Personalized, context-aware communication in multimodal public transport

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ABSTRACT

The way we experience time is based on its psychological value. Time spent efficiently or pleasantly positively influences the time experience. When choosing a transportation mode, people highly value flexibility, reliability, and autonomy. Public transport, although used frequently, does not always fulfill these values. With personalization, the public transport experience could become more efficient and pleasant. This Ph.D. research aims to personalize public transport information systems (PTIS) through context-aware communication. To achieve this goal, the following activities are planned: (1) a systematic literature review of personalization in public transport; (2) creating an elaborate passenger context model based on existing literature, expert reviews, and user studies; (3) applying this model to offer context-aware information, advice, and inspiration to public transport passengers. At the time of writing, an initial version of the context model has been produced. The next step will be validating and improving the model.

CCS CONCEPTS

• **Human-centered computing** → *HCI theory, concepts and models.*

KEYWORDS

multimodal public transport, personalization, adaptation, context-aware, transport information systems, communication

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1 INTRODUCTION

Everyday people are on the move. Whether for work, leisure or social reasons, considerable time is spent travelling. Valuable time to get things done or that we want to spend on enjoying life. The way we experience time is not solely based on hours and money spent but also on the psychological value of the time [19]. In many of our activities, we try to optimize efficiency and quality of time. We do it in our work, communication, while doing groceries, and personal transportation is no different. In the decision on their preferred mode of mobility, people highly value flexibility, reliability, and autonomy [13].

Public transport is frequently used. However, its information systems often provide a one-size-fits-all solution. Identical recommended itineraries are offered to all travelers. The information provided to a commuter taking the same trip every day is similar to that to someone traveling to a new place for fun. Individual travelers, however, have different needs in particular situations. Consider the following two examples:

1) "Mary commutes daily from Nijmegen to Amsterdam. She knows the route and likes to work on the train. Her train is delayed and she misses the connection in Utrecht and has to wait 15 minutes for the next train. She wonders what to do when she reaches Amsterdam, as the bus only leaves once per hour, and she does not fancy waiting 45 minutes."

2) "Susan is going to the beach with her 3 study friends. They take the 2-hour train ride to The Hague. On their way they switch trains in Utrecht, a large station they do not often visit. They arrive with 10 minutes to change to the tram. They fail to find the platform in time and miss the connection. Large crowds are trying to get to the beach, causing trouble to fit into the tram.

Mary knows her connections and does not want to be bothered with general information. However, she may like to know where she can quietly work on the train. In case of disruptions, she wants alternatives to get to work on time. In contrast, Susan is not familiar with the route or the stations, and might need more assistance along the way. She is more flexible. If one beach is unreachable due to crowds, she may be happy with a recommendation to go to a different site.

The one size fits all system of public transport can negatively impact traveler satisfaction [5, 22]. Planning a trip takes up more mental capacity. Additionally, disruptions can make a journey cumbersome. It is a reason why people prefer private car use [5]. Although, many private vehicles on the road can cause time-consuming congestion, and contributes to air pollution threatening our climate [17] and health [24].

Public transport can offer a pleasant and efficient experience whilst not giving up on flexibility, reliability, and autonomy. Many public transport providers are shifting to a multimodal system. Mobility-as-a-Service is making its way onto the innovation agenda all over world [e.g., 7, 14, 15] and can provide a seamless door-to-door travel experience.

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An approach to attend to the individual needs of travelers even more is personalization. Our thesis research, in collaboration with the Dutch Railways (NS) focuses on context-aware information, advice, and inspiration in PTIS. An important part of this research is building upon this and creating an extensive, well-evaluated passenger context model and use it for personalized passenger communication.

2 RELATED WORK

Personalization in public transport. The concept of personalization is multidimensional and has different definitions depending on the people and their research area [3, 16]. We define personalization as *"the process of adapting an information system to (a group of) users based on personal and contextual factors. This adaptation can be both implicit and explicit and aims to achieve a particular goal"*. Various research demonstrated the need for and potential benefits of personalization in public transport [e.g., 4, 10, 31, 34]. Moreover, different ways of personalization can be identified in the context of public transport [2, 8, 9, 18, 28, 29, 40, 42]:

- *User set preferences.* Personalization based on preferences that are explicitly stated by the user. E.g., preferences regarding route (quickest route, the route with fewest changes, etc.), mode, time, or price. A distinction is made between set preferences for a particular moment or those persisting over time.
- *User behavior.* Personalization based on previous behavior from the user. E.g., extract previously used modes from historical data, and make predictions using content-based and collaborative techniques.
- *User ratings.* Personalization based on ratings given by the user on previous recommendations. Makes use of content-based and collaborative techniques.
- *User features.* Personalization based on the features of the users. E.g., age, occupation, income.
- *Context.* Personalization based on the context of the user. E.g., weather, location of the vehicle.

As the main focus of our research is on personalization using context we will discuss this more deeply.

Context-awareness in public transport. For this research, context can be described as *"information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."* [1]. Various research exists that aims to adapt traveler context in public transport. Vieira, Caldas, and Salgado [38] presented UbiBus, a system that uses several contextual elements such as the location of the bus and the average speed of a bus to provide users information. Kühn, Lemme, Pfeffer, and Schlegel [27] studied adapting information on a public screen based on the location of the user, the daytime, and the distance between the user and the display. Titov, Keller, and Schlegel [35] investigated the use of augmented reality screens in railway transport. They aimed to inform passengers on Points of Interest during the journey based using "SmartWindows". Al-Rahamneh et al. [2] propose a smart mobility service that obtains data from external sources including contextual data. Using this information, they guide the traveler by updating these environmental elements that may change during their journey. Even though this research is promising, it is often that limited contextual factors have been taken into consideration. Moreover, they do not take the interaction between these factors into account, nor do they consider the influence of other journey aspects.

Context models. To be able to adapt to the travelers' context, it is necessary to analyze and model the contextual elements that could be of influence. An analysis of context factors in public transport by Krömker and Wienken [26] makes use of both literature and expert workshops. They differentiate between the levels of abstraction (macro level, micro-level and situational level). De Oliveira et al. [11] defined a transportation ontology for content personalization of PTIS. Their context model makes a distinction between three main components: the user profile, the platform, and the environment. Keller et al. [25] presented a more elaborate context model for adaptive PTIS. Their model was created using both a top-down and bottom-up approach. They made a distinction between seven context dimensions: task context, interaction context, spatial context, temporal context, user context, physical contex and social-technical context. Moreover, Jevinger and Persson [23] identified how and what context information is important when supporting travelers during unplanned disturbances. Besides literature, their study is based on workshops and interviews with domain experts. They defined several disturbance scenarios in which context-aware travel planners could be useful. While this research provides a good basis for context models in public transport, it has limitations. Currently, the models hardly consider how the importance of contextual factors changes in different stages of the journey. Moreover, most models are rather superficial and do not contain much detail. Also, while some have been validated by experts, none have considered what travelers consider to be important contextual factors.

Research by the Dutch Railways. One objective of using personalization is to improve the traveler experience. Within the NS, several studies on traveler experience were conducted by van Hagen. Experiences and emotions in a specific step affect the evaluation of overall journey and negative experiences are weighted more heavily [36]. Most *negative* emotions (tense, annoyance) are experienced during interchanges. Most *positive* emotions (relaxation) are experienced during the in-train phase [20]. Trip valuation is influenced by the way a traveler is able to spend travel time and the purpose of the trip [21]. van Hagen and van Oort [37] introduced the passenger satisfaction pyramid as guide to make efficient design choices. Additionally, an analysis has been performed of attitudes towards multimodal traveling [30]. Master theses investigated personalization to improve customer satisfaction [6], and analyzed travel planner usage, route choice behavior and passenger predictions [39].

3 RESEARCH QUESTIONS AND APPROACH

The main goal of this research is to offer personalized and context-aware communication to (multimodal) public transport passengers. In addressing this goal, the following research questions have been formulated:

RQ1: What is the State-of-the-Art on personalization in public transport? Several studies have shown the added value

of personalization in public transport. Yet, there exists no general understanding of the state-of-the-art of personalization in public transport. Hence, as one of the first steps in our research we will create a structured and rigorous overview of personalization in public transport through a systematic literature review following the PRISMA method [32]. This to answer the following subquestions: *(RQ1.1): What are the characteristics used for personalization? (RQ1.2) What is being personalized? (RQ1.3) What methods are used to personalize? (RQ1.4) How is personalization evaluated? (RQ1.5) What research gaps and potential future study lines can be identified?*

RQ2: How can a good (multimodal) traveler experience be defined? Our research should have a positive effect on the traveler experience. To be able to measure and achieve this, we first need to understand what a good (multimodal) traveler experience is. The following sub questions have been formulated: *(RQ2.1) Which factors influence the traveler experience (most)? (RQ2.2) What stressors do travelers experience? And how do they affect the experience? (RQ2.3) What pleasures can travelers experience? And how do they affect the experience? (RQ2.4) How does this depend on traveler journey, context, profile, and the interaction of these?* We will answer these questions by combining knowledge from related work and user studies. These user studies will include, but are not limited to, surveys, interviews and diary studies. The latter will helps us understand what factors influence the experience in real-life situations. A panel offered by the Dutch Railways (NS panel) is available to us for these studies. The panel consists of a diverse set of 80.000 participants.

RQ3: In what ways can personalized communication improve the traveler experience? Once we understand the travel experience, we can investigate how it relates to communication needs. We distinguish four types of communication in public transport: (1) Information (e.g., departure times, disruptions, instructions, or the location facilities) (2) Advice (e.g., Next best action, where to go, or what mode to use) (3) inspiration (e.g., what to do at the destination) (4) input and feedback (e.g., reporting noise, feedback on recommendations). For each of these types of communication it is necessary to understand *when, what* and *how* to provide it such that it improves the traveler experience. Moreover, we need to understand how this depends on the traveler journey, context, profile, experience and the interaction of these. To answers these questions we will use user studies with prototypes. We will work with AI teams from the NS and use the NS panel.

RQ4: What should communication be adapted to? Following upon the previous research question (RQ3) it is necessary to understand what communication should be adapted to. We divided the research question into the following sub questions: *(RQ4.1) To which journey aspects? (RQ4.2) To which context aspects? (RQ4.3) To which traveler profile aspects? (RQ4.4) To which traveler experience aspects?*. To answer this question we plan to create a passenger context-model. The categories and factors in this model are defined from existing literature or taxonomies. Examples of the latter are: NS defined station facilities, weather alerts of The Royal Netherlands Meteorological Institute, and a national holiday calendar. Using the NS panel, we will evaluate the influence of these factors through both surveys and user studies with prototypes.

RQ5: How can the dimensions of good (personalized) communication be defined and measured? As a next step, to be able to evaluate personalized communication in public transport, the dimensions of good personalized communication need to be defined. These dimensions for example consist of appropriateness, accuracy, effectiveness, trust, fairness, transparency, etc. When the different dimensions have been defined we will explore how they can be measured in the area of public transport. This will be done based on previous literature as well as creating our own scales which we will validate.

RQ6: How can personalized travel communication be evaluated in a human-centred manner? In addition to RQ 5, the evaluation of personalization is challenging and requires a layered evaluation approach [33]. Another example of a challenge is the capability uncertainty and output complexity [41]. It is important to evaluate the impact of personalization on traveler experience in a valid and human-centred way.

4 RESULTS AND CONTRIBUTIONS TO DATE

Systematic Literature Review. At the time of writing, we are working on a systematic literature review using the PRISMA method [32]. This systematic literature review will give insights into the current state-of-the-art of personalization in public transport.

Analysis of multimodal mobility (pilot) applications. An analysis of existing applications and pilots was done based on scientific literature, European reports and exploration on the internet. This to understand the market of multimodal mobility. A total of 58 applications were identified, 23 still operational. These were categorised based on functionalities, included transport modes, and whether it includes personalization aspects. The latter was the case for 37 applications. Examples are saving preferences, route optimization or personalized information; all based on contextual and personal factors. Other personalization aspects were gamification, AR assistance, or individual deal matching.

Defining travel journey. As previously stated, we need to understand which situations ask for which adaptation. To be able to do this is an understanding is needed of the various traveler journey aspects. We started with investigating the travel steps for different travel modes. This distinction is based on existing work from the Dutch Railways and substantiated by work of Digmayer, Vogelsang and Jakobs [12]. We distinguish three phases in the journey: (1) before the trip, (2) during the trip, and (3) last mile and after the trip (see initial version in Figure 1). Each having steps, depending on the travel mode. For each step an initial list of information needs has been created.

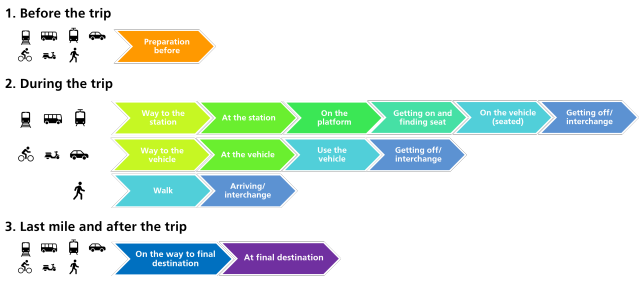

Figure 1: Travel steps per travel mode.

Defining context. Based on the previous literature on passenger context models an initial context model has been created. The articles described in the related work sections were used as main source. First, an inventory of the different factors and dimensions used was made. In brainstorm sessions the contents of this inventory were combined to create a more complete model. The factors were structured in a way deemed logical by the researchers. Our context model differs from previous models in the sense that it focuses on multimodal public transport and that dimension and factors are weighted.

The context factors in the initial model were divided in six dimensions. The dimensions are *Social context, Physical context, Spatial Context and Temporal context, Network context, and traveler context.* The first four are clustered together as Environmental context. Figure 2 shows the relation of these dimensions. To visualize the complete context model a zoomable sunburst was made. In this visualization one can zoom in on the different dimensions to see the underlying factors. It can be found here: http://passengercontext.com/sunburst/.

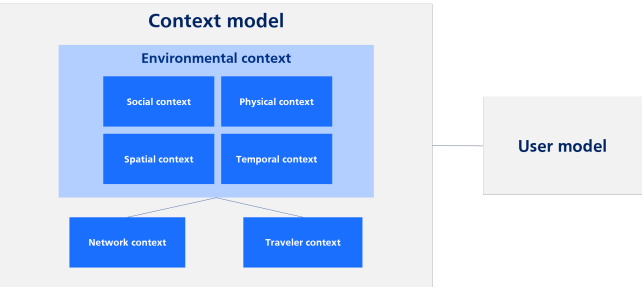

Figure 2: Initial context model based on existing literature

5 NEXT STEPS AND LONG-TERM GOALS

This research aims to include user and expert input in the context-model. As a first step, focus groups with the NS panel will be organized. Participants will share their experiences with public transport, and there will be an emphasis on the (contextual) factors influencing their experiences. After these focus groups, we hope to better understand people's travel experiences and which stressors and pleasures exist. We will identify a set of context factors to be included in the model and get a sense of the importance of these factors.

The second step will be to validate the improved context-model in expert review sessions. We aim to get experts from diverse backgrounds within the public transport domain. We will invite experts with a human-centered background, a data-centered background, or anything in between. The expert sessions will serve two purposes. (1) To evaluate the completeness of the factors included, and (2) to evaluate how to logically structure the included factors.

Based on the outcome of the validations sessions, the set will be defined. This model will serve as a base for follow-up user studies. We aim to understand the importance of the various factors in each stage of the journey and how they interact. Through multiple user studies, we will investigate the influence of the contextual factors on travelers' information, advice, and inspiration needs. Due to the scale of the model, we plan on studying one dimension at a time while controlling for others. We will do this by designing these surveys based on scenarios. This way we can assure other dimensions and factors remain constant. The large passenger panel will allow us to gather sufficient user data. To apply our findings, it can be coordinated together with data and AI teams within the NS which data is already available and where new data sources might be needed. In collaboration with the NS teams, we expect that in the long term our work will be implemented in the NS passenger information system, and to have made a substantial contribution to knowledge on how to personalize communication in public transport.

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