BT_apps) are also common. The same kind of information retrieved by apps (real-time bus arrival time) can be found in the LB website (BT_web), which of course can be accessed using the same mobile phones on which apps are installed. Nevertheless BT_web is much less popular. Probably this is linked to the greater user-friendliness of apps. Even though the two sources communicate the same information, they may be used differently, with the web-based information consulted more through computers. In the following, since BT_apps and BT_web provide the same information and can be used by the same phones, we consider them together, as a single source called BTw_apps that is consulted by 48.6% of respondents (BTw_apps takes value 1 if BT_web and/or BT_apps is used). Printouts (of maps and timetables at stops) are still largely used. Sources able to provide prescriptive information are not very common in general but their popularity doubles in peak times: the web-based LB journey planner (JP_web) is used by 5.5% respondents in non-peak times and by 10.6% in peak times. The analogous percentages for Google are 6.2% and 11.8%. The result about BTw_apps shows the large diffusion of descriptive information broadcasted though mobile phones, i.e. of a type of real-time information that, being available before going to a stop, can generate substantial traveller behaviour changes. Note that the scarce use of prescriptive information does not necessarily imply that itineraries are fixed. It could also be that travellers do not need prescriptive information because they are familiar enough with the trips and the network to know the existing alternatives and to choose them on the basis of real-time information on bus arrivals.

People using JP_web more use Printouts and Google significantly more (TABLE 3). The former result is surprising because the JP_web information outperforms that of Printouts from every point of view so one might think that people using JP_web do not need Printouts. A likely explanation is that travellers confirm the JP_web information looking at Printouts. This would mean that respondents trust "hard" sources more than electronic ones. The association with Google is more expected, since both sources provide itineraries, but one has real-time information and the other can advise on different modes. It might be that passengers, after deciding to travel by public transport consulting Google, look for real-time information in JP_web.

Defining the information versatility of each response as the versatility of the most versatile used information source ([a], [d] in TABLE 1), we find that 46.7% of responses show a low versatility (0-1) and 39.5% a medium one (2). The level of versatility is significantly higher during peak times (cases with versatility=3 are 18.1% in peak and 9.9% in non-peak periods). Responses with versatility=0 (i.e. cases in which only Printouts are used) range from 3.8% in the evenings to 14.1% in the midday periods.

DECISION-MAKING

Objectives

The responses about the three main decision-making objectives show that Getting to destination ASAP, Reducing travel time and Reducing waiting time are more important than Reducing walking distance, Reducing transfer numbers, and Spending more time at the origin (Q.VI). 82.9% of respondents indicate one of the objectives in the former group as their most important goal. The cumulative frequency of the group becomes 73.4% and 62.0% for the variable describing the second and the third most important objective respectively.

The association between decision-making goals has been studied by looking at the mentions of each objective among the three most important criteria. The related binary variables are indicated by the prefix F3OBJ: e.g. F3OBJ_Get_to_des is 1 if the respondent indicates Getting to destination ASAP as first, second or third criterion. TABLE 3 shows that Getting to destination ASAP is not significantly associated with Reducing travel time: this is as an evidence that travellers are able to distinguish the two concepts, which might have been confused by non-specialists. Getting to destination ASAP is significantly associated with Reducing walking time but not with Reducing transfer numbers. The opposite holds for Reducing travel time. The result suggests that the overall effect of RTPI in terms of transit service use is influenced by the primary objective of the traveller.

Respondents seem to decide about their journeys considering mainly the features of the trip: the only non-travel-related objective, Spending more time at the origin is among the most important criteria only in 17.2% of cases and it is significantly more common as one of the first three objectives in non-peak (21.5%) than in peak times (12.5%).

Dimensions

In the following, decision-making "dimension" means a specific choice considered in a decision-making process involving decisions of different types, e.g. deciding the bus to board. Decision-making dimensions are investigated through Q.V. Only 16.7% of the respondents do not use the acquired information to make decisions, which means that in the vast majority of cases information does change the way in which the transport system is used. Information influences all the passenger dimensions considered in the four-step model: the decision of making a trip (Journey), the selection of the final destination (Final_des), the modal choice (Transit). We consider the departure time from the origin, the departure stop (Dep_stop), the bus departure time, the used line (Line_ch) and the alighting point as dimensions defining the route choice. In the practice of modelling, often the departure time from the origin is neglected and the first and alighting stops are considered input. Here they are included among the route choice dimensions because they can modify the loads of lines and buses *(30)*, being determinant in the assignment stage. 78.0% of respondents use the information to decide at least one route choice factor. In particular the time of the bus to board is the most commonly affected choice dimension, followed by the line and the departure stop. Changing the alighting point is an almost completely neglected option, even less frequent than Final_des.

The number of the dimensions potentially affected by the retrieved information is an indicator of the flexibility of choices. 55.9% of the responses consider changes in no more than one dimension, 79.1% in no more than two. The probability to consider changes in at least one dimension is significantly higher (1.3 times) when RTPI is sought than when no information or historic information only is consulted. This demonstrates that RTPI enables less rigid choices. The frequency of Line_ch and Dep_stop demonstrates that many passengers adopt a strategic decision-making behaviour, in which more itineraries are considered attractive and the chosen one depends on the occurrence of random events such as the departing time of a given bus. Both variables are significantly and positively associated with looking for information within half an hour before getting to the stop (TABLE 3). This supports the expectation that pre-trip RTPI increases the number of considered alternatives.

The flexibility of choices does not change significantly with the demand segment, although in midday and PM peak hours there are more cases in which more than two dimensions are considered. The only dimensions that have a significant association with the demand segments are Line_ch and Final_des. In peak times, i.e. for regular trips, fewer alternative lines are considered. Instead the set of destinations of the non-regular trips is larger in non-peak times (TABLE 3).

CLASSES OF TRAVEL CHOICE BEHAVIOUR

In this section we characterise the TCBCs of LB passengers using information by detecting patterns of association among the variables describing the use of information and the decision-making objectives and dimensions. To this purpose we use variable cluster analysis.

We present two analyses, defined by the decision-making dimensions included in the model. In the "strategic model", we study all the dimensions included in the four-step model. Decisions related to route choice are represented by the aggregate variable Route_ch, which is equal to 1 if a change is considered by the respondent in at least one of the route choice dimensions (Origin_time, Bus_time, Dep_stop, Line_ch). The possibility of making no change is also considered through the variable Nothing. In the "route choice model", only route choice dimensions are studied. The choice of the alighting point is not included in the presented analysis, because its elimination does not affect the results (as it can be expected given that the option is chosen only in very few cases) and it makes their presentation easier. The decision-making objectives are represented by the "F3OBJ" variables (the prefix is omitted in the discussion below).

Hierarchical variable clustering is applied in both cases using SPSS 20. SPSS 20 implements an agglomerative approach: starting from the situation in which each element is a cluster, similar elements are progressively merged in the same cluster until all elements are part of a single cluster. The average linkage between groups is chosen as clustering method: at each stage, the two clusters with the highest average similarity are combined, where the average similarity is the ratio between the similarity of the two groups and the product of the number of elements in each of the two clusters *(36)*. The similarity between two variables is measured by Phi ([a], [b] in TABLE 3). The dendrograms representing the two agglomerative processes are shown in FIGURE 1. The vertical lines connect the elements which are combined in a cluster at a given stage of the process. The distance of the vertical line representing a cluster from the left side of the diagram is proportional to the difference between the elements merged in the cluster at that stage. In the figures, the prefix INFO is used for the variables representing information and DIM for those representing dimensions.

Strategic behaviour

The strongest links are those between the elements of the clusters {Google, Final_des} and {Red_wait, BTw_apps} (FIGURE 1(a)). The first clusters to form with more than two elements are {BTw_apps, Red_wait, Route_ch} and {Google, Final_des, Journey}. This shows that Google is used for highly "undefined" trips, i.e. when the traveller is uncertain about the destination or whether to make the journey. BTw_apps is strongly associated with the attempt to reduce waiting time by changing route choice elements. We can conclude that passengers conceive Google as a planning tool and BTw_apps as a tactical resource to implement travel plans (defined by destination and mode) effectively.

Clustering is an unsupervised learning technique. The output of a clustering procedure is a partition of the cases or variables of a dataset in homogeneous groups. Although some indicators are available to measure the quality of a division in groups, there is no conclusive criterion to affirm that a given partition is better than another, and so to decide how many clusters (in our case how many TCBCs) are present in a dataset. The partition which better represents the structure of the data has to be defined considering the objective of the analysis and the characteristics of the clusters in the partitions. Among the criteria proposed in literature to guide the decision on the number of clusters in a hierarchical clustering procedure, we adopt that of the maximum gap: In a dendrogram consecutive vertical elements far from each other point out stages of the agglomerative process in which the algorithm somehow "forces" the formation of a cluster, i.e. it combines elements that are loosely linked. The clustering before the largest gap between consecutive vertical lines is a good starting point in the search for the "natural" number of clusters. In our model, the largest change is between stages 2 and 3, but the agglomeration is not advanced enough to suggest any meaningful insight. The second largest variation (between stages 14 and 15) suggests two clusters: {Nothing, Get_to_des, BT_stops, More_orig} in the lower part of the dendrogram, and that gathering the remaining variables in the upper part. However looking at the signs of the similarity measures between the objectives included in these clusters, we think that the most meaningful partition is that in which each of the two clusters is divided in its two main components. Eventually our analysis highlights the existence of four TCBCs (red boxes in the figure): the first, {Google, Final_des, Journey, Transit, Red_walk, Printouts, JP_web, Red_trans}, is characterised by the fact that the respondents consult information sources to make decisions concerning the higher levels of the four-step model. The association between the decision-making dimensions and the information sources in this class has two possible explanations: On the one hand, in unfamiliar trips, defined with the help of Google and JP_web, travellers tend to reduce elements decreasing their confidence, such as walking along unknown paths or changing bus. On the other hand, there might be cases of travellers who venture into unknown trips to walk or transfer less. In the second cluster, {BTw_apps, Red_wait, Route_ch, Red_trav}, travellers aim to reduce travel time, acting on the wait time. To achieve their goal, they need the help of ubiquitous real-time information on bus departure and they must be available to change their route choice. In the third TCBC, {Nothing, Get_to_des, BT_stops}, the respondents want to get to destination at the earliest time. They consult BT_stops but often they do not to change their travel choices. Probably this class is typical of regular trips, in which travellers normally do not have or do not consider the possibility of changing their habits, and information has mainly psychological and/or confirmatory value. The last cluster is made up by More_orig, not associated with any strategic decision or source of information.

Route choice model

BTw_apps is strongly associated to Origin_time (FIGURE 1(b)), i.e. ubiquitous BT information is much used to decide the departure time from the origin. Interestingly Origin_time is linked more to Red_wait than to More_orig, i.e. travellers seek information to reduce the discomfort of waiting more frequently than they do to enjoy more time at the starting point of their trip. The second most homogeneous cluster with more than two elements is {Printouts, Bus_time, Line_ch}. The link between these variables shows that Printouts are still used to select lines and departure times. This happens frequently in unfamiliar trips, as suggested by the fact that the cluster is grouped with {Google maps, Dep_stop} at a later stage: indeed it can be expected that travellers decide the departure stop by consulting Google when they are not acquainted with the trip.

The "natural" clustering identified by the largest gap method includes three clusters – {BTw_apps, Origin_time, Red_wait, More_orig}, {JP_web, Get_to_des}, {Google, Dep_stop, Printouts, Bus_time, Line_ch, Red_walk} – and three single variables – Red_trans, BT_stops, Red_trav. Red_trav is the last variable to be merged in a cluster and it is associated with the same strength to the variables in the upper and in the lower part of the dendrogram. This shows that reducing travel time is an overarching objective of route choice. Similarly, the difficulty to include BT_stops in a specific cluster may be ascribed to the fact that looking at displays at stops is a very common habit, shared across objectives and dimensions in the lower part of the dendrogram. The result regarding Red_trans can be explained by the fact that not many transit trips in Edinburgh involve transfers, and so the occurrence of this choice in the responses is highly random. In conclusion the route choice model brings to light three TCBCs (blue boxes): from the top of the dendrogram, the first is that in which descriptive real-time information is consulted before starting a trip to decide the departure time from the origin in order to minimise the wait time. Then there are the trips in which getting to destination ASAP is important and JP_web is used. Although the link between the two variables is not very strong, two applications of JP_web seem to emerge, corresponding to the characteristics of its information: at a strategic level its capacity to suggest itineraries is used to plan unfamiliar trips. When it comes to put plans into practice, its real-time information help minimising the arrival time. The last TCBC is defined by bus and/or stop changes. In this case, BT_stops is crucial and Printouts are used above all when passengers are not familiar with the itinerary.

SYNTHESIS AND CONCLUSIONS

RTPI can affect travellers' cognition of transit services and hence it can change their behaviour. Knowledge about the behavioural dynamics triggered by the interaction of multichannel RTPI with decision making objectives and dimensions, and their consequences in terms of network performance is limited and fragmented. We contribute to the understanding of the topic through a survey among bus passengers in Edinburgh.

Although respondents are very familiar with their trips, information is largely used. Descriptive RTPI (real-time bus arrival time) is much sought, both at stops (BT_stops) and via internet (BTw_apps variable). The latter channel allows accessing the information before starting traveling and so enables the choice of different departure stops, as assumed in recent models of transit systems *(27, 29, 30)*. BTw_apps are used by almost half of respondents. Prescriptive RTPI (real-time optimal paths) is much less widespread, but its popularity doubles during peak times. Printed information has still a large appeal, probably as a way to confirm the electronic one. When RTPI is available, different decision-making objectives can lead to different route choice decisions *(30)*. Our survey shows that reducing travel time, the only objective traditionally considered in urban transit system models *(24, 25)*, is not the only aim pursued by bus riders: getting to destination ASAP is more important and reducing wait time is not much less common. In the vast majority of cases (about 85%) information does have a behavioural impact. All the choices entailed by the four-step model are affected by information but route choice is by far the most influenced (in almost 80% of cases). The bus departure time is the most commonly affected single decision-making dimension. 30% of respondents consider changing their departure stop and/or line, i.e. they show a strategic approach to route choice. Passengers whose attractive travel choice sets include multiple stops and lines consult pre-trip information more often. This confirms that ubiquitous information fosters more adaptive behaviour. The study of TCBCs shows that descriptive

RTPI is especially sought for tactical reasons, i.e. to modify route choice in the attempt to reduce waiting time. In particular BTw_apps are more strictly associated with deciding the departure time from the origin, whereas BT_stops with selecting a different bus. Prescriptive RTPI has two applications: at the strategic level it is used to plan unfamiliar trips; at the route choice level, to minimise the arrival time. The limited use we find can be explained by the acquaintance of most respondents with their trips.

Our analysis, concerning a successful transit system, proves that RTPI – above all the descriptive one – is largely consulted by passengers, irrespective of their familiarity with the transit service, and it is linked to significant behavioural changes. Such changes are associated with decision-making objectives and types of information in well-characterised TCBCs. This suggests that transit providers should keep investing in RTPI, allocating resources according to the characteristics of the travel demand. For instance, regular customers interested in reducing their wait time could value improvements in the availability and accessibility of real-time information on bus arrival times more than the possibility of obtaining real-time optimal itineraries.

Our work can be extended in several directions. Our dataset should be further analysed to estimate the impact of RTPI and decision-making objectives on particular travel choices. Further behavioural research is needed to study the relation between habitual and planned behaviour *(4)* in the presence of RTPI, as well as the prevalence of different TCBCs and their links with transit service features. Finally, an effort is required to develop new models to assess the impact of the behavioural changes induced by RTPI, in particular that of a greater flexibility of choices, on system performance.

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TABLE 1 Information sources for LB passengers

Source of information	**Type of information**	**Availability** [Local (i.e. only at stops): 0[a], Ubiquitous (i.e. via web): 1]	**Up-to-dateness** [Scheduled: 0, Real-time: 1]	**Content** [Bus Arrival Time and/or Route only: 0, +Itinerary[b]: 1, +Mode[c]: 2]	**Versatility[d]**
Printed timetables and maps at stops	Descriptive	Local	Scheduled	Bus Arrival Time and Route	0
Bus Tracker at stops	Descriptive	Local	Real-time	Bus Arrival Time and/or Route	1
Bus Tracker at LB website	Descriptive	Ubiquitous	Real-time	Bus Arrival Time and/or Route	2
Mobile apps	Descriptive	Ubiquitous	Real-time	Bus Arrival Time and/or Route	2
Journey Planner at LB website	Prescriptive	Ubiquitous	Real-time	Bus Arrival Time and/or Route + Itinerary	3
Google maps	Prescriptive	Ubiquitous	Scheduled	Bus Arrival Time and/or Route + Itinerary + Mode[d]	3

[a] Versatility score of the attribute (see note [d] below for more details)
[b] Here "Itinerary" means a combination of walking and on-board segments (possibly including the use of different lines) suggested by the source to get from the origin to the destination of the journey
[c] Here "Mode" means that the source suggests also travel solutions which do not involve public transport
[d] The versatility index measures the ability of an information source to support real-time route generation and assessment. The index is the sum of the versatility scores of the information source attributes.

TABLE 2 Questions in the survey

Question	Available answers [a]	Statistic
Please answer the following questions regarding the journey you are currently making. In the following, by "origin" we mean the place where you were before going to the bus stop. The "destination" is the final place you are going to. A place can be your home, a school, a shop, a park, etc.		
I. How frequently do you make this journey, i.e. how frequently you travel between the origin and the destination of this travel (considering also other means of transport)? Please choose one of the following.	1: Usually every weekday 2: Not every weekday but at least once a week 3: Less than once a week 4: Very few times/it's my first time	50.6[b] 31.7 10.7 7.1
II. What is the destination of your journey? Please choose one of the following.	1: Home 2: Work or study place 3: Personal or family business place (i.e. shop, GP, nursery) 4: Leisure place (i.e. gym, theatre, park) 5: Other	30.3[b] 41.3 7.5 16.2 4.7
III. What source of travel time information have you used or are you going to use? Please select all that apply.	1: None 2: Printed timetables and maps at stops [Printouts] 3: Bus tracker at stops [BT_stops] 4: Bus tracker at Lothian Buses website [BT_web] 5: Journey planner at Lothian Buses website [JP_web] 6: Mobile apps [BT_apps] 7: Google maps [Google] 8: Others [Other]	9.0[c] 30.9 74.7 12.5 7.4 41.1 8.1 1.5
IV. Where have you consulted or are you going to consult your information sources (if any)? Please select all that apply.	1: More than half an hour before starting travelling 2: Less than half an hour before going to my departure stop [Less_half] 3: At the departure stop 4: At each stop involved in my journey (if you have to transfer) 5: On board	15.7[c] 37.1 64.2 7.6 7.0
V. What have you decided or are you going to decide using the information (if you use it)? Please select all that apply.	1: Whether to make my journey [Journey] 2: Whether to use public transport [Transit] 3: The time at which I left from my origin [Origin_time] 4: The departure time of my bus [Bus_time] 5: The departure stop [Dep_stop] 6: The bus line(s) [Line_ch] 7: The alighting point [Alighting] 8: The final destination of my journey [Final_des] 9: I have not changed/I will not change my plans [Nothing]	6.8[c] 10.5 24.3 46.8 28.1 30.9 3.7 12.1 18.1

VI.	What are your goals in deciding your itinerary? Please rank the three criteria most important to you listing them from the most to the least important.	1: Getting to my destination as soon as I can [Get_to_des]	32.1;22.0;21.1[d]
		2: Reducing my travelling time [Red_trav]	27.2; 26.8;19.1
		3: Reducing my wait at stops [Red_wait]	23.7;24.5;21.8
		4: Reducing the distance to walk [Red_walk]	7.0 ;12.3;14.9
		5: Reducing the number of transfers [Red_trans]	5.0;7.0;13.6
		6: Spending more time at the origin [More_orig]	5.1;7.4;9.4
VII.	If when you consulted information sources you realised you had some spare time before the arrival of your bus, how did you use it? Please select one of the following.	1: I spent more time at the origin of my journey	26.9[b]
		2: I did business on my way to the stop or nearby the stop	15.1
		3: I walked to a further bus stop	27.0
		4: I did not do anything but I felt more relaxed whilst walking/waiting	31.0
VIII.	Who are you travelling with? Please choose one of the following.	1: Alone	78.4[b]
		2: With children	2.8
		3: With children and other adults	4.0
		4: With other adults only	14.8
IX.	What line are you going to take?		
X.	Are you male or female?	1: Male	53.2[b]
		2: Female	46.8
XI.	What's your age?		24; 32; 45[e]
XII.	How familiar are you with the city of Edinburgh? Please select one of the following.	1: I live and/or work here	86.4[b]
		2: I am a frequent visitor	5.6
		3: I am an occasional visitor	8.0

[a] The abbreviations in square brackets are used to indicate the attributes in the remaining of the paper. The abbreviations are also used as names of binary variables equal to 1 if the attribute has been selected in the response: e.g., JP_Web=1 if in Question III the respondent said that s/he used Journey planner at Lothian Buses website. The meaning will be made clear by the context.
[b] Percent of valid responses
[c] Percent of cases
[d] Since respondents were asked to rank the goals and there are 6 possible goals, 6 variables are defined from this question: the first considers the choice concerning the most important goal, the second the replies regarding the second most important goal, and so on. The percentages here are the frequency with which the attribute has been selected as 1st; 2nd; 3rd choice respectively.
[e] 25th; 50th; 75th percentile respectively

TABLE 3 Associations between some variables

Variable A	Variable B	Significance of the association[a]	Strength of the association[b]	Section[c]
JP_Web	Printouts	0.001	1.8	Use of information
JP_Web	Google	0.000	3.3	
F3OBJ_Get_to_des	F3OBJ_Red_trav	0.748	1.0	Objectives in Decision-making
F3OBJ_Get_to_des	F3OBJ_Red_walk	0.000	0.5	
F3OBJ_Get_to_des	F3OBJ_Res_trans	0.052	0.5	
F3OBJ_Red_trav	F3OBJ_Red_walk	0.140	0.8	
F3OBJ_Red_trav	F3OBJ_Res_trans	0.020	0.6	
Less_half	Line_ch	0.000	1.7	Dimensions in Decision-making
Less_half	Dep_stop	0.002	1.5	
Peak_time	Line_ch	0.042	0.8	
Peak_time	Final_des	0.020	1.7	

[a] p-value of the Phi coefficient between the binary variables A and B. The squared value of Phi is equal to the Chi-square divided by the sample size. Phi can range between -1 and +1 with positive values indicating that concordances (i.e. cases in which the attributes are either both present or both absent) outnumber discordances.

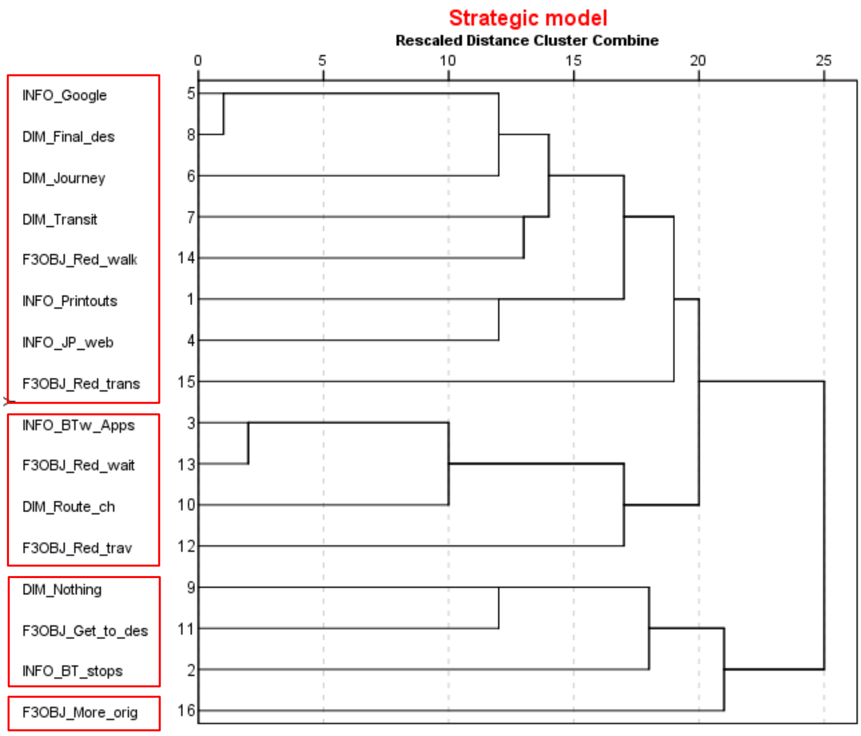
[b] The value of Phi is influenced by the marginal distributions: when the distribution of cases in either variable is very different from 50%-50%, the absolute value of Phi cannot reach 1. Therefore relative risks are presented here to describe the strength of the association between attributes *(35)*:

$$\text{Relative Risk }(A,B)=\frac{\text{Prob}(B=1|A=1)}{\text{Prob}(B=1|A=0)}$$

Where Prob indicates the observed frequencies. Relative Risk $(A,B)>1$ means that subjects with the attribute A are more likely to show the attribute B than those without it.

[c] Where the association is discussed in the paper

(a)



(b)

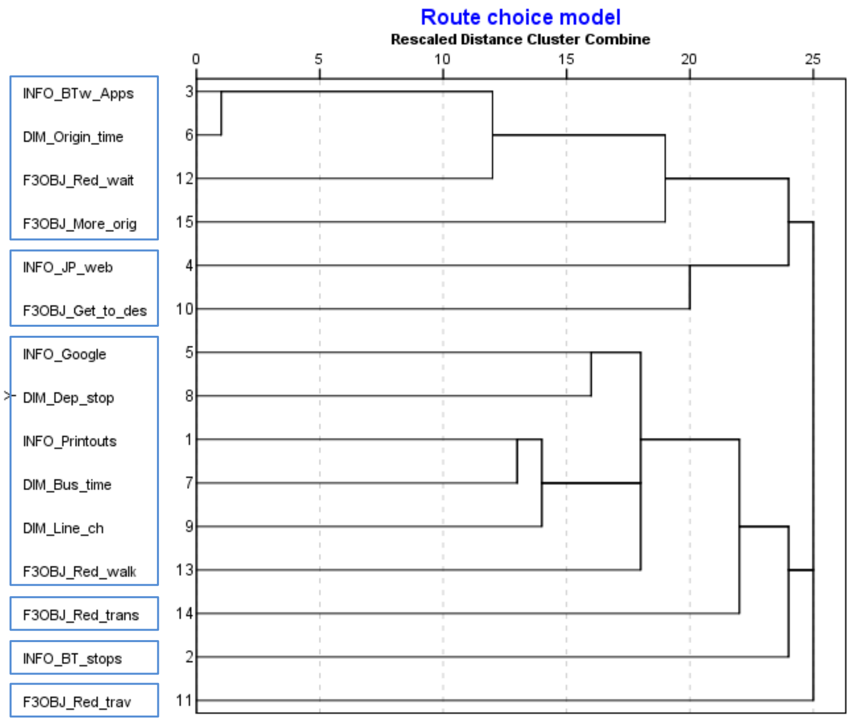


FIGURE 1 Dendrograms of the strategic (a) and route choice (b) model