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User-Centred Design in Public Transport: Discovering Mobile User Needs

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Abstract
In recent years, the design of mobile transportation apps has become a key area for cities and transport operators. However, less common is user research for the purpose of informing design. This paper reports findings from a mixed-method user study, which examined journey planning habits, usability of commercially available mobile transportation apps, and attitudes towards probabilistic recommendation ('predictive') digital journey planners. The study is part of a project aimed at incorporating a structured user-centred design process in the design of mobile apps for transportation, with study methodology intended to serve as an exemplar for future user-centred mobile app projects. Such a process is important for ensuring that transport apps are as successful as possible in meeting passenger needs. Findings will inform a later mobile app prototype, based on key design implications identified in the study: designing for distinct user groups, trust, user context, and adapting user research methods in transportation.

Keywords: Journey Planning, User-centred design, Usability, MaaS

Introduction
Digital journey planning has become an important part of the travel experience, whether intra-urban or intercity, but especially in large urban agglomerations with complex multi-modal transit systems. Increased proliferation of mobile devices, coupled with transport data being made available by cities under an 'open access' model, has created a multitude of websites, apps, and technological platforms that are used by commuters. Governments on the national and local level promote the development of journey planning technologies in order to optimise commuter interactions with transportation systems.

The use of mobile apps is increasingly becoming a key part of urban mobility. Commuters as well as transport system operators are increasingly recognising the benefits such apps have in making the urban commute quicker and more efficient. Companies in the transportation domain are working to develop technological solutions that will facilitate this objective, either by competing for officially sanctioned 'design and build' contracts, or by developing independent consumer-facing solutions. Transport operators have acknowledged the need for design research as one of the means to improve customer experience, with customer experience being a key study field in the recent Train Operator Competition 2016 [33]. Transportation technology companies routinely incorporate user-centric elements into their products to varying extents – from market research [27] to interaction design principles [26] as well as to user studies [44][42]. This approach is often mandated by government regulators; However, operators also see in it the potential for creating operational efficiencies such as reduction in customer service queries. More importantly, the data generated by continued engagement of passengers with products such as mobile apps can be utilised by operators to generate new revenue from areas such as advertising and retrospective ticket pricing [23].

Despite this, examples of a structured, well-defined User-Centred Design process in the development of these technologies are rare in the transport field. User-Centred Design (UCD) is an approach that places end-user needs and goals, rather than engineering goals, as the starting point and as the central driver of system design requirements [31]. It also defines an iterative process through which these user needs can be embedded into both system functionality as well as its user interface [32]. In the transportation field, the approach by experts to the design of consumer-facing technology is largely "ticket-oriented", often prioritising system interoperability and the demands of numerous stakeholders ranging from transportation companies to government – over the needs of end-users [19]. Adopting a structured and methodical UCD process to the development of mobile transportation technologies will give user needs a more central role in their design. This approach holds the potential to make digital services such as journey planning more responsive to user habits and needs, a concept demonstrated in other domains such as healthcare [10], E-commerce [35] and academia [36]. This in turn will make user interactions with transit systems more efficient, benefitting the individual commuter as well as the transit system as a whole (on issues of capacity under- and over-utilisation, for example).

The current study is the first phase in a project to create a mobile transportation app prototype within a user-centred design process. This phase is of fundamental importance in the UCD process, as it is meant to discover user needs and capture requirements early in the design process and produce subsequent designs that fit those user requirements. This paper details the mixed-method approach taken to elicit these user needs, and how they were adapted to suit constraints that are inherent in transportation research. Additionally, this paper discusses the implications and insight from key findings in the study for the design of mobile transportation apps, and examines the value of the methodology used in the study to user-centred design of mobile transportation apps.

Related Work

Investigations of travel behaviour and commuting habits are common in transportation research, with studies commonly focusing on *in*-situ passenger surveys [46][45], stated and revealed preference experiments [41][3][8][9], and analysis of journey information stored by transport operators [40]. While these investigations do not ignore design requirements for mobile apps, UCD insight is not their primary focus, and specific design-related research and discovery of user information needs is rare.

Digital journey planning is part of a larger subject-matter area known as Intelligent Transportation Systems (ITS), which deal with the dissemination and use of transit information by its various stakeholders: cities, passengers, and transportation technology companies. In the context of journey planning and end-user transit systems, ITS often refers to technological platforms that make 'intelligent' use of transit information – i.e. that suits the needs of a specific stakeholder. Schönfelder and Axhausen [37] attempted to capture the definition of a 'journey' or a 'trip' in the eyes of both users and transit agencies in different countries. Other research has focused on predictive concepts, i.e. 'learning' a user's regular travel patterns to determine optimal route choices and travel paths based on an individual user's preferences and smartphone sensor data [17][11]. In the context of mobile information services, a new approach known as *Mobility as a Service* (or *MaaS*) has evolved, which aims to introduce a higher level of seamlessness than that which exists today – to the multi-modal element of transport (i.e. transferring between modes) as well as to its payment methods, and envisions an ecosystem that does not require proactivity on the part of users for trip planning and payment [14].

User-centred design techniques often contribute to product design in the transportation domain, however, less common are implementations of UCD as a structured methodology to research and articulate user needs, and then prototype, design, develop and test new concepts. Examples do exist of UCD being applied to address targeted issues such as visual impairments [24], but not as an end-to-end methodology to discover user needs and address them through an iterative design process. André et al. implemented an iterative user-centred design process to develop a web-based prototype for a journey planner, and highlighted the importance of having user needs inform design [2]. Perhaps the most extensive work to develop a user-centric approach to ITS has been conducted by Hörold, Mayas and Krömker, who developed guidelines for incorporating user-centred methods and usability tests in the design of public transport information systems. Their guidelines focus on discovering and articulating different user groups for a transportation system, and on using methods that will accurately describe passenger information needs at every stage of their journey [19][20]. They also describe several dynamic contextual factors that affect information needs and interaction for users of public transport [21][22]. The need to explore these contextual factors had an important role in the choice of methods for the current study, as evident from its contextual 'in-the-wild' approach to data collection.

The current study adds to these earlier works of UCD in transport by adding usability evaluations of existing mobile transport apps, and attitudes towards predictive journey planning as additional data sources in the process of capturing user requirements – in addition to user habits and information needs. By synthesising findings from all three elements, the study hopes to paint a broader picture of user requirements for mobile transport apps. This will in turn serve as basis for future app that place as much focus as possible on passenger needs.

Method

Data collection focused on three topics that were identified potential basis for user requirements and prototype design later in the process: **user needs and habits**, **use of digital journey planners**, and **attitudes towards predictive journey planners**.

Location

Information was elicited from participants by interviewing them at Farringdon railway station in London, UK – a major interchange between several London Underground lines, suburban rail services, and numerous bus routes. Passenger traffic at the station is characterised by commuters who work in the area, and air passengers who utilise direct services from the station to two major London airports.

Participants

Participants were recruited by being approached at the station's ticket halls and rail platforms. Apart from research ethics-related requirements, the following two criteria were articulated for participation: 1) Use of digital journey planner (web or app-based), and 2) Participant is a regular commuter in London (rather than tourist/occasional visitor). Only a minimum age requirement and use of journey planner were defined imperative and explicitly confirmed prior to the interview.

Procedure

Several data collection methods were used. Each method was adapted for limited availability of participant time and attention in the study, and was designed to elicit complimentary information to the other methods, with the aim of better understanding distinct elements of user behaviour and attitudes.

Semi-structured contextual interviews: the overarching method in the study, which guided participant questioning throughout data collection, aimed at better understanding the user context and environment [18] (in the current study: waiting for a transport connection at a railway station), and potentially gain contextual stimulation of participants, thereby enriching the information provided by them. Contextual interviews were therefore ideal for this study. The interviews were semi-structured [16] in order to obtain data on topics of interest while allowing flexibility for participant elaboration.

Stated preference questions: for some interview questions, participants were asked to express and explain their preference between desired scenarios or between desired choices in a given scenario.

Critical Incident Technique (hereafter CIT): aims to examine the effect of a particular event (or: *incident*) on an individual's behaviour. The definition of an incident as 'critical' varies, but was originally defined as having a purpose or intent that is clear to the observer, along with a clear understanding of the event's consequences and effects [15]. More recently, the technique has been appropriated for investigating user behaviour in information seeking [25][43], owing to its flexibility for application in a wide variety of disciplines and for use with multiple methods of data collection [7].

In the current study, CIT involves a participant discussing in detail a memorable example such as a journey they planned, with the purpose of providing a more accurate depiction of that specific user experience, and to compliment stated preference data in the study with revealed preference data.
Simplified Think-aloud protocol: an adaptation of the Think-Aloud protocol popularized in the Human-Computer Interaction field [28], and argued by Nielsen [29]. Think-aloud involves a user thinking aloud as they perform a specific set of tasks on a system (in this case – a journey planner). It was adapted to suit constraints of participant time and attention inherent in the current study, and aimed to evaluate the usability and user experience of digital journey planners used by participants.

The interview included an initial screener followed by three modular sections. Each modular section was designed to be independent of the others, in order to make it flexible for both short and long passenger dwell time at the platform. Table 1 below details each of the modular sections.

Table 1 - Modular Interview Sections and Example Questions

Interview Section	Example Questions
Approach and screening: potential participants were approached and asked to participate in a passenger survey whilst they wait for a train.	*"We are conducting a passenger survey about using apps and websites to plan your journey"* *"Can you confirm that you are over 18 years of age?"*
CIT and journey planning habits: participant asked journey planner was used for current journey. If not, passenger is asked to recall a recent example. For both options, participants were asked if everything worked as expected, or if anything was unusual or unexpected.	*"Did you use [app/website] to plan your current journey" / "Think of a recent time when you did"* *"Can you show me how you used your device to plan the journey?"* *"Think about a recent journey on public transport that was unusual to you"*
General usability and data reliability: participants probed about perceived accuracy and reliability of information given by the journey planner.	*"What do you like about [app/website]? What do you dislike?"* *"How easy or difficult was it to plan your journey? Why?"* *"Have you encountered inaccurate information?"*
Predictive features: participants were asked questions about openness to predictive journey planning and potential privacy issues associated with such functionality.	*"If we were to develop a new service that would notify you proactively about travel disruptions and suggest alternative routes – would such a service be useful to you? How?"* *"Would you be willing to let such a service access your device's GPS functionality to learn your travel habits?"*

Data Analysis

Analysis was influenced in part by the topical focus of the study – habits and needs, usability and user experience, and predictive features. As study aims were largely exploratory, it took an open-ended data analysis approach that sought to uncover potential new areas of interest as well. To this end, data analysis was conducted on a thematic, semi-inductive basis, based in part on the principles of thematic analysis set out by Braun and Clarke [6]. Audio recordings were reviewed and important passages were documented, and were then categorised into new or existing categories of findings.

Findings

Findings are divided into three topics, which guided during data analysis and roughly align with the original topics of the study: journey planning habits, currently available digital journey planners – usability and user experience, and predictive journey planning. Some findings were expected prior to the study, though some unexpected findings about passenger behaviour were unexpected.

Journey Planning Habits

This section details user behaviour findings that are not technology- or product-specific. Such generic findings help understand the context in which journey planning happens and the resultant user information needs, and provides basis for future product functionality. Journey information centres around two types of data: route planning / timetable information, which does not change frequently, and Real-time Passenger Information (hereafter RTPI), which does change frequently – often minute-by-minute. In the current study, RTPI consists of ETA data (Estimated Time of Arrival) of a specific mode of transport [8], and of information about disruptions (i.e. delays and cancellations). Findings for both data types are articulated in Table 2 below as distinct use case (and non-use cases). Use cases were found to be an ideal vehicle for describing these findings, as they allow to match different scenarios to likely user groups and the needs of each group within a given scenario [5].

Table 2 – Use / Non-Use Cases for Journey Planning Information Types

Type of Information	Description
Route planning / timetables – use cases	Unknown area: current or future location is a geographical area that the passenger has not travelled to previously. Information need: complete routing from point A to B. Non-routine route: travel from home or work to a previously unvisited / infrequently visited location. Often combines a familiar route (e.g. to a rail/bus station) and a non-familiar route (e.g. an intercity train). Potential shorter journey: travel on a familiar route but shorter journey time is desired. Alternative route is chosen only if it offers significant time saving.
Route Planning / timetables – non-use cases	Known commute / direct route: everyday commute (e.g. work or school) or other frequent destination for which and has existing knowledge of modes and timetables. Known route with perceived high frequency: same as 'known/direct route', but with transport modes perceived to be frequent enough that they prior planning is not needed (e.g. metro services such as London Underground).
RTPI – use cases	Known commute route / direct route: everyday commute such as work or school. RTPI can significantly alter travel plans (e.g. suspended service forces alternative route). Known route with perceived high frequency: ETAs and disruption information (i.e. delays and cancellations).
RTPI – non-use cases	Casual travel on known route: travel on familiar route with knowledge of available transport modes and route options. Time is not of essence. Passenger arrives at usual point of departure, assuming departure within reasonable time.

Overall, use cases for timetable and RTPI data were inverted to non-use cases for route planning and vice versa (e.g. on a known route, timetable and real-time data are needed, whereas route planning was not). This has implications for interface design, which will be discussed later in this paper.

Some participants noted instances in which they prefer using a static map (i.e. non-interactive or even paper) to plan their route using a combination of visual information presented on that map (e.g.

interchange points) in combination with their own pre-existing knowledge of the transport network. While the journey planner Citymapper[1] was often cited in this context, static maps exist in other journey planners as well.

Participants also described a routing difficulty they often face during multi-part or multi-modal journeys: when interchanging at a large station or an area with many transport links, they experience difficulty in finding the physical location of their onward transport link. This happens despite being given an exact platform or bus stop number, and can best be described as a difficulty of spatial orientation. Participants indicated that neither signage nor existing journey planning services provide directions at station-level granularity, and therefore are not useful for resolving these challenges.

Currently Available Journey Planners: Usability and User Experience Gaps

This section details findings about user experiences with commercially available digital journey planners mentioned in the study by participants. An effort was made to generalise findings and establish common patterns among them, but several product-specific findings are included if justified by participant responses, or if specific functionality illustrates a significant usability issue. Findings focus on three main topic areas: data reliability, user context, and graphical user interface (GUI).

On the topic of data reliability, the study draws a distinction between perceived Accuracy and perceived Reliability of journey planning data. Accuracy is defined as the correlation between information disseminated to passengers and the actual operations to which that information related (e.g. whether a train departed at its denoted time). Reliability of information is an evaluation of information usefulness by a passenger considering its perceived accuracy (i.e. 'is this information accurate enough so I can make a decision based on it'). Most participants treat journey planning information with an attitude of 'trust but verify'. It is an essential step in their journey, but one they do not like to rely upon exclusively. Participants often described the supplementing of digital information with pre-existing knowledge and other information sources as needed. While not all participants had the same level of technical proficiency, they understood the mechanics of disseminating RTPI on one level or another. The majority of participants repeatedly cited a 'dissemination disparity' between RTPI and 'real-world' operations, but at the same time most were forgiving towards it, as they recognised the inherent unpredictability of train operations. Despite a certain level of tolerance to data inaccuracies, data reliability was described to be the key component in building trust with users, which in itself is a key factor in user engagement with a given journey planner. Participants mentioned this repeatedly as a factor that they continuously evaluate, both in comparison to their peer group, as well as on their own. Participants also described mitigation techniques for data inaccuracies, the leading of these being multiple app use. A majority of participants indicated that they often use more than one journey planner on a regular basis. This is done in two main scenarios: in the first, participants viewed a

[1] https://citymapper.com/

different app as better suited for each mode of transport they use (e.g. using the 'National Rail Enquiries' app[2] for long distance rail, and 'Bus Times' for bus arrival times). In the second scenario, participants described using different apps to get the same information (e.g. train checking departure times), as a way 'cross-check' the information and verify its accuracy. While the first scenario was sometimes due to perceptions of data availability within each app (e.g. passengers perceiving rail information to be available only in the 'National Rail' app) or familiarity and convenience, the second scenario carries an explicit purpose of trust and need for reliability by participants.

On the topic of user interface, findings are inherently interface-specific (to be detailed in 'comparative evaluation'), however, two particular insights arose from the study. First, most participants discussed the amount of information presented to them in a journey planning interface, either as a stated preference or when describing experience with current journey planners. Participants referred to this as on-screen 'richness' vs. 'clutter', and cited Citymapper as the most frequent example. Citymapper's interface was described by some participants as 'cluttered' and having "too much information" on screen, whereas other participants were pleased with the large amount of information on the screen, and especially with the way in which Citymapper displays different routing options. This diverging view has specific design implications: designing for different and distinct user groups, as well as customisability. The second user interface-related insight was that of information distinction. A near-consensus among participants was that Google Maps[3] is not their go-to service for RTPI. There were two prevailing reasons for this: first, participants were not sure where to find RTPI on Google Maps, and were not even sure that Google Maps included RTPI or live departure information. Second, users who did know where RTPI is shown within Google Maps expressed uncertainty as to whether such information was up-to-date, therefore questioning its reliability: *"I struggle to trust information from Google […] I assume Google is pulling information from different sides, but I don't know that necessarily train cancellation are taken into account, or if it's just reading timetables"* (P31)

One of the main usability issues described by participants was the lack of contextualisation. A nearly universal issue was what can be described as 'formulaic results', i.e. information that is not suited to individual journey preferences such as transport modes. One participant noted about this: *"... [apps] think like machines and not like humans"* (P21). A more prevalent issue was that of mid-journey information needs – i.e. after a journey has begun, with a majority of participants citing the lack of journey planning information when no data connection is available. Interchanging is an additional leading area of negative experience: alongside the spatial orientation challenges previously discussed, participants noted an additional challenge: even though they check for onward travel information (i.e. line and platform number) they often do not know which platform or stop their earlier transportation mode is arriving at, preventing them from contextualising the information given to them by a journey planner and planning their route between transport modes: *"I would like to know […] which platform*

[2] http://www.nationalrail.co.uk/
[3] https://www.google.com/maps/

I'm about to get to, and I also think it's really important to know which platform the train is going to be [arriving] on" (P35). Additionally, participants noted the need for more proactivity on the part of journey planners in cases of missed transport connections – both in identifying the event as well as in proposing an alternative route.

While comparing a specific set of journey planners was not the intent of the study, the range of planners used by participants provided data for a comparative evaluation, presented in Table 3 below. Criteria for the evaluation (user needs, in table columns) as well as the findings (journey planner experiences, in table rows) – were both compiled based on participant responses. This represents an inductive approach that inherently structures findings around criteria that are important to users. Each finding is categorised by one of the following symbols (additional notes appear below symbol):

✓ – Need fulfilled / overall positive response to attribute

✗ – Need not fulfilled / overall negative response to attribute

✱ – Neither positive or negative / other response

Table 3 – Comparative Usability Evaluation of Journey Planners

	Accuracy and Reliability	User Interface	Context and Customisability	Interchange Support	Technical Issues / Bugs
Google Maps	✗ User uncertainty whether ETAs are indeed RTPI	✓ User interface lacks distinction for RTPI.	✗ Settings customisable, but participants often utilise pre-existing knowledge	✗ Contextual and spatial issues noted. See 'Journey Planning Habits'	✓
Citymapper	✓ Buses noted in particular	✗ Participants divided over 'richness' or 'clutter'	✱ Settings customisable, but many are not aware of this.	✗ Contextual and spatial issues noted. See 'Journey Planning Habits'	✓
Trainline[4]	✓ RTPI 'dissemination' disparity'. See 'Currently Available Journey Planners'	✓	**N/A** Commuter / long-distance trains only	✓	✓
National Rail Enquiries	✱ RTPI 'dissemination' disparity'. See 'Currently Available Journey Planners'	✗ Shows only recent journeys and does not 'remember' frequent / regular journeys	**N/A** Commuter / long-distance trains only	✓ Positive about recently introduced real-time platform information	✗ Frequent issues with data server not being found by mobile app

[4] https://www.thetrainline.com/

TfL Journey Planner[5]	✓	✱ Some preferred to see results for the current time rather than default time range view	✗ Settings customisable, but participants often utilise pre-existing knowledge	✗ Contextual and spatial issues noted. See 'Journey Planning Habits'	✗ Issues with page rendering and selection of route options

Participant share for each of the digital journey planners mentioned in the study was as follows (note: the majority of participants indicated use of more than one journey planner): National Rail Enquiries – 51%, Google Maps – 41%, Citymapper – 29%, Trainline – 27%, TfL – 20%, Others – 2%.

Predictive Journey Planning

Findings focused on three core topics with particular implications for mobile transport app design: disruption notifications and alternative routes, context, and privacy.

Disruption notifications (i.e. for delays, cancellations and other service alterations) were described to participants as both proactive and personal. 'Proactive' was defined as being delivered without the need for preceding user action, and 'personal' as relevant to individual commuting habits. Participants expressed near-universal openness to this: the proactivity element negates user forgetfulness, and is perceived to be seen earlier than any user-initiated action – giving more flexibility to plan and reducing the probability for a disrupted journey.

However, some participants indicated that their openness to predictive journey planning hinges on relevance of results to their individual journey. Two related points were noted in particular: First, notifications must not be excessive and avoid oversaturation, thereby negating their effectiveness. Second and more importantly, the 'personal' element of these notifications is key to their success – they should be relevant to a passenger's journey, otherwise future notifications will be ignored. Further emphasising this, participants noted that alternative route suggestions must improve on their 'formulaic' nature described earlier in this paper. Such improvement upon gaps in today's journey planning experiences was noted frequently as a prerequisite for using predictive journey planning – from contextual information during interchanges to offline availability of journey information, as well as 'soft' elements such as mode preference and preferred interchange locations. The reason for this is what can be described as giving up control. Participants explained that in current journey planners, they compensate for gaps in functionality or for data accuracy issues by making tweaks and customisations to settings, and also apply pre-existing transit system knowledge when needed. A proactive journey planner does not give them this opportunity, hence less user control.

A particularly unexpected area of findings regarded attitudes towards privacy, and specifically, the

[5] https://tfl.gov.uk/plan-a-journey/

level of participant concerns about a mobile app that would continuously track their movements in order to 'learn' their commuting patterns. Participants expressed near-universal willingness to allow access to GPS on their device, citing two reasons: The first, to quote one participant, was that *"a lot of apps do that anyway"* (P19): participants indicated that they have grown accustomed to allowing such access, and did not feel that journey planning would be different. The second and more notable reason was the concept of 'privacy as an exchange': giving up privacy in return for tangible value. GPS access would not be granted to any app for no apparent reason, but it would be allowed if an app offers clear benefits to them. Previous research on the economics of privacy supports a nuanced valuation of privacy, or 'Willingness to Accept' [1] a decrease in privacy in return for financial or other value [34]. However, determining the applicability of these principles to commuting and urban mobility will require further research.

Discussion

Several areas of findings are presented below, which have research and design implications for digital journey planners: designing for distinct use cases, trust, user context, and study methodology.

First, the distinct use cases that emerged from this study call for designs that address the needs of clearly differentiated user groups. This is exemplified in participant responses by views on the Citymapper interface (i.e. 'rich' vs. 'cluttered'). Additionally, participant uncertainty about RTPI on Google Maps illustrates a potential need to create distinct interfaces for distinct needs. Common methods to articulate user groups include personas, user scenarios, and storyboards [13], which will be used in this project. A common method that allows designers to address needs of different user groups in a single product or interface is the concept of depth vs. breadth [12], which describes the balance between the number of options available on the screen at a given time vs. the hierarchal depth at which specific functionality is located (e.g. 'advanced' or less frequently used functionality requiring additional steps or actions than 'basic' or more frequently used functionality). Further research will be needed to establish the suitable depth vs. breadth balance for our prototype. Use cases found in this study can also benefit from further research both in terms of number as well as detail.

Second, a higher degree of user trust in transit data will be crucial going forward. A consistent thread in participant responses is that they prefer to supplement information given to them by digital journey planners with other information: pre-existing knowledge, paper-based journey planners, and information from other transit apps or from other types of services all together (such as social networks), and not rely on digital journey planners exclusively. Based on these findings, this preference can be easily addressed in today's journey planners (by adding a static map in an app, for example), or can be ignored altogether, without significant effects on user engagement. However, in a scenario of predictive journey planning, users will be asked to trust that a computerised process will incorporate their nuanced journey preferences and respond to an event such a disruption similar to how they would respond. This will be a pivotal part of user needs when designing a predictive journey planner, and will present a roadblock to user adoption if not addressed. When designing predictive transit systems, it will be important to address the user experience gaps found in today's digital journey planners, as well as to still provide passengers with the ability to customise journey settings.

Third, transit information should be better adapted to user context. Despite advances in methods of dissemination and presentation of transit data to users, little progress has been made to incorporate individual user contexts into that data. Doing so holds the potential to make journey information more relevant and useful to the user. Despite functionality in today's journey planners that shows departure times for the nearest station or alerts users when their desired stop is the next one – functionality that largely relies on GPS coordinates – participants repeatedly expressed a need for journey information to incorporate individual context. Incorporating context might be achieved with existing and established methods such as GPS: a frequently noted example was to suggest alternative routes in case of a missed departure, based on location and current time (e.g. if the departure time has passed and the passenger has not left the station, an alternative route will be suggested). Other examples, such as spatial orientation during an interchange, will likely require additional research in terms of technological implementation as well as user behaviour.

Finally, key elements of methodology presented here can be adapted by transport industry professionals to capture user requirements that will inform future product design. For example, the Think-aloud technique, typically used for longer usability evaluations in user-centred design projects, was adapted for the current study by using short questions that can be answered while a passenger waits for a transport connection, and by relating these questions to an already-recalled critical incident. An additional example of methodology adaptation is the use of CIT in the study. By triggering a 'incident' in participants' minds that was meaningful to them, the study addressed a common challenge in user research – how to create the context and circumstances where a participant exhibits a behaviour of interest. These examples illustrate that the key to implementing a user-centred approach in transportation or in any other domain – lies not in highly regimented use of an individual method, but rather in adaptation of methods that are appropriate for a project's goals and constraints, so long as these methods support an iterative design process that is consistently informed by user needs.

Conclusion

Study findings show numerous user needs not addressed in today's digital journey planners, in three key areas: designing for distinct user groups, user trust, and incorporation of user context into journey information. The findings provide a basis on which to enhance the functionality of today's digital journey planners as well as to design more useful predictive journey planners and other transportation apps in the future. In particular, the mixed-method approach allows for generic as well as technology- or product-specific elements of behaviour to be researched (see table 'Modular Interview Sections and Example Questions'). Additionally, this approach elicits both stated and revealed preferences, thereby providing insight not only into what users say they do, but also into what users actually do when planning a journey within a given context – an important distinction [30]. The study also illustrates how data collection methods normally utilised in usability research can be adapted for in-situ constraints typical of passenger research in transportation, such as participant time and attention. Findings can be extended by identifying additional use cases and distinct user groups, and by testing the validity of findings in additional locales and transportation markets. Findings also illustrate how a methodical approach to requirement capturing and discovery of user needs can inform the design of mobile transportation technologies, and give user needs a more central role in the design process.

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