Travel Chains in Urban Public Transportation: Identifying User Needs, Travel Strategies, and Travel Information System Improvements

GEO 511 Master's Thesis

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Abstract

The implementation of a functional public transportation network has many benefits for a city, among other things, a way of sustainable mobility. Today, urban areas face the challenge of keeping up with technological trends and encouraging mobility activities using public transportation. For this reason, it is important to understand public transportation user behavior and, consequently, the motives and challenges related to urban travel.

Research in the field of urban transportation mainly focuses on systematic and network-related issues to improve the travel experience. However, examining urban travel from a user's perspective is equally essential to improving a city's transportation network.

With the help of twenty participants, an extensive travel study in the urban area of Zurich took place. The research design consists of a three-step mixed method approach. Data on travel behavior, mobility preferences, and information needs are obtained. The data is explored using an advanced travel chain structure, revealing results in the context of individual travel phases.

The results show that urban travel relies heavily on the information apps provide, especially when planning. This need is mainly bound to spatial and temporal properties, for which app elements such as maps, dynamic timetables, and real-time information are most valued. Furthermore, travel using public transportation is approached by evaluating suggested routes according to the journey's duration, efficiency, and complexity. However, decisions are often based on familiarity with the general area or interchange points. Uncertainties during urban travel are mitigated by walking when suitable, avoiding complex interchanges, and monitoring all phases with the help of an app.

User results also indicate no serious issues regarding the City of Zurich as a public transportation provider. Nonetheless, measures could include integrating crowdsourced and context-aware data to meet the demands of adaptive and accurate travel information needs.

The broader implications of the thesis outcome support cities and transportation service providers in understanding travel behavior. Consequently, this insight enables them to address specific needs and thus encourage sustainable mobility.

Keywords: *Urban Mobility, Public Transportation, Travel Behavior, Travel Information System*

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1 Introduction

It is in a city's best interest to promote ways for sustainable mobility and, consequently reduce urban congestion. Public transportation is an ideal alternative to individual car use but needs to appeal to potential users. Therefore, understanding public transportation expectations and areas needing improvement can lead to sustainable mobility developments. Wittmer (2017) even considers mobility to be part of one of eight gigatrends, representing a dynamic solution to market and transport policy inefficiencies. In European cities, the transportation sector is responsible for around 70% of emissions harmful to the climate (Jones, 2020). Cities already implement measures such as limiting urban parking and expansion of the car traffic network in order to reduce incentives for car usage in cities. However, at the same time, measures to encourage a shift towards public transportation are equally necessary (Menendez & Ambühl, 2022).

The City of Zurich hosts a highly coordinated public transportation network, which plays a fundamental role in the city's efforts to cut personal energy use to 2'000 watts per year (Cebr, 2017). The vision is to have each mode of transportation used according to its strengths and efficiently embedded into the network while intermodal transportation capacities are continuously optimized (EWP & Schweizerischer Städteverband, 2019).

Identifying how the attractiveness of public transportation can be increased is important for many urban areas. This means analyzing and understanding what users appreciate and expect from a public transportation system. Subsequently, the knowledge of user behavior reveals how public transportation usage can be increased.

Information is key to shaping travel behavior in public transportation and can be examined from a supply angle, meaning service providers, and from a demand angle, which are passengers. Providing and obtaining relevant and up-to-date information directly affects the success of urban public transportation travel outcomes. Beul-Leusmann et al. (2014) state that the success of a public transportation service depends on the quality of the provided information and the usability of the system. Thus, when developing a travel information system, it is crucial to understand user information needs and how the complexity of travel phases is managed (Digmayer et al., 2015). However, studies on the interactive aspects and acceptance of travel apps and the information they provide are still lacking (Altay & Okumuş, 2022).

Due to the complexity and irregularities in urban transportation networks, travel is not always a straightforward activity, and there are many relevant information sources (Nandan et al., 2014). How these sources are handled depends on the general objective of the trip, mode and phase of transportation, and lastly, personal characteristics (Casquero et al., 2022; Digmayer et al., 2015). Despite the existence of many travel information sources, creating a full-value mobile application as a motivational tool in supporting urban public transportation is perhaps the most important (Strenitzerova & Stalmachova, 2021).

Thanks to the global digitalization trends, new types of personal transportation service opportunities are emerging (Smith, Sochor and Karlsson, 2018), and with the progressive development of such technologies, urban mobility experiences have changed significantly (Lopez-Carreiro et al., 2020). Users can access high-value travel information provided by smartphone technology, impacting public transportation needs and strategies (Casquero et al., 2022). In fact, 74% of people today are using the internet, mainly thanks to the widespread usage of smartphones, data availability, and an increase in fast network coverage (Strenitzerova & Stalmachova, 2021). In Zurich the amount of daily timetable queries using a smartphone app has more than doubled since 2013 (ZVV, 2021).

This thesis has three core objectives. The first includes the identification of public transportation user needs, which includes how information sources are utilized and how travel uncertainties are perceived. The second objective is to expose strategies a passenger applies for urban travel. The third objective focuses on the supply of travel information, meaning system improvements regarding user demands. Since urban public transportation is a central component of this thesis, the City of Zurich represents the grounds on which these objectives will be asserted.

Literature, related work, and fundamental concepts help form a better understanding of the matter. The next chapter explains the methodological approach to this thesis, a three-stage user study conducted with twenty participants. This mixed method approach allows for in-depth data to be obtained in the form of a study done in the urban area of Zurich. The results chapter will present and summarize the outcome of all study stages. The results will then be put into perspective of the thesis's core objectives and discussed in detail with the support of relevant literature.

The conclusions drawn from this thesis can support cities and their transportation services to recognize areas where public transportation can be improved. Therefore, public transportation usage can be made more appealing and be part of promoting sustainable urban mobility.

2 Background

This work touches upon many different topics, each with a vast amount of literature published. For instance, the amount of literature on and around navigation and travel seems endless, which both, in many ways, show relevance to this thesis. A similar statement could be made about urban mobility or information systems. The following chapters present, and review obtained literature and explain specific terminologies and concepts relevant to these subjects.

2.1 Related Work

Although research in and around urban structures is not new, its relevance today is more present than ever as solutions regarding urban density, traffic congestion, and environmental concerns are in high demand (reference). Sustainable mobility is still a concept yet challenging for researchers to explain and support key stakeholders regarding the future of urban mobility (Foltýnováa et al., 2020). Literature found on the subject of urban mobility highly emphasizes the significance of public transportation. Even though the degree of public transportation usage may vary geographically from country to country, its successful implementation in urban areas correlates with economic prosperity (Lerner et al., 2011).

However, not only is just public transportation viewed as a promising solution to urban traffic congestion and different environmental concerns. Much research is also devoted to its combination with other persisting modes of transportation, thus fostering ideas of intermodal, multimodal or shared mobility concepts. For instance, Reck and Axhausen (2021) examine how city transport issues could be resolved by filling accessibility voids between a public transport station and a destination. This *problem* is also often referred to in the literature as *the last mile problem*. It describes the issue users may have when using public transportation, and one's end destination may not be near or accessible enough to the nearest transport node. Wang and Odoni (2016) see the unavailability of this service as one of the main deterrents to using public transport in urban areas. This is especially true of particular demographic groups, such as schoolchildren, seniors, and the disabled.

Several approaches have been made to capture the combination of transportation modes as a model. The simplest is unimodal travel, which in theory, is not even a combination of transportation modes but just describes the usage of a single mode of transportation. However, the exact definition of intermodal travel deviates throughout the literature. Digmayer et al. (2015) state that most literature focuses on unimodal travel schemes, and few publications examining intermodal travel can be found. The latter concept is used for models for more than one mode of transportation.

Intermodal travel can become quite complex and multifaceted, but combining more than one mode offers those systems benefits while avoiding their weaknesses (Spickermann et al., 2014). Diaz Olvera et al. (2014) examine public transportation in combination with walking, which, if carried out long enough, can be considered a separate mode of transport and thus intermodal travel.

What prevents city inhabitants from using intermodal travel, or what could motivate them to adopt it? These are just questions Dacko and Spalteholz, (2014) try to answer in their research regarding intermodal travel concepts. Gebhardt et al. (2016) find that research on intermodal travel, particularly in urban areas, is assumed to be a key factor for a sustainable and scalable urban transportation system. They further state that user patterns and motives behind intermodality as a daily practice are hardly studied in the literature (Gebhardt et al., 2016). Using Berlin as the location for their study, Jarass and Oostendorp (2017) investigate user characteristics of intermodal travel users. Results of the study become quite complex as the possible combination of transport modes rises. However, it is concluded that just a tiny portion of routes are covered using two or more modes of transport (Jarass and Oostendorp, 2017).

Research regarding intermodal travel can also be found in Switzerland. An extensive survey was done by Atasoy et al. (2013) and data on travel habits and preferences were obtained across Switzerland. By using attitudinal indicators, two models are used, which aim at better characterizing the behavior behind choosing a mode of transport. Meyer de Freitas et al. (2019) compute network models of Zurich's Street and public transportation network to analyze urban intermodal traveling. An exciting outcome they observe is that, in a high-frequency transit network like the one in Zurich, users do not base their travel decisions on headways but on service reliability (Meyer de Freitas et al., 2019).

Although less common, multimodal travel is another concept relevant to this thesis's objective. Nobis (2015) differs between multimodal and intermodal travel by bringing time into the equation. Multimodal travel consists of the usage of multiple changing modes of transport over a more extended period of time, as opposed to a single route, as in intermodal travel.

However, in most literature, unimodal, intermodal, and multimodal travel concepts consistently need to be defined or redefined for their research (Gebhardt et al., 2016). Hence, the literature does not observe a coherent and structured explanation for each of these terms.

Publications on travel behavior often structure a trip in different segments, simplifying and assigning user demands to just a portion of a journey. Grotenhuis et al. (2007), make this distinction by analyzing travel in three parts: Pre-trip, wayside, and onboard. Results show how travel habits influence trip planning and implementation and, more importantly, that needs differ enormously depending on the travel phase. This segmentation of travel phases is often referred to as travel chains. In a study by Bruinsma, Rietveld, and van Vuuren (1999), travel chains are analyzed according to their reliability, concluding that longer travel chains are significantly more prone to delays and are thus less reliable. Further attempts have been made to classify information and assign it to links in the travel chain, as done by Hörold et al. (2012).

Digmayer et al. (2015) built open travel chains using current intermodal concepts. In their research, a clear breakdown of travel phases and modes of transport is made while addressing the *last mile problem*.

The term trip chain is less widely used but still relevant, which suggests the exact methodology behind travel chain analysis. Huang et al. (2021) compare trip chain concepts and choice of travel mode.

Although highly complex, intermodal transportation is very flexible and therefore necessitates extensive decision-making (Beul-Leusmann et al., 2013). As with any choice, one must have the relevant information to make it. Therefore, a widely discussed notion in publications around urban travel is using public transportation to retrieve adequate details. Many studies show that not being informed or unable to access travel information hinders public transportation usage, and individual motorized transport may be preferred. Beul-Leusmann et al. (2014) find that decent passenger information systems are crucial to the success of a public transportation experience. Information on the network and potential issues must be readily available and simplified for a user to understand. As existing studies have established, Jamal and Habib (2020) confirm that technology highly influences how humans travel and increases travel outcomes.

Research around information systems for public transportation mainly focuses on technological trends and developing a tool to inform passengers. Grotenhuis et al., (2007) for instance, systematically define information into types, which public transport system needs to share with their users for them to be able to make a travel decision. An agent-based approach in Zurich by Leng and Corman (2020) researched how information during delays affects a public transportation user. Using three scenarios, such system disruptions are communicated to users through timely, advanced, or even no info to research information effectiveness.

In recent years attention increasingly shifted towards the demand side of transportation. What kind of requirements does a passenger have regarding information needs, and how does its quality or timeliness affect travel? All authors agree that up-to-date, usable, and qualitative information is crucial for a public transportation user (Beul-Leusmann et al., 2013). However, these needs change depending on the type of transportation and the situation at hand. Hence, the level of detail in which information is presented to the user can be very different (Digmayer et al., 2015).

The most significant asset a public transportation user could ask for is app-based technology, aiming to address such needs. Application and smartphone research has consistently been increasing in past years, which can also be observed regarding public transportation information. Smartphones enabled ICT in public transport to have a direct line of communication between user and provider. Especially in travel-related studies, smartphone and their applications have become a widely used data collection tool. However, authors Jamal and Habib (2020) explain that such studies are mainly market-based research focusing on the market’s demand for a product and features. They further state that there is still a lack of evidence regarding the extent to of different factors influence smartphone usage for trip planning and travel outcomes. Research has only recently begun exploring the different behavioral dimensions of smartphone app usage for traveling (Jamal & Habib, 2020).

Passengers adapt their behavior to uncertain situations such as network disruptions, which is why research on this subject is especially important for transportation agencies. Approaches by Leng and Corman (2020) or Samsel et al. (2014) are examples of works contributing to this demand. The latter of which build and test a public transit app and then compare it to a current successful public transportation agency app. Specifically, in-app features, ticket purchasing, user-friendliness, and dealing with delays were aspects of the project. Another example is a system developed by Siemens, in which information on travel mode, uncertainties, and suggested alternative routes in case of delays is integrated on a single platform for travelers (Dacko and Spalteholz, 2014).

Technological developments are constantly increasing the possibilities an app offers a public transportation user. Altay and Okumuş (2022) mention how apps in the early 2010s provided simplified transit information such as timetables and search functions. While today a user not only has the option to customize and compare transport routes but also access information on other modes of transport. In the wake of such trends, navigational, wayfinding, and map studies began to center themselves around smartphone or app-based technologies. Core functionalities of a smartphone opened the door for modern research on GPS, location awareness, and map visualization (Abraham, 2019).

This integration of different transport systems and modes of apps further drives the concept and, therefore, research on intermodal travel (Altay and Okumuş, 2022).

Likely, mobility research focusing on ways for travel to become more sustainable in cities mentions the concept of mobility as a Service (MaaS). Many researchers see it as the next step of intermodal travel, offering users a more comprehensive range of mobility services (Lyons et al., 2019). According to Li and Voege (2017), a system such as MaaS has the potential to profoundly change mobility behavior and provide a paradigm shift in urban mobility.

Lim et al. (2015) highlighted an essential aspect: user behaviors differ significantly across countries. Hence, app research, development, and implantation in areas such as public transportation can be universally applied and requires local research.

Even though technology plays a substantial role in helping users find their way, core navigation and wayfinding principles are still involved. They are subjects that have been researched for centuries. For decision-making processes, spatial knowledge is crucial. Planning a route to a destination requires knowledge of one's position and the spatial relationships between reference points (Bakdash et al., 2008). Passini's conceptual framework of wayfinding (1981) is still relevant today as it explains the fundamentals of the human spatial problem-solving process.

Moreover, literature regarding spatial knowledge (Montello, 1998; Parush et al., 2007), navigation principles (Montello, 2005), or choosing route directions (Dalton, 2001; Wiener et al., 2008) can be related. At the core of most of these theories and concepts are behavior and psychological reasonings, which also play a part in the role of this thesis. Work by Brunyé et al. (2015b) highlights how perceived and learned space perception in relevance to our surroundings affects our navigation. How humans visualize routes and surroundings and navigate an environment relates to cognitive mapping, which has been researched by Tversky (1993) and Lloyd and Cammack (2007).

For the purpose of this thesis, all included app developers or the companies behind them were asked to contribute information. The *Zürcher Verkehrsverbund* (ZVV) was the only provider who responded and was willing to answer a few questions. Mrs. Andenmatten from the digital distribution department at ZVV, which includes the ZVV app, was kind enough to provide information about their app. All answers can be viewed in the 9.7). The following paragraphs summarize the most important statements.

The motivation behind developing the ZVV app is to simplify the urban travel experience and to meet digitalization trends and demands. The value position of the app is in its simplicity and user-friendliness, while its features aim to assist and guide users in many ways, and the use of customer data and advertising is avoided.

The app was developed over several years, undergoing extensive user research and pilot tests. Until the old app was replaced in 2022, many usability walkthroughs were done, and UX concepts were considered. The new app was consistently being reviewed and refined, making sure app features fulfill user needs. Although the app was developed natively by ZVV, national and international digital best practices were identified and considered in the development. According to Mrs. Andermatten, all ZVV channels use the same data source, meaning information sources are, in theory, synchronized in real-time across the network. Due to digital shifts, the pressure for real-time and accurate travel information is increasing. ZVV aims to meet such needs by providing personalized and situation-specific information. Lastly, it is stated that the app does not intend to replace any non-digital travel information sources. Adequate alternatives will continue to be offered for user groups that cannot or do not want to use digital channels.

Many different approaches can be found when it comes to research methods of any related field to this thesis. For instance, research involving spatial analysis or passenger flow models is done using large data quantities and can then later be statistically evaluated. When it comes to a public transport user's requirements or preferences, methods tend to involve a more qualitative approach. Usability studies of apps or stakeholder interviews show how related research may also use qualitative methods. Qualitative methodologies represent a suitable instrument in similar studies where transport user needs and expectations are captured and evaluated (Lopez-Carreiro et al., 2020). At the same time, quantitative research approaches can also be found, which are helpful in thoroughly documenting observations and revealing user patterns, leading to a significant conclusion (Sandelowski, 2001).

Amongst studies exploring a user's technological perception, qualitative approaches are common (Schmitz et al., 2016). In particular, in the field of transport and travel behavior, this method is widely used (Lopez-Carreiro et al., 2020). A qualitative research method makes sense when researching technologies such as mobile apps because it allows in-depth insight into a user's adaption, needs, and perception (Peng et al., 2016). Similar reasoning is driven by Kenyon & Lyons (2003) as it allows to probe in-depth attitudes towards and motivations underlying travel choices and the role of information in challenging these decisions. In the case of their study, a quantitative approach would fail to uncover the thinking behind travel choices to the required depth (Kenyon & Lyons, 2003).

In some cases where user needs and preferences are evaluated, quantitative methods can come into play or even represent the core of a study's research design—for example, comparing travel chain choices (van Eck et al., 2014) or surveying mode choice (Atasoy et al., 2013) or mobility apps (Kim et al., 2021). In fact, many studies in the same field as this thesis conduct a survey and evaluate results as part of the leading research method.

2.2 Terminologies and Concepts

This thesis refers to several terms and concepts. Not only is it essential to understand these, but also to know how they are used for the purpose of this thesis. The following six subchapters individually outline such terms or concepts.

Mobility

This thesis uses the term mobility similarly to Wittmer (2017). It is not understood in the general sense of a person's physical movement but instead as an instrument describing transportation in which mobility is perceived. Hence, urban mobility describes the ease with which people utilize transport networks or services to move to a destination (European Court of Auditors, 2020).

Intermodal Transportation

The term intermodality is not defined in a completely unambiguous way (Gebhardt et al., 2016). As mentioned in the chapter on related work, multi or intermodal travel and travel chain concepts are commonly referred to but are not consistently defined. The origin of intermodal transport can be found in the field of logistics, in which cargo is handled by different companies and modes of transportation (Jarass & Oostendorp, 2017).

In the case of this study, the definition of intermodal travel aligns with the work of (Nobis, 2015), who describes it as the usage of different modes of transportation for one route. Thus, several modes of transportation, including walking, can be part of an intermodal travel path.

There is no consensus across definitions that public transportation should be considered one or several modes of transportation (Meyer de Freitas et al., 2019). In this thesis, each bus, train, or tram ride is accounted for as an individual mode of transportation.

Even though, strictly speaking, walking is part of any form of travel, it is considered a mode of transport that must be distinctly defined (Digmayer et al., 2015). For a stretch covered on foot to be considered, the same threshold chosen by Diaz Olvera et al. (2014) is used; five minutes. This means distances traveled on foot under five minutes are not counted as a single mode of transport but are part of the previous one. Other authors set a threshold distance of 25 meters, but this seems unreasonable considering travel distances at larger Swiss train stations.

Travel Chain

Research such as one conducted by Huang et al. (2021) uses the terms trip or travel chain to define a sequence of out-of-home activities with the same start and end point. This makes sense for behavioral studies and to analyze everyday routine travel scenarios. However, this thesis looks at individual journeys between two destinations. A route is, therefore, one travel chain consisting of different phases, which will be identified and analyzed. Grotenhuis et al. (2007) suggest a classification between pre-trip, wayside, and onboard travel, which thus uses a travel chain approach based on travel phases. In other studies, travel chains are activity-based, focusing on the traveler's actions. A handful of studies combine both, which is more complex but allows for more detail (Digmayer et al., 2015). The travel chain method used in this thesis combines phases and user activities. The travel phases are planning, waiting, walking, onboard travel, and getting on or off.

Additionally, the mode of transportation is further described for onboard travel, which can be a bus, tram, or train. The activities consist of the type of information source used at that point. Therefore, travel chain analysis in this thesis focuses on a route between two different points in space where users experience different travel phases and activities.

Information Sources

It is necessary to distinguish between information and information technology. Information technology is the hard as well as the software used to collect, transmit and process data, while information can be defined as data that is collected for specific use (Olaisen, 1991). Therefore, information systems are complex structures handing practical information from collection to presentation to a user (Grotenhuis et al., 2007).

When faced with any spatial task, a human cognitively captures and processes tremendous amounts of information. This can include spatial information encoded in our memories through learning processes or maplike mental structures (Lloyd & Cammack, 2007; Tversky, 1993). It is, therefore, impossible to observe and account for all information sources used during a single travel activity. The information sources considered in this study consists of physical and non-physical perceivable information. The former refers to data that can be visually captured, e.g., a sign at a station indicating the direction to a platform or a travel app suggesting a route. Non-physical information sources can stem from almost anything, such as past experiences, knowledge of an area, or intuition. Some approaches focus just on information related to public transportation. For instance, Hörold et al. (2012) break down information sources into location information, time-related information, connection information, ticket information, vehicle, network plan, and disturbance information.

This thesis considers the information sources: apps, station displays, vehicle displays, signs and signals, knowledge of surroundings, intuition, landmarks, printed timetables, or maps. A detailed list with descriptions and examples of all physical information sources can be viewed in the 9.1).

Travel-related Technology

The provision of public transportation information has two key players: a service provider, which is responsible for the infrastructural information system, and on the other hand, the user who retrieves the information for travel. Travel information assistance is the term used for bridging these two players.

Looking at the public transportation user, numerous travel technologies have been developed to support needs (Schwanen, 2015). A mobile device, or more contemporary, a smartphone, is one of these technologies used in travel and is a handheld device able to communicate, access the internet, and facilitate customizable and adjustable information on a display. However, such devices are, in fact, not very *smart* without the software applications that give them their actual usability (Schmitz et al., 2016). Today there is an entire virtual market where companies and agencies share and sell their mobile applications (apps) (Wu et al., 2021). A smartphone app can be an end-user software application designed for a mobile phone operating system and can extend the device's capabilities by letting the user perform tasks (Schmitz et al., 2016). A smartphone's hardware enables apps to access global positional services and provide location-based information, successfully completing spatio-temporal tasks (Richter et al., 2010). Any essential functionality or a service an app provides for a user can be considered a feature (Wu et al., 2021).

Regarding travel, apps today can provide navigational instructions, public transportation information, or maps, making such technologies very useful. The main available operating systems, Android (Google devices) and iOS (Apple devices), each also offer its native wayfinding app (Ricker and Roth, 2018).

On the other side of the equation are public transportation providers, which include agencies, the government, or private companies. They are responsible for constructing and maintaining a public transportation network and providing users with travel information. For instance, Mrs. Andenmatten from a local service provider (ZVV) says they have digital screens that show wait times and connections while also offering an app to users with public transportation information. Advanced traveler information systems (ATIS) mentioned by Camacho et al. (2013) represent a form of technology in which information is acquired and presented to a passenger to use. Real-time passenger information (RTPI) takes it further by using network positioning sensors. For example, a bus is synchronized with the system and can automatically show a potential passenger that it is delayed (Camacho et al., 2013).

Mobility as a Service

In recent literature, *Mobility as a Service* (MaaS) has been brought at an increasing rate. The general idea and goal of MaaS is to shift people away from an existing ownership-based transport system to an access-based one, meaning to provide an alternative to a private car (Jittrapirom et al., 2017; Lyons et al., 2019). The concept calls for a restructuring of passenger transportation caused by societal, urban, and technological changes in the development of addressing needs in transportation (Heikkilä, 2014).

MaaS bundles offers of multiple means of transportation for solving everyday travel needs (Smith et al., 2018). Three specific characteristics are outlined by Lopez-Carreiro et al. (2020). First, MaaS provides an on-demand multimodal mobility package tailored to individual travel needs. Second, it enables access to all city mobility services, including payment and ticketing features. Thirdly, information is accessible through a user-friendly single digital platform, ideally in the form of a mobile app. Jittrapirom et al. (2017) use a mobile phone plan as an analogy, which lets a user choose and combine different services in a monthly paid user package.

Not only is MaaS still considered a niche development (Lyons et al., 2019), its success is highly dependent on understanding an individual’s needs and responding to their demands (Alonso-González et al., 2020).

2.3 Study Location

The City of Zurich

This study takes place in the City of Zurich, Switzerland. The choice of selecting this city as the location for the study is for the simple reason that the University is located here. Zurich is the largest city in Switzerland in terms of population and urban area. As of 2022, the municipality has around 439,000 (Stadt Zürich, 2022b), and the canton has 1.56 Mio inhabitants (Kanton Zürich, 2022). Economically Zurich plays a vital role in Switzerland's finance sector as many banks, insurance, and international companies are situated here. The City of Zurich can easily be reached by train from most European cities within a few hours, and the nearby international airport serves as a connection point for travel and trade. Many tourists come to explore the city's cultural history, shop at high-end brands or enjoy the natural atmosphere in or along the lake (Switzerland Tourism, 2022).

Only behind Singapore, Zurich is ranked second in the intelligent city index, which attempts to reflect the efforts made by a city to balance *economic and technological aspects* with *humane dimensions* (IMD, 2021). Other international indexes consistently rank Zurich at a top position, for example, regarding sustainability or quality of life (Arcadis, 2017; Mercer, 2021). *Figure 1* shows a map of the greater area of Zurich. The city is located in north-central Switzerland and the metropolitan area spans around the northwestern tip of *Lake Zurich*. (Stadt Zürich, 2022a)

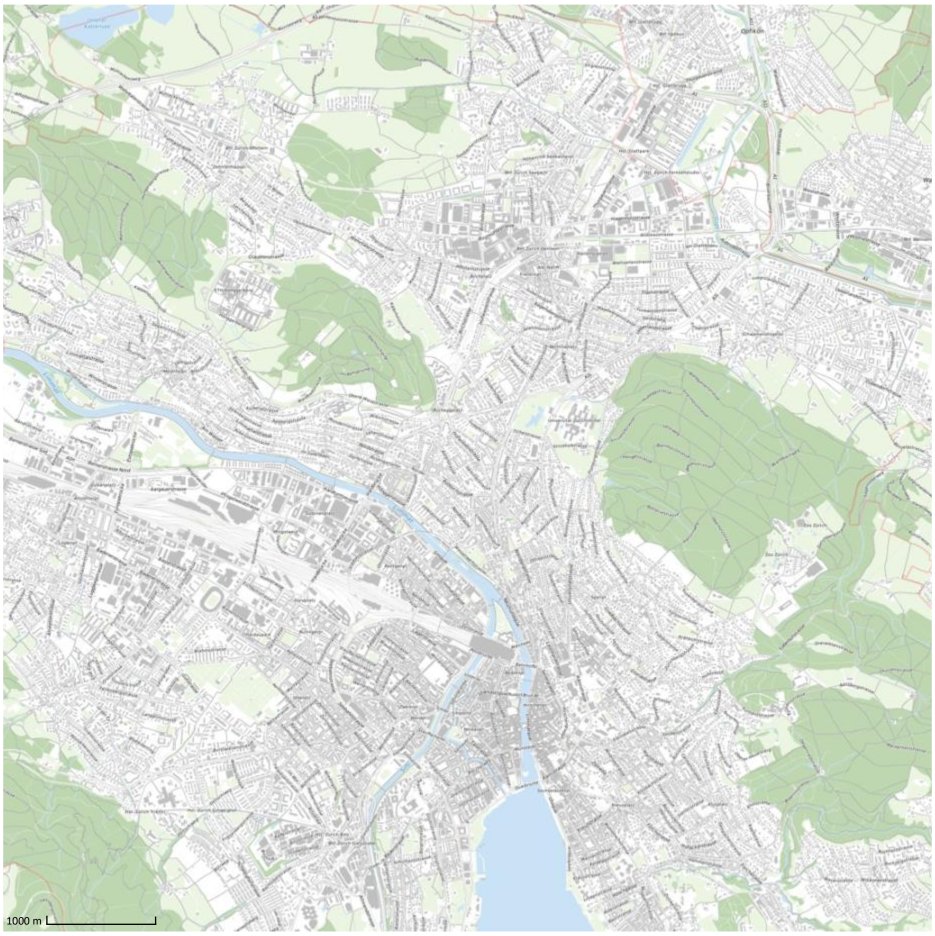


Figure 1: Map of the City of Zurich (Stadt Zürich, 2022)

Public Transportation in Zurich

Particularly in the second half of the 20th century, motorized vehicles were prevalent and the preferred mode of transportation in Switzerland. In the 1990s, however, cities, such as Zurich, were confronted with the problem of traffic congestion while also beginning to show awareness of environmental concerns. As a solution, more public transportation projects were implemented, expanding the urban transport network, thus making urban commutes by bus, tram, or train more appealing. While more connections and destinations were being integrated into the network, hubs such as centrally located train stations were developed into sizeable multipurpose transfer points (EWP & Schweizerischer Städteverband, 2019).

Through the historically strategic city located at the head of the *Lake of Zurich* and along the rivers *Limmat* and *Sihl*, the city today hosts a uniquely designed public transit network and a combination of means of transport. Multiple inner-city bus and tram lines run diagonally through the city, connect the center with outer areas or run as a tangent along city limits. In some urban areas, cars had to make way for tram and bus lines. *Figure 2* shows a representation of Zurich's transportation network.

Today, Zurich's transportation network, just like Switzerland's as a whole, is internationally perceived to be well connected, modern, and efficient. This is also reflected in different international studies and rankings, which highlight the city's excellent level of service, network usability, and reliability

(Carrasco, 2012; Nash et al., 2020; Omio, 2019). Furthermore, minimal levels of air pollution, a lack of traffic congestion, ample access to green spaces, and robust transport infrastructure are responsible for placing the Swiss city in the top five of the urban mobility index (Cebr, 2017).

As far as railway station indexes go, Zurich's central train station, situated at the heart of the city, is rated overall second in Europe (Consumer Choice Center, 2020) and is reportedly used daily by more than 400'000 commuters on weekdays (SBB, 2022).

According to a statistical report by the Canton of Zurich, nine out of ten inhabitants are mobile daily, which is well above the national average (BFS, 2018). Zurich's transportation association, *Zürcher Verkehrsverbund* (ZVV), is the largest in Switzerland and unites over 30 transportation companies (ZVV, 2022). One of which is the *Verkehrsbetriebe Zürich* (VBZ), which is wholly owned by the city itself and operates many tram, trolleybus, and bus lines in the urban area of Zurich (VBZ, 2021). The central train station, in the city center and the largest in the country, houses above and below-ground long-distance and local train lines while providing adjacent short travel options with different tram and bus stops.

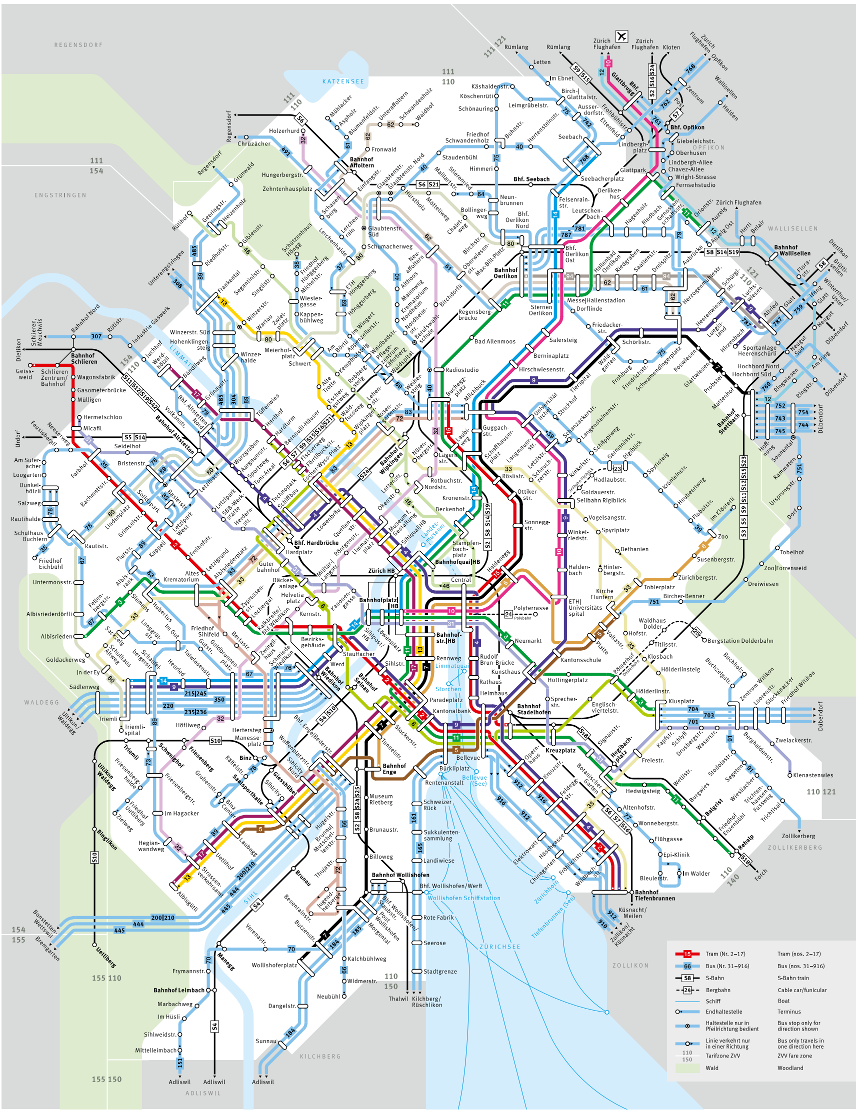


Figure 2: Transportation network of the City of Zurich (ZVV, 2022)

Apart from the central station, other stations in the metropolitan area of Zurich rank very high when it comes to passenger numbers: *Oerlikon* to the north (7), *Stadelhofen* to the south (9), and *Hardbrücke* to the north-west (11) (SBB, 2022). This shows that the region hosts a high commute volume in a dense station network. According to a report by the City of Zurich, 84% of people living in Zurich in 2015 had a transportation pass. Furthermore, from 2000 until 2015, the share of people using public transportation increased from 30% to 41%, while motorized transport dropped from 40% to 25% (BFS, 2018). This shows that public transportation is highly valued among the city's residents. However, the network also becomes more complex by constantly increasing the system of connections and options.

As one expects from a dense urban area, cultural, sports, or music events, as well as demonstrations, frequently occur, affecting the public transportation network. Since most of Zurich's city public transport system runs above ground, one might assume the network is especially prone to such events. However, 98% of inner-city trains, buses, and trams are always on time, while over 95% of all daily connections are successful (ZVV, 2018).

The City of Zurich as a mobility study location is comparable to other international cities, as a substantial shift towards promoting, developing, and expanding the public transport sector can be observed. On the other hand, the diverse range of modes of transport and their intersectionality in the urban landscape is unique.

3 Objective

Now that the general subject has been put into perspective with conventional literature, the following subchapter underlines the research gap this thesis attempts to fill. In 3.2 the three core research questions of the thesis are presented, together will their hypothesis.

3.1 Research Gap

Many resources are devoted to the supply side of public transportation systems, meaning the development of information technologies. On the other hand, daily practices, patterns, and motives are not well covered (Gebhardt et al., 2016).

There are many publications on research regarding travel services and projects to improve information systems. However, it seems that due to constant technological developments, specific research on mobile devices and app usage surrounding urban travel has been two steps behind. An example is MaaS, which is evolving faster than relevant literature can keep up with (Lopez-Carreiro et al., 2020). Research has not extensively covered the full-scale implications of such a mobility concept on the user. In particular, the question of how modern-day public transportation users require combination of information sources, and the degree of quality is yet to be profoundly analyzed (Altay & Okumus, 2021; Smith et al., 2018). At the same time digital information sources such as travel apps, confront developers with the challenge of not knowing enough about the end-users needs and preferences and thus must constantly adapt (Lim et al., 2015).

Therefore, the general focus of this work is the demand side of public transportation, focusing on the user. In particular, what information users need for efficient travel and which strategies are implemented. The assessment of information needs for urban travel and identifying strategies related to public transportation is yet to be profoundly researched, making the objective of this thesis unique. This thesis aims to reveal how public transportation users handle relevant information to travel efficiently throughout an urban environment and how modern travel information systems are perceived.

The outcomes and conclusions this thesis yields can help policymakers, and public transportation agencies recognize the challenges users in urban areas have and what needs should be addressed. Moreover, this thesis represents a call for more attention to future research surrounding public transportation user demands and thus promoting sustainable urban transportation.

3.2 Research Questions

In the wake of the research gaps highlighted in the previous subchapter, three research questions have been derived. The thesis is structured around addressing and answering these three research questions and their hypothesis.

Research Question 1

Which user information needs can be identified in public transportation and what is the role of apps and their features for urban travel?

Hypothesis

Public transportation users have the constant need to be informed regarding problems and their progress along the route. Information related to space and time are of particular need to passengers. Travel apps represent the most helpful information source across all travel chain phases, especially due to features providing real-time data.

Research Question 2

Which travel strategies do public transportation users follow and how are travel related uncertainties delt with?

Hypothesis

A public transportation user follows a travel information retrieval routine, from destination search and decision-making processes to travel mode choice. Strategies are therefore firmly based on habitual preferences and how well the area and public transportation lines are known, thus physical information sources are preferred. Digital information sources only become a main part of a strategy once travel related problems come up.

Research Question 3

How can service providers in the City of Zurich improve their travel information systems to ensure easy urban travel?

Hypothesis

Public transportation providers need to find a way to address all user needs in a single and easy-to-handle app. As urban mobility becomes more complex, the need for technologies to advance and incorporate suitable alternatives grows. There is a demand for all digital information sources to be synchronized and reinforce each other during travel.

4 Methods

The objective of this thesis is to assess the strategies and needs of public transport users as well as to identify opportunities for digital systems to improve. Therefore, research methods need to be able to capture and focus on individual users' preferences and behavioral details, which point to a qualitative approach. Subchapters 4.1 and 4.2 present an overview of the methodological approach to this thesis before subchapters 4.3 – 4.5 explain the three stages in detail.

4.1 Research Design

This thesis's research design uses qualitative and quantitative approaches for these reasons. Integrating quantitative elements enables qualitative research results to establish the significance and documentation of a research problem (Sandelowski, 2001). Such a mixed methods approach enables one to obtain detailed information about a user's strategy and behavior while quantifying needs and preferences, allowing a balance of qualitative and quantitative research results.

Creswell and Clarks (2017) describe in detail how mixed-method models and procedures are chosen and how they are applied. The core mixed method design choice must suit the study's purpose. One is the convergent core design, which allows one to obtain data through qualitative and quantitative approaches, simultaneously independent of one another (*Figure 3*). The results of each approach are then interpreted together. The authors imply that such a design intends to obtain a complete understanding of a problem and even to validate a set of findings with another. Furthermore, the strengths of the qualitative and quantitative approaches are combined in a convergent design (Creswell and Clark, 2017). Considering the information to be collected for this study, a convergent core design is appropriate. *Figure 3* shows a rough overview of how the methods are to be applied and used for the thesis.

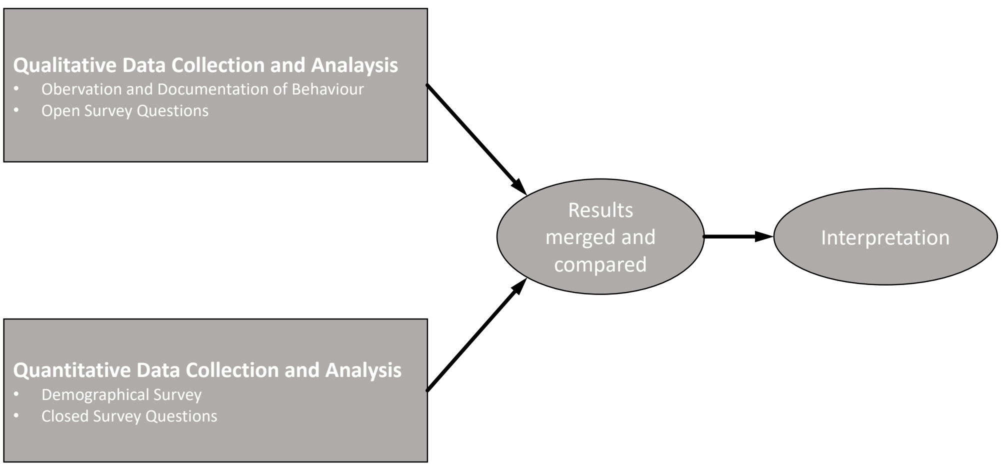


Figure 3: Diagram of Convergent Design, adapted from Creswell and Clark (2017)

The qualitative data for this thesis stems from two sources. One of which is through the observation and documentation of behaviors and strategies of participants solving predefined tasks. The second source is generated by participants answering open survey questions related to the previously solved assignments.

The quantitative data for this thesis is generated through a short survey focusing on demographics and general mobility information and an extensive in-depth survey, which follows up on mobility preferences and usage of information while using public transport.

Qualitative studies are based on conducting, documenting, and then analyzing types of interactions, commonly done as an interview. Although less widely used, Braun et al. (2021) see a survey format as an adequate tool in qualitative research methodology. It also offers an in-depth approach and allows participants to share their narratives, experiences, and discourses. Using a survey enables the study to increase consistency across all sessions, follow a more transparent structure, and prioritize qualitative research *values* alongside qualitative techniques. In addition, a digital survey has the significant benefit of accumulating the data and making it comparable with less effort (Braun et al., 2021).

Even though the study done for this thesis does not use interview-based research methods, it nonetheless has a similar depth and approach. In a study by Baudisch and Rosenholtz (2003), twelve participants were asked to solve four user tasks before being debriefed on their experiences in the form of an interview. Such methods, which combine two approaches, enable detailed results because the tasks are consistent across the participants instead of broad experiences. The tasks stimulate one to reflect and then share it in the interview.

A similar design is implemented in this study. However, instead of an individual interview with each participant, a comprehensive questionnaire in the form of an online survey must be filled out.

In studies similar to this, data is mainly obtained through interviews, which were done with 10 – 20 participants of varying lengths. Some authors conducted in-depth interviews, even using multiple focus groups; thus, there is a need for a high number of participants (Beirão & Sarsfield Cabral, 2007; Lopez-Carreiro et al., 2020).

Even though the initial aim was to recruit 12 – 16 participants for the study, 20 participants ended up taking part, which aligns with similar academic studies. Considering that each participant needed to devote a lot of their time, no compensation was offered, and the data collection phase was limited, having 20 people participate is quite respectable.

4.2 General Procedure

The study is done in several stages. A script of each stage can be viewed in detail in the appendix (9.2). All stages of the study are done individually with a single participant, who have the choice of partaking in English or German. In the first stage, a participant takes an online survey, which serves as a baseline and gathers general demographic and mobility information. Once this is completed, the second stage can begin, which consists of a series of four tasks to be done in the urban area of Zurich. Each of these tasks follows the same procedure: to reach a specific location in the city using public transportation. All four destinations are identical for all participants and are given in the same order.

After this stage is complete, or rather the last destination is found, the third stage can be done. This final stage is a further survey for the participant to fill out and serves as a kind of debriefing. Its focus is to make the participant reflect on the experienced tasks, share their strategy, and reveal general mobility habits and preferences.

The tasks are intended to put the participant in a real-world setting and be confronted with specific problems in urban mobility. The survey-based approach, as a debriefing after the completed tasks, enables the participants to express their thoughts and experience in a qualitative format. The survey has a mix of open, closed, and matrix questions. The open questions allow participants to freely write detailed answers, while closed and matrix questions suggest a series of responses one needs to select. As with any digital data collection software, an online survey has the significant advantage of summarizing and grouping the outputs. This means the results of each question can be obtained as a bundled statistic and when in the form of a graph, are consequently already processed to some extent. *Table 1* sums up all these steps which a participant goes through.

Table 1: Summary of steps each participant experiences

1. Invitation	• Potential participants receive an email with a short study description. • The invitation includes a signup link (Doodle) with available time slots.
2. Registration	• Signed-up (potential) participants receive another, more detailed email, which includes further requirements. • The email includes the first survey link (first stage) and the form of consent to review in advance.
3. Reception (First Stage)	• The participant signs the form of consent, which was ideally reviewed in advance, and fills out the first survey. • Any open questions and concerns regarding privacy, study procedures, or study objectives are addressed.
4. Study (Second Stage)	• The participant is instructed in detail on what the second stage is about and is given instructions on what to do. • The participants follow through with all four tasks throughout the urban area of Zurich.
5. Debriefing (Third Stage)	• The participant receives a link to the third stages survey. • The survey covers questions about the previous stage, general mobility apps, and usage.
6. Results	• At any time, the participant can withdraw, in which case their results are extracted from the study. • If requested, a copy of the results and thesis outcome can be shared later with the participant.

Study Requirements

For the study to take place, specific requirements need to be met. This also includes predefined circumstances for the study even to be conducted. In other words, purposeful sampling was used to recruit participants who fit the needs of the study.

The objective is to analyze common travel behavior of public transportation users. Thus, participants should be familiar with the City of Zurich and it’s public transportation system. Furthermore, participants need to be able to actively engage in the tasks and handle travel-related technologies such as travel apps. By agreeing to the described terms in the form of consent, risk and data privacy issues are acknowledged.

The conditions in which the study can take place are defined as well. Only during daytime and dry weather will the study take place. Nighttime or wet conditions can be an inconvenience to participants and may cause irregularities in the network and therefore change the session outcome. This is closely monitored beforehand and if necessary, sessions are rescheduled. All individual criteria for the study to take place are listed and described in detail in the appendix (9.4).

Data Confidentiality

During the study, different types of data are collected. Personal information, such as names and contact information, is only known by the study organizer. This information is only used to contact and communicate with the participant. The signup process is set up so that one can only see the available timeslots, thus not indicating who takes part and when. Each participant receives an individual and unique participation number, which is used across all data collection phases. By doing this, any collected data is not tied to the participant's persona but is only known to the study organizer in the form of a secured list. Once the participant has set up a date to do the study, they are told what their participation number is.

The first survey (stage 1) collects basic demographic information of the participant (age, gender, urban whereabouts). Before these questions are answered, the study and its data collection process are explained within the survey. Then the participant enters their unique participation number and follows through with the survey.

In the second stage, tasks need to be completed. Participants are provided with a smartphone to be used for the duration of the tasks. After each session, the smartphone is erased and reset, making it impossible for a participant to see what the previous participant did. During the tasks, the smartphone does a screen recording, which captures everything that happens on screen, but does not use any microphone or camera components. Therefore, the output is a video file showing what is shown on the smartphone screen. The only personalized setting is the background, which is automatically set to the corresponding participation number and has the sole purpose of keeping the video files sorted.

The observations made by the study organizer are entered into a log, which does not include any personal information. The travel phase, together with the used information sources, is logged with symbols, while no notes regarding the character or any private-based information are taken. The log itself is named and filed according to the participation number.

In the second survey (stage 3), participants choose and answer a diverse array of categorized questions. Participants are free to answer the open written questions in any way they want. Questions that may relate to a personal preference or an opinion always have the option to select "no answer" or skip.

Once one has signed up for a session, further detailed information is sent, and a form of consent is to be reviewed. This form of consent explains in detail how data is collected for a scientific purpose, the potential risks, and that the obtained data will be analyzed and published. Personal information will not be part of the study and will only be known to the organizer and encrypted by unique participation numbers. Before each study session begins, the participant discusses and signs this document. The entire form can be viewed in the appendix (9.3).

4.3 First Stage – Introduction and Demographic Survey

After a participant meets the requirements and selects a time slot to participate in the study, the first stage can be initiated. This stage is either done together with the study coordination at the time of the booked time slot or individually in advance by the participant. In the case that the form of consent has not yet been read or understood, this step is done at this point. The participant receives a link to a short survey, which they must fill out. This first survey takes approximately 10 minutes and covers basic information. The first questions relate to demographic information (gender, age category, and basic spatial whereabouts). These questions aim to check for a fair demographic balance across the participants. The detailed survey questions can be reviewed in the appendix (9.9).

4.4 Second Stage – Main Study

The second stage represents the main part of the study. This part is done in person, and the study organizer is present throughout the entire stage. Each participant has selected and scheduled an individual time slot. The meeting point is *Bellevue Zurich*, a large intersection near the city center. This was chosen as a starting point since it is easily accessible and situated in a well-connected part of the city, making it an ideal meeting and starting spot. After meeting with the participant, this study stage is explained in more detail. The stage has four tasks that need to be solved. All tasks are built the same way and aim to arrive at a specific location in Zurich. Once the first destination is reached, the first task is complete. Then the second destination is announced; thus, the second task begins, and so on, until all four tasks are completed. Four destinations must be reached, meaning each participant travels four routes to four different urban locations.

Instructions

Even though the tasks may seem straightforward, a set of instructions are communicated to the participant. These were formulated beforehand and explained to each participant before the beginning of the first tasks in this stage:

- Travel to *Friedhof Zürich Schwandenholz*
- Travel there as a pedestrian and/or public transportation user.
- Shared, paid, or private transport services are not to be used (e.g., rental bike, e-scooter, Uber)
- Travel there in the way and manner you usually would.
- Anything can be used as a source of information.
- If one uses a smartphone, the provided phone must be utilized.
- Only use the apps that you usually use and that you are entirely familiar to you.
- There is no time limit, and there is no right or wrong.
- I will be with you throughout the study but will not help you.
- I will only interfere with the study itself if necessary.

Tasks

Each of the four tasks consists of a single destination to which the participant should travel. All destinations and, therefore, all tasks are the same for all participants. The participant receives one task at a time, and the order is the same for all participants. The meeting and the starting point are *Bellevue Zurich* (Point S). Here the participant receives the instructions, which include the name of the next destination, in this case, *Friedhof Zurich Schwandenholz* (Point A). Once arrived at the location, that task is complete, and the next can commence with the announcement of the following location. This procedure is done four times; thus, four destinations are announced, ending at Point D. *Figure 4* shows all four tasks and their destinations as points (A – D). The dotted lines represent the direction and order the tasks are solved, but have no relevance to the actual route to be taken.

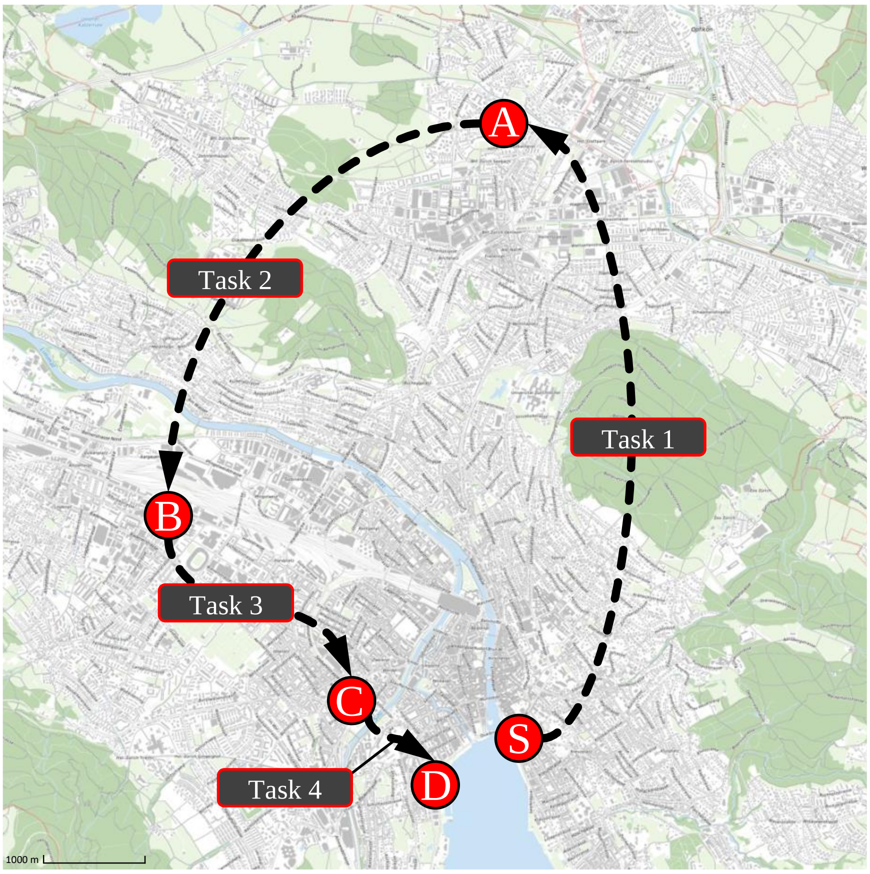


Figure 4: Map of Zurich showing all destinations and tasks of the second stage (Stadt Zürich, 2022)

Each of the tasks connects two different urban locations of the city and are chosen to the uniqueness of routes between them. *Table 2* lists all tasks with their start and end points, as well as provides additional information on some characteristics of the route and possible modes of transportation.

Table 2: Listing of task details: start and end point, distance, possible transport modes and routes

Task	Start point	End point	Linear Distance	Modes of Transport	Route Characteristics
1	Bellevue (S)	Friedhof Zürich Schwandenholz (A)	6 km	• Available tram lines in multiple different directions • Possibility of train station connections nearby (Stadelhofen; 5 min on foot)	• Urban route: south to north • At least two modes of transportation needed • Multiple options possible • Ideal connections depend on the day and time of day
2	Friedhof Zürich Schwandenholz (A)	Letzipark (B)	4.8 km	• Seebach or Oerlikon trains stations are close • Altstetten train station close to destination • Series of buses for direct route	• Direct but most complex route uses multiple buses • Possibility to backtrack • High terrain in-between start and end point.
3	Letzipark (B)	Sportanlage Sihlhölzli (C)	2.9 km	• Nearby bus and tram stops are available.	• Routes cut directly through densely populated urban area
4	Sportanlage Sihlhölzli (C)	Rentenwiese (D)	1.1 km	• No direct station/stop available • Tram and bus options are available within walking distance.	• The direct route is extremely short. • The relief (hill and river) makes a direct public transport route impossible.

Technical Setup and App Selection

The participant is given a smartphone to use during this stage. The provided device is an iPhone 11 Pro (Apple) running iOS 15.3. Using a built-in programmable focus mode option, the device is set up fixedly so that specific features are limited or unavailable. The connection to the internet is fixed to a local hotspot, and options to receive or make calls, as well as any notifications, are blocked. Furthermore, only one app page is visible, with twelve preinstalled apps for the participant's use. The screen recording is started and ended only by the study organizer. After the recording is terminated, the file is automatically saved. Then the device is reset, and all in-app settings, including search histories, are deleted. An external power bank is provided if the device's battery runs out.

Twelve apps were provided for participants to choose from freely. Many apps would suit the purpose of the four tasks. However, the selection is limited to twelve to keep the choices consistent across all participants and not to provide so many apps that it takes time to find the app on the screen. The choice of which apps would be available was made according to three criteria: popularity, appropriate usability, or locally based. The popularity of an app can be measured by its ranking within the relevant category, which in this case is navigation and travel. Thus, apps suitable for the study and ranked high were considered. However, the apps are ranked on an overall national download and usability scale and may therefore vary geographically. To counterbalance this and to refine the options, a simple online survey was conducted on a local scale, in which the usage and popularity of relevant apps were assessed. The results of this small online survey can be viewed in the appendix (9.5).

A further criterion in the selection process is the appropriate usability of an app for the study. Many apps are multifunctional and can serve different needs regarding travel and navigation. Also, apps serve specific types of travel or navigation. For example, a visitor to the city may use an app that focuses on popular places and how to navigate as a tourist. Among the travel and navigation apps, there might be apps used for motorized vehicles or ride-sharing companies. Therefore, only appropriate apps relevant to the study's tasks are considered, mainly apps providing intermodal travel options or focusing on urban-based navigation.

The last criterium in the selection process is the locality of the app. The national, but also local transportation agencies provide their apps. These apps have many different features, providing a ticket system, timetables, and maps while focusing on the regional transportation network. With these criteria in mind, the following apps were selected and provided for participants to use (*Figure 5*). A detailed description of each app can be viewed in the appendix (9.6).

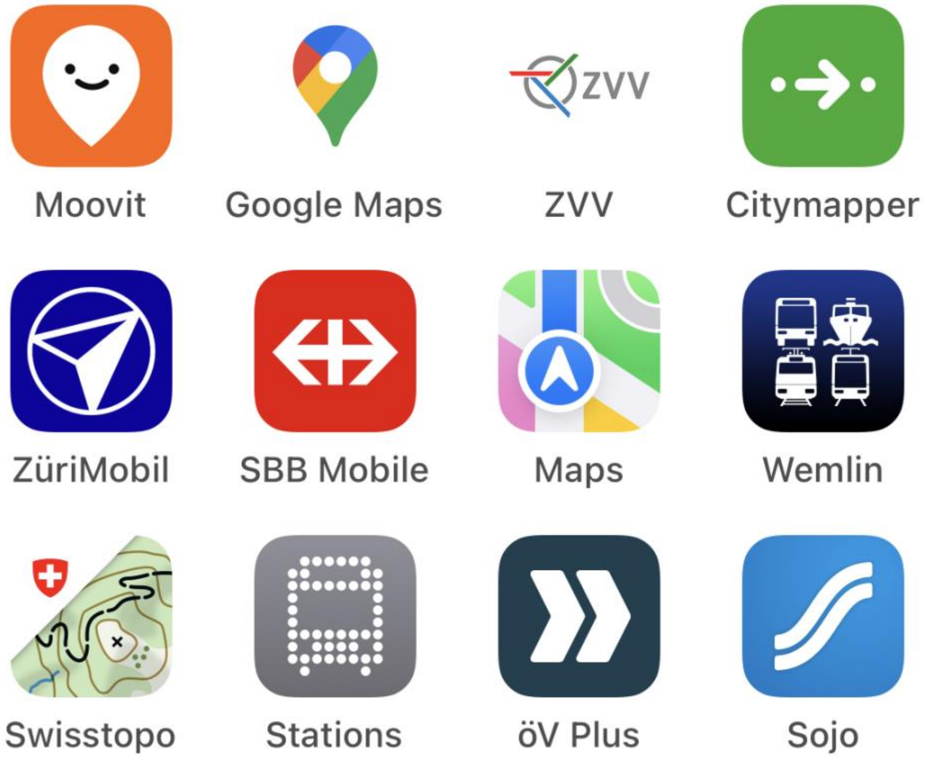


Figure 5: The 12 apps provided to participants to choose from while solving the tasks

4.5 Third Stage – Debriefing Survey

The third and last stage of the study consists of another online survey. Like the first stage, the survey was created and distributed using the LimeSurvey tool. This study stage is intended to debrief the participants on their experience during the previous tasks. Researching and deciding the ideal way to reach a destination during the tasks should have prompted a reflection on one's preference and strategy of traveling by public transport. The survey's questions are intended to extract these perceptions of travel and thus relate to the study's research questions.

The survey is divided into thematic question groups and uses open and closed question methods. The closed questions consist of different formats, including multiple or single choices and matrix question groups. Where appropriate, the questions follow the principles set by Likert (1932). This means techniques for measurement of attitude with multiple options are applied, thus giving participants the chance to answer on a scale instead of a yes/no format. The open questions let participants write individual answer to the questions, thus encouraging explanations of specific subjects such as strategies or perceptions.

Each question group targets a specific area of interest for this thesis research. The first questions focus on the previously solved tasks, their difficulty, and the reason for it. Participants have the opportunity to rank the tasks according to their difficulty. In the second question group for each of the travel phases a usefulness ranking of the information sources must be done, as well as how each source did in terms of reliability. The following questions are centered around travel strategies, where participants are open to write how they approached and solved the tasks. Next, participants are asked about app features, before the subject of travel uncertainties is touched upon. The last two question groups focus on travel in an unknown environment and thoughts on the future developments of urban mobility. All survey questions and answer options can be viewed in the appendix (9.9).

4.6 Data Collection

Survey Tool

The surveys used in this study were created using LimeSurvey (first and third stage). Choosing this specific survey tool for this thesis' study has simple reasoning. For one, thanks to the University of Zurich, its usage is free of cost and is officially known as a legit scientific online survey tool. Furthermore, the UZH has implemented its predefined user interface, thus implying credibility and professionalism.

The usage of such digital online-based survey tools has multiple advantages. Apart from the apparent paperless format of filling out and submitting with the click of a finger, this approach also allows the creator to control variable answers, adjust and change before publishing, and obtain additional comparable metrics between the participants regarding how the survey was filled out. Distributed under the GNU General Public License, the German company states it is "a simple tool that can achieve a lot" and represents "… the optimal online survey tool for research institutes, universities, and other educational institutions". As a survey creator, the tool lets one select from 28 different question types, ranging from simple selection-based question groups to extremely complex conditional-based matrixes. LimeSurvey's approach is based on data security, transparency, and openness. (LimeSurvey GmbH, 2022).

The survey tool lets one structure the questions individually or in groups. There are all different kinds of question types one can choose. A text field can be arranged for open questions, and its maximum word capacity is defined. There are setups for multiple, single choice, or even matrix and dual matrix configurations for complex questions where one needs to select from predefined answers. There are always further options for each question, e.g., conditional settings, making a question mandatory, or adding text to explain what is being asked.

LimeSurvey lets the creator monitor the questions and answers while the survey runs. There are tools in place which allow the creator, ideally when all answers are in, to compute a statistical overview of the results. For each question, one can specify how the data is shown. The type of output visualization one chooses depends on the data obtained by that question. Once a satisfying data output is found, one can export it as a file. However, to format and improve design options, the data was not exported in a visualized form but as raw data. Thus, the downloaded data can then be locally stored and imported, and further edited in programs such as Microsoft Excel or R.

Task Documentation

During the second stage of the study, participants must solve four tasks throughout the urban area of Zurich. While this is done, the study organizer documents specific events and noteworthy occurrences. Each task is documented individually and is done with consistently observed actions during distinct travel phases.

Participants use different information sources to satisfy their information needs throughout the task. Each of these actions can be categorized into a type of source: orientational purpose (e.g., landmarks), information retrieval using a physical source (e.g., signs, displayed information, timetables), or information retrieval using a digital source (smartphone apps).

Similar to how Digmayer et al. (2015) divided a journey into multiple phases between two points, five intermodal travel phases are identified: waiting, walking, getting in or out, and onboard travel. The participant's current travel phase is noted, and further information on their actions during this phase is documented.

Once one of these *events* takes place, it is entered into a log alongside the intermodal phase. This log is to collect all observations in a structured and efficient way. For that reason, each phase and event receive a predefined symbol. The following tables (*Table 3* and *Table 4*) show how each source and phase is defined and which symbols are used.

Table 3: Travel log set up: intermodal travel phase with corresponding symbol

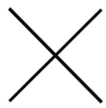
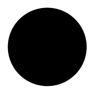
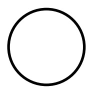
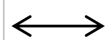
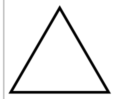
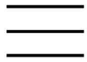
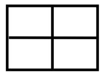
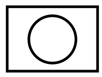
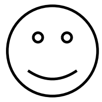
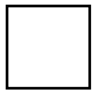
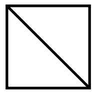
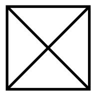
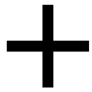
Phase	Description	Symbol
Waiting/ Stationary	When a participant remains in the same location, this includes waiting at a station, stopping for a vehicle to arrive, or staying in the same place because a direction has not been chosen yet. Waiting inside public transportation is excluded.	
On foot	Once a participant moves in a direction by walking.	
Getting on	The phase in which a participant is at a station or a stop and is prepared to enter the stationary or approaching vehicle until they are within the vehicle when it leaves the station or stop.	
Getting off	The phase in which a participant prepares to disembark the vehicle and arrives at a station or a stop until a direction on foot is chosen.	
Onboard Travel	The phase in which one is inside the transport vehicle, and it is in movement.	

Table 4: Travel log set up: intermodal travel phase with corresponding symbol

Type	Event	Symbol
Orientation	**Landmark:** Any form of built or natural element in the environment used to help a participant's orientation or navigation (church, lake/river, intersection, building, statue, etc.).	
	Compass: A participant uses the smartphone's compass function (within the app) to position themselves in the correct direction.	
Information retrieval	**Station timetable:** The participant retrieves information by looking at the printed timetable at the station.	
	Station display: The participant retrieves information by looking at the electronic display at the station (indicates line number, wait time, accessibility and warnings).	
	Vehicle display: Participant retrieves information by looking at the electronic display within the vehicle (indicates line number, time until next station, connections and warnings).	
	Human Interaction: The participant interacts with someone else (asks for directions, asks the driver, etc.).	
Screen time	**Short:** Participant quickly glances at the smartphone screen. < 4 sec	
	Medium: Participant glances at the smartphone screen. 4 – 20 sec	
	Extensive: Participant extensively glances at the smartphone screen. > 20 sec	
Interference	**Interference protocol** is used, thus disrupting the travel behavior. (time limit, incorrect action/direction/choice, hazards, etc.)	

Using this symbology, each task is documented with the observations made in this task. *Figure 6* shows an example of a travel log. It displays a vertical timeline and intermodal travel with events. Time stamps are captured in intervals to make the travel chain analysis easier. Using the corresponding symbols, the phase is noted in the first column, where the observed events and used information sources are documented with symbols.

For example, at 11:23 the participant is walking using navigational assistance. A brief glance at the app information and comparison to a landmark is observed. Then another passenger is asked if it is the correct station. In this described example the travel phase is walking, which is logged as a horizontal S shape. The events are individually logged using the arrow (navigation), square (glace at app), triangle (comparison to landmark) and a smile symbol (interaction).

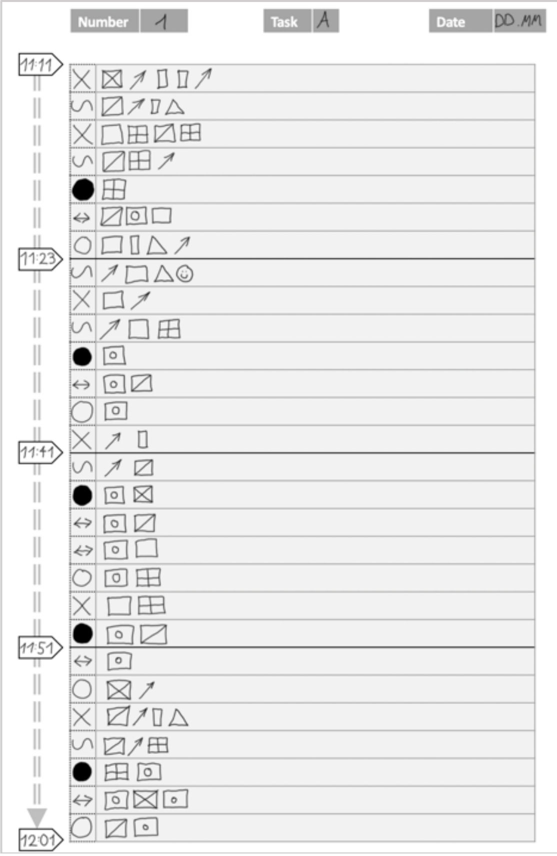


Figure 6: Example of a travel log with corresponding notes

Screen Recording

In addition to the log as a tool for documentation, all interactions with the provided smartphone are also captured. This data is not intended to be analyzed in-depth but used as an additional supporting data source to the observations. Before each task, the screen recording is manually activated, recording everything happening on the screen. This way, all app switching, information sources, features within the app can be tracked. In addition, since the screen shows a digital clock, the material can easily be compared to the log. The device only records what is happening on the screen and cannot record camera or voice content. Before the second stage starts, these facts are communicated again to the participant. At the end of each stage, the recording is stopped and saved. Therefore, for each participant, four separate video files containing the video recordings are collected. The screen background of the smartphone is set to the participation number of the corresponding participant, which serves as additional help in assigning the exact recordings to the right session.

Travel Chain Approach

In a literature review and scenario-based approach done by Digmayer et al. (2015), the different phases and travel activities are summarized visually using travel chains. These models show a basic timeline of the user's trip segmented into phases, represent intermodal travel. *Figure 7* is an example of such representations, as it shows the start and end points of travel, and all the intermodal phases and events along the route, including the modes of transportation.

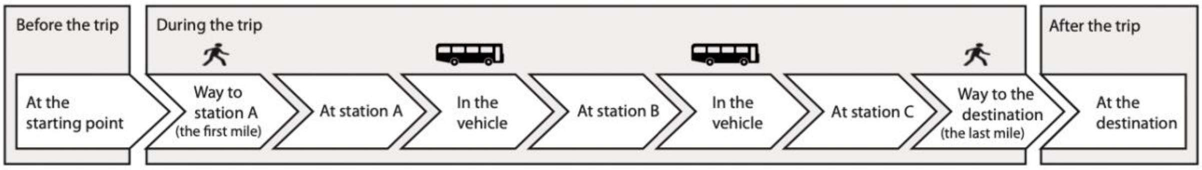


Figure 7: Basic public transportation travel chain by Digmayer et al. 2015

A similar model can be derived from the logs and the screen recordings gathered in this study. The travel log provides information on the intermodal timeline and the types of information sources used along the route. The screen recordings provided the exact timestamps as verification and also show at which point an app was used. These elements can also be visually summarized as a travel chain, but in this case with an additional dimension.

Figure 8 shows an example of how the intermodal travel information in this work can be visualized. The core structure of the travel chain is the same as in *Figure 7*. However, since data on events and usage of information can be observed at a more detailed level, these dimensions have been added. The four information sources, which can be observed during the tasks, are individually classified. The interactions with these sources are indicated along the travel chain, thus displaying the point usage during intermodal travel. Nevertheless, this is model represents a general example of a possible travel scenario. In reality, many details are needed and information sources are perhaps combined or used simultaneously, which this model is not able to fully capture.

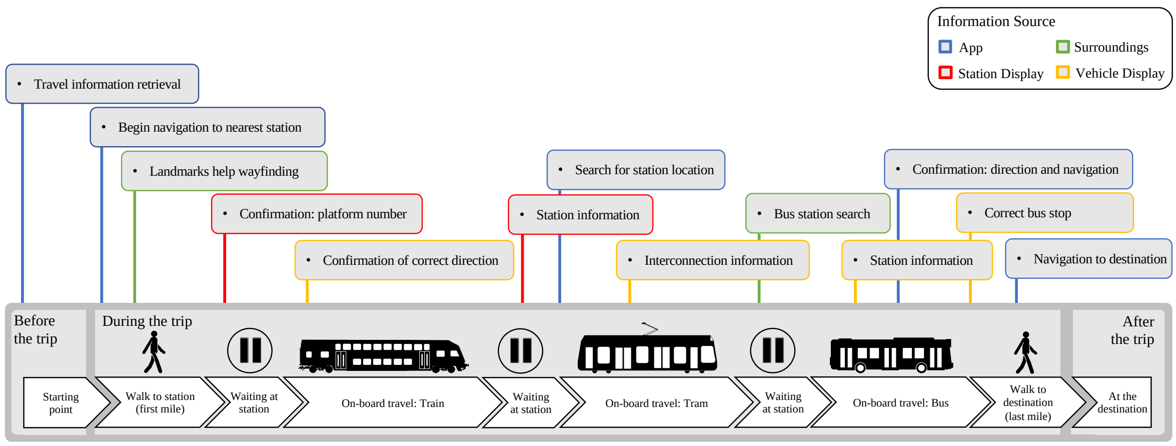


Figure 8: Proposed intermodal travel chain combining mode of transport and information sources

Interference Protocol

Before the study, a set of inference rules in the form of a protocol was set up. This protocol aims to have an actionable response to any type of abnormal event that might occur during the tasks. The participants do not know what is included in these rules. However, they are told that the study organizer has a set of guidelines they follow when interacting with the participant. These rules include general safety and environmental concerns and what to do if a participant makes a severe mistake or if technical issues arise. By following and applying these rules, interactions as a response to any type of issue are consistent across all sessions. A detailed listing of each possible issue and the corresponding interference can be viewed in detail in the appendix (9.8).

5 Results

The results in this chapter are presented in the same structure and order they were derived from the study. Therefore, 5.1 displays demographic results produced by the first survey, 5.2 covers all observational results and lastly, the debriefing survey results are shown in 5.3.

5.1 First Stage – Demographic Results

The study consists of 20 participants who complete all three stages. In the first stage, demographic background information is collected using an online survey. Between men and women, there are almost the exact amount (nine female, ten male); one gender is not specified. There are six age groups one can choose from. Eleven participants are between 21 and 29 years of age. Three are between 30 and 39. Four are between 40 and 49, while one person in the age categories 50 – 59 and 60 participated.

Regarding geographic mobility (*Figure 9*), all 20 participants relate to the city in some way since none indicate that they are *never* in the city. Some still visit agglomeration and countryside areas daily, but generally, the frequency is lower.

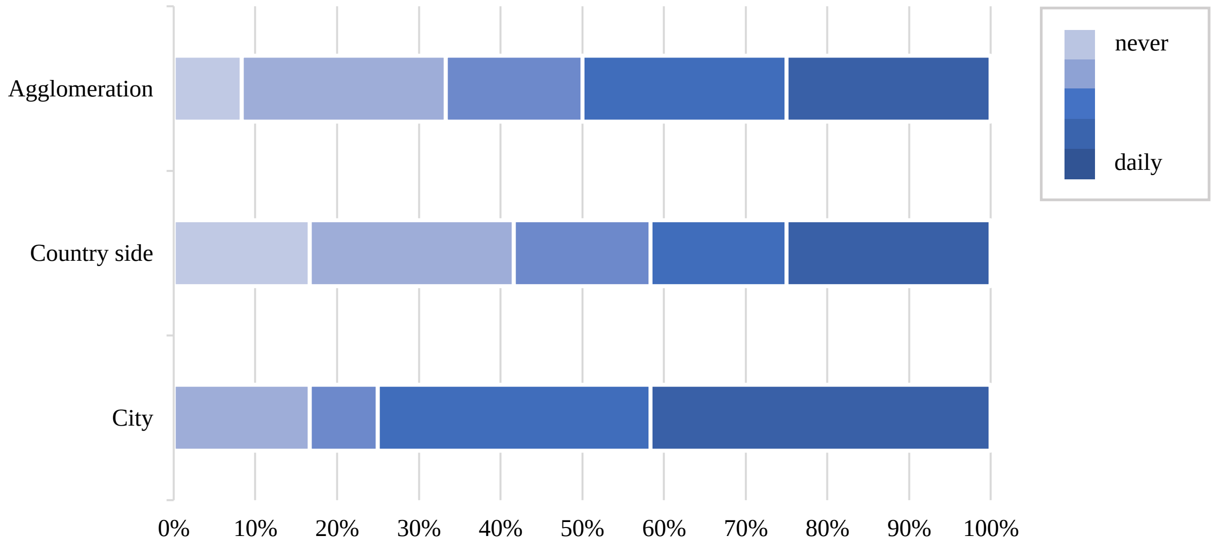


Figure 9: Geographic mobility of the participants

Only three do not have any transportation pass. Twelve have a *Halbtax*[1] pass, and a few have a general pass or a type of travel card. It is important to note that there are often combinations possible since passes do not all have the same purpose, while the renewal of a pass may also vary. Other not depicted survey results indicate that all participants frequently use public transportation. Almost half use it either daily or even multiple times per day. The most selected answer is using public transportation 4 – 5 times a week.

[1] *Halbtax* is a swisswide pass provided by SBB and allows the purchase of any public transportation ticket to half price.

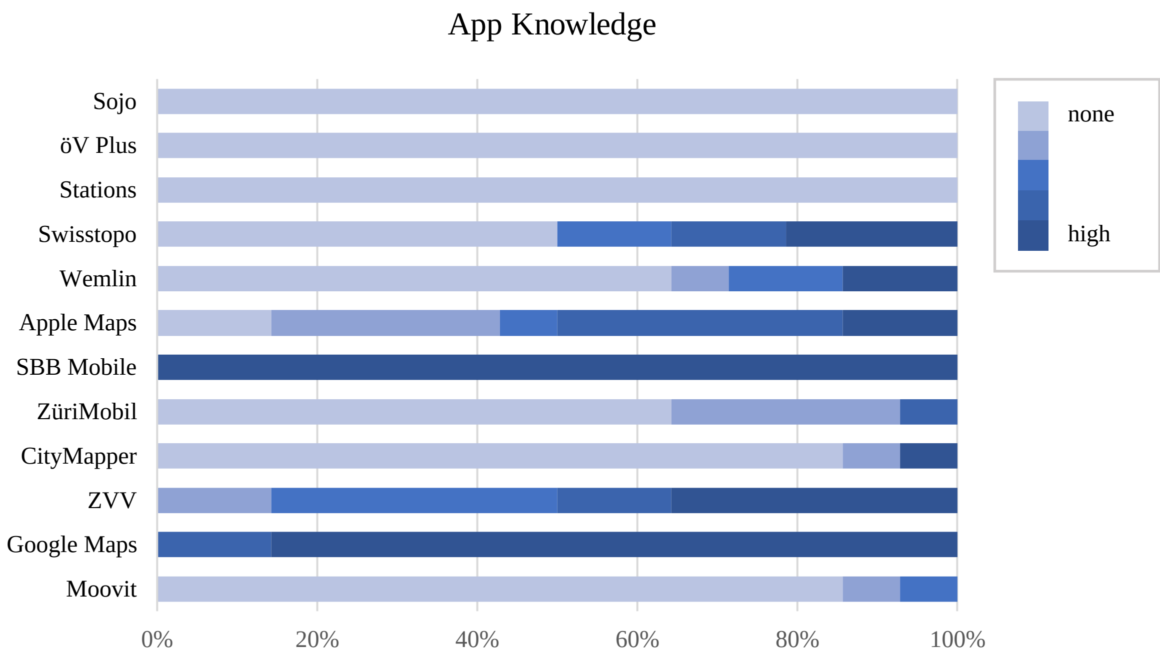


Figure 10: Participant knowledge of all twelve provided apps in the study

Figure 10 shows the results of how familiar the participants are with the twelve selected apps. The apps Moovit, CityMapper, Stations, öV Plus, and Sojo, are barely or not known at all. In contrast, Google Maps, ZVV, and SBB Mobile are exceptionally well-known to all participants. A few have heard of ZüriMobil and Wemlin. Apple Maps is also adequality known across all participants.

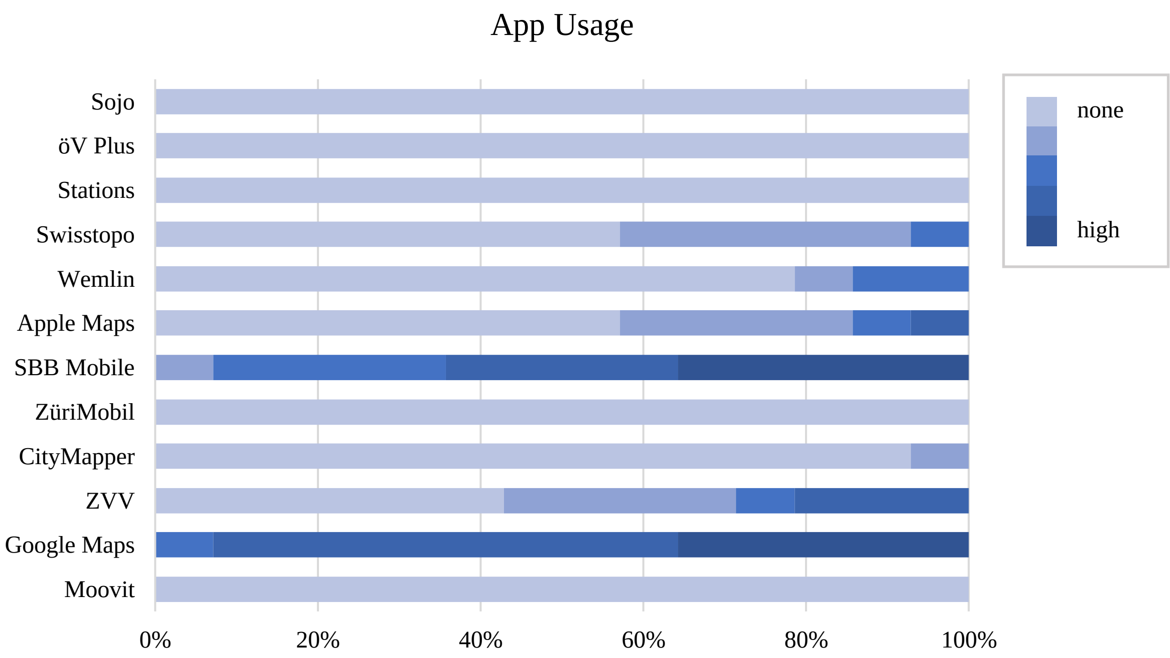


Figure 11: Participant usage of all twelve provided apps in the study

Using the same app selection, participants are asked how often they use the apps (*Figure 11*). Results are similar to app knowledge from *Figure 10* but are, in addition, sharper. Google Maps and SBB Mobile are clearly the most frequently used, for a lot, even almost daily. ZVV and Apple Maps have some frequent users, while most participants use the others relatively rarely or never.

5.2 Second Stage – Task Results

The study sessions, or tasks, only took place during daylight and in dry conditions to keep consistency. Each day of the week had, at some point, at least one participant taking part in the study. This means no days of the week were excluded from the study. Three session time slots were offered: 9:00 until noon, 13:00 until 16:00, and 17:00 until 20:00. The afternoon and evening sessions were more popular, with each having eight participants sign-ups, while four took part in a morning session. Time of week and time of day are equally distributed. All sessions took place in April and May of 2022 in the City of Zurich, and none of the sessions needed to be postponed due to weather.

The following subchapters show and describe results from the second study stage, in which the tasks were solved. These results stem from two information sources: the documented notes using the travel log and the smartphone screen recordings.

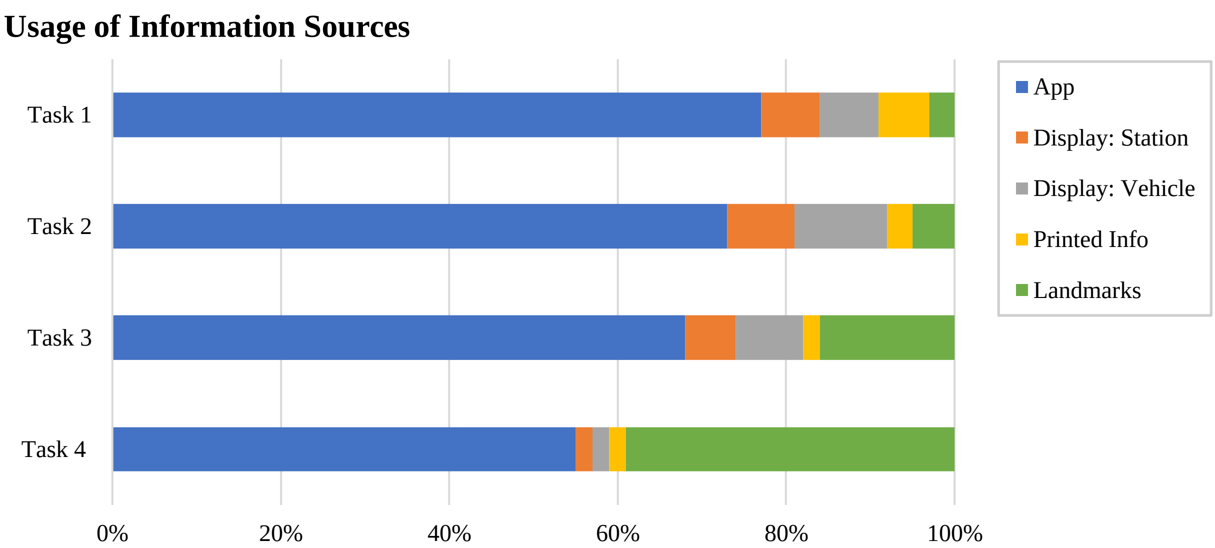


Figure 12: Observed participant interactions with information sources across the four tasks

Figure 12 shows how information sources are observed to be utilized across all four tasks. Travel apps are the dominant source of information, taking up 55% – 75% of the usage. However, app usage decreases throughout the study. On the other hand, using landmarks to help get around becomes more important, especially in task 4, where usage almost reaches 40%. Printed information which includes maps and timetables, is never or hardly used in any tasks. In the first three tasks, both station and vehicle displays are each used to around 10%.

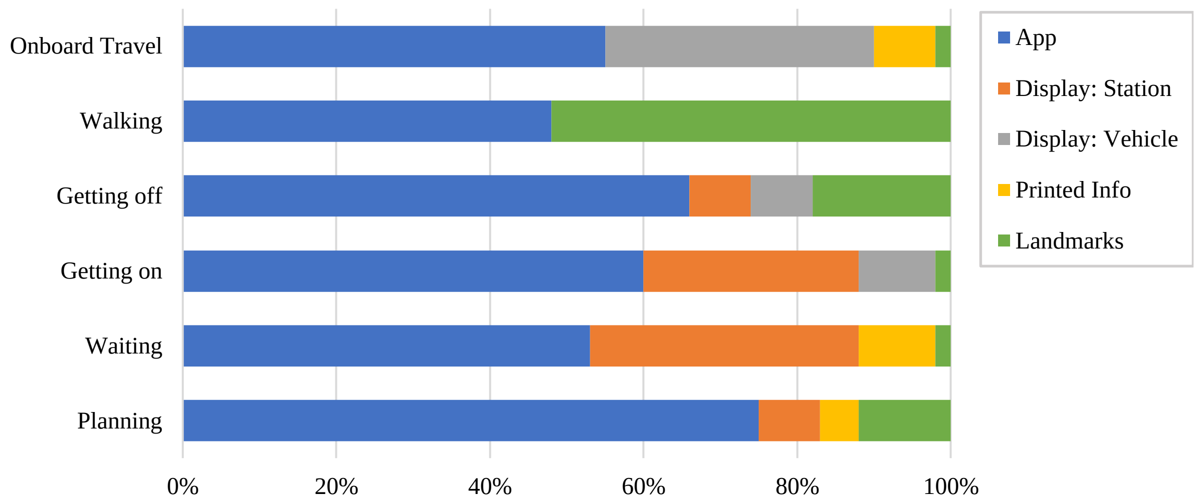


Figure 13: Observed participant interactions with information sources across travel phases

The usage of information sources across each intermodal travel phase is visualized in *Figure 13*. Except for traveling on foot (48%), the app is used the most as a source of information. Especially for planning a trip, its usage is high (75%). During the other phases, travel apps are consistently used as a source of information more than half the time. The usage of landmarks is highest when traveling on foot (52%) and when getting off public transportation (18%), as well as when travel is planned (12%). Station displays are used most while waiting (35%) and when getting on public transportation (28%). Displays within public transportation were mainly used while traveling (35%). Printed information was never used except for brief moments during planning, waiting, or traveling.

Usage of App Features

The following results of this subchapter include the usage of app features observed during the tasks. The results stem from the screen recordings, which show how often these elements were used during intermodal travel and across all tasks.

The observed interactions and usage of these elements are assigned to one of four categories. Maps include any geographical representations provided as an interface for users to obtain spatial information. Search outputs in the form of a route meeting the participants' requirements are categorized as *route suggestions*. Interactions related to directional information, where one’s current location in proximity to the destination is used, are included as a navigation source. Lastly, any feature providing information on the current location, such as possible transportation lines or departures, is categorized as *location info*.

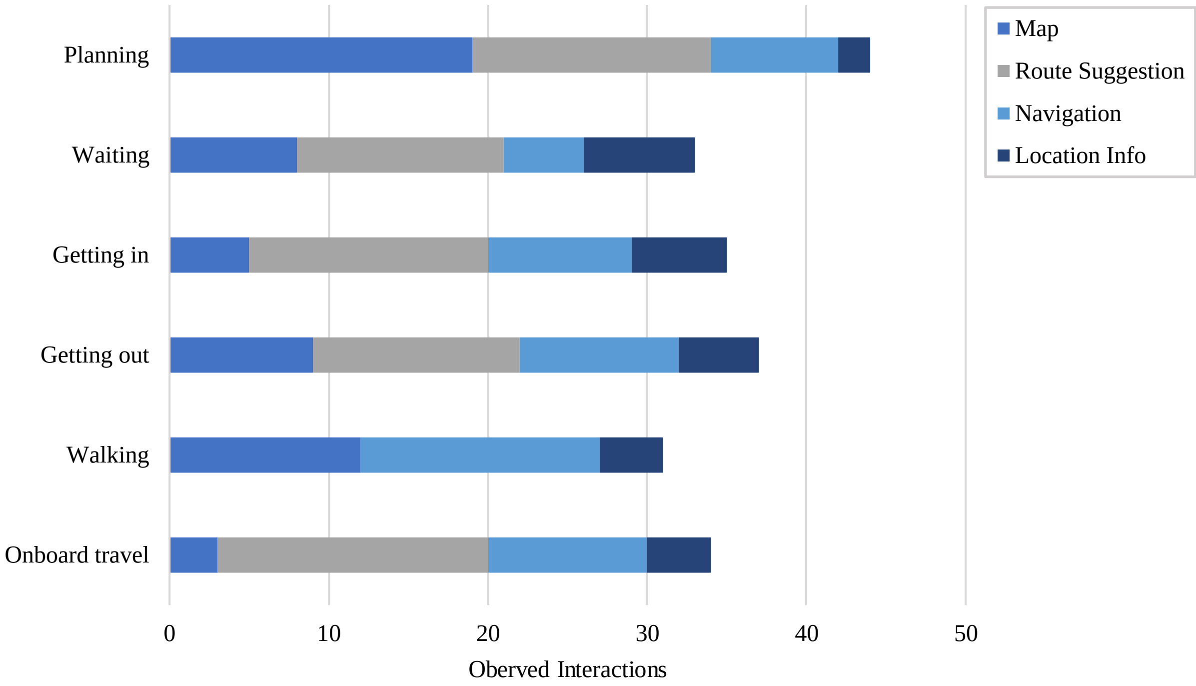


Figure 14: Observed participant interactions with app features across travel phases

The observed intermodal usage of in-app features is visualized in *Figure 14*. Since app usage is high across all phases, overall feature usage reflects the same pattern. Therefore, feature usage is also high, during travel planning, showing over 40 app feature interactions, almost half of which are with a map (19). Although less dominant, maps are also interacted with while waiting (8/33), getting in (5/35), getting out (9/37), walking (12/31), and onboard travel (3/34). With the exception of walking, route suggestions features are observed to be consistently used 30 % – 40% overall, while half of the features used during onboard travel are credited to route suggestions. Around half of the features used during walking are related to navigation (15/31). Features showing location information are overall the least used.

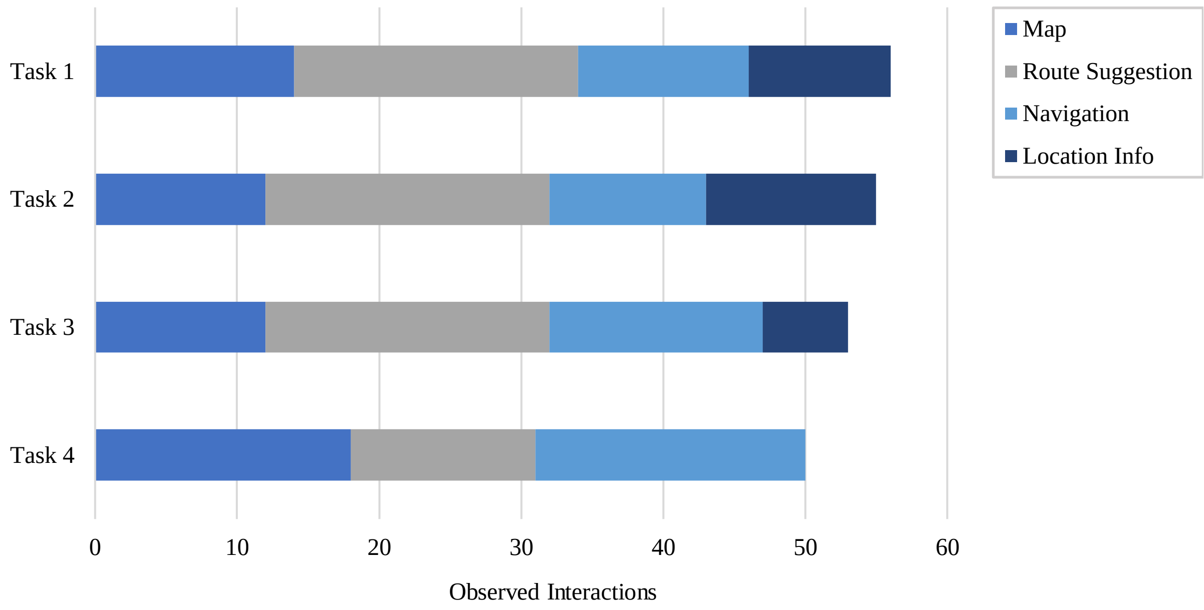


Figure 15: Observed participant interactions with app features across all four tasks

In the same way as *Figure 12*, usage of information sources can also be observed across all tasks. *Figure 15*, therefore, shows a decrease in feature usage as the study goes on. The proportions of observed interactions with the app features stay consistent, with the exception of task 4. Map feature interactions increase in task 4, while route suggestions decrease, and no location information features are used.

Decision-Making

To solve each task, there are numerous possible routes, which were consequently also mostly all taken across all participants. Visually mapping each of these routes in accordance with the task would result in a complex web of results. Moreover, choice of mode, route, and interchange points could not be accounted for. Therefore, instead of a map, individual flow diagrams (*Figure 17 – Figure 20*) visualize the decision-making processes behind each task.

The *flowcharts* (*Figure 17 – Figure 20*) show each task's routes, their frequency, the points that participants interchange, and the type of transportation.

The sequences are read from left to right, representing the route between the start and the endpoints. Connection locations can also be seen, which include bus stops, tram stops, and train stations. The lines between the locations are the routes of travel using public transportation or on foot. The thickness of these lines represents the popularity of that route, meaning the thicker a line is, the more participants travel that same route. *Figure 16* displays a legend of all relevant information for understanding the diagrams.

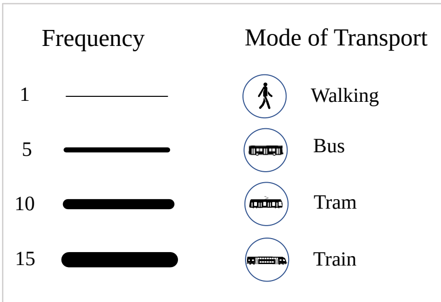


Figure 16: Legend for Figures 17 - 20.

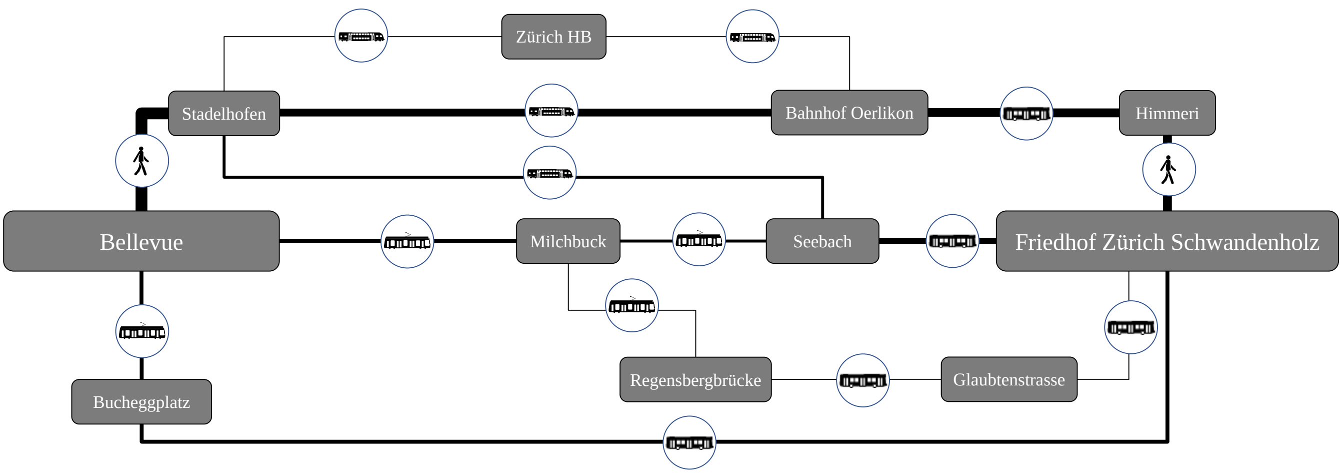


Figure 17: Flowchart of participant routes, transport mode and frequency (Task 1)

Many different routes are used to complete the first task, the most popular of which uses train stations *Stadelhofen* and *Oerlikon* (8/20), which is, in theory, the fastest route. Twelve participants choose to walk and then take a train at *Stadelhofen*. This choice also means that the first and last stretches most likely need to be done on foot. The other two main routes participants choose to take require almost no distance to be covered on foot: via *Seebach* (6) or *Bucheggplatz* (4). The latter is, in theory, the easiest in terms of interchanges since only one stop needs to be made. From the various route options in the first task, participants choose efficiency (fast and direct) over comfort (least changes and minimal walking).

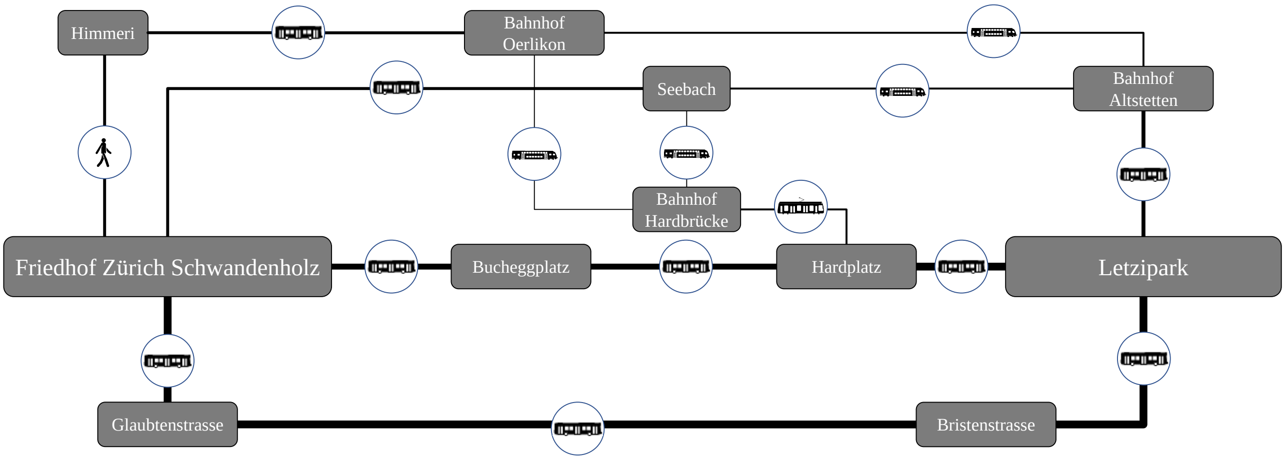


Figure 18: Flowchart of participant routes, transport mode and frequency (Task 2)

There are also quite a few routes for the second task, as seen in *Figure 18*. The most popular connection (8) uses a series of three buses, with no need to walk. The route via *Bucheggplatz* and *Hardplatz* is also quite popular (6) and is, in fact, the most direct in terms of distance. The most time efficient routes all include interchanges at a train station (*Oerlikon*, *Seebach*, *Hardbrücke* and *Altstetten*) and are in total used by six participants. In the case of the second task, multiple interchanging is unavoidable, but bus routes are generally preferred. Even though train routes are more time efficient, participants prefer less complex routes using buses.

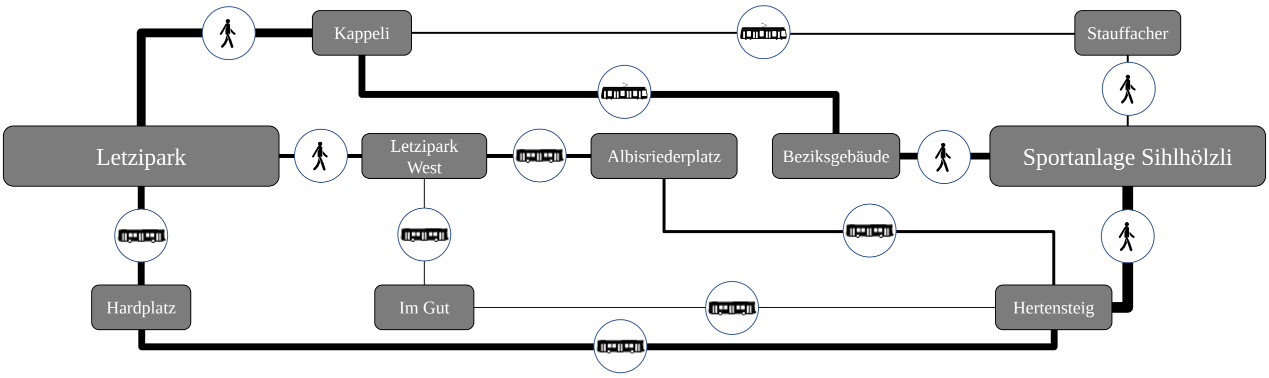


Figure 19: Flowchart of participant routes, transport mode and frequency (Task 3)

In the third task, a walking phase at the end cannot be avoided. Overall, three main routes are chosen, the most popular one using a tram (*Kappeli* to *Bezirksgebäude*), but it requires a walk to get to the tram stop. The second route consists of changing buses early on at *Hardplatz*, and the third frequently used route is similar, but interchanging buses occurs halfway at *Albisriederplatz*. The stretch used the most (11) is from *Hertensteig* to the destination, which is also the shortest distance to walk. Therefore, participants generally choose a route with fewer changes and do not mind walking for it.

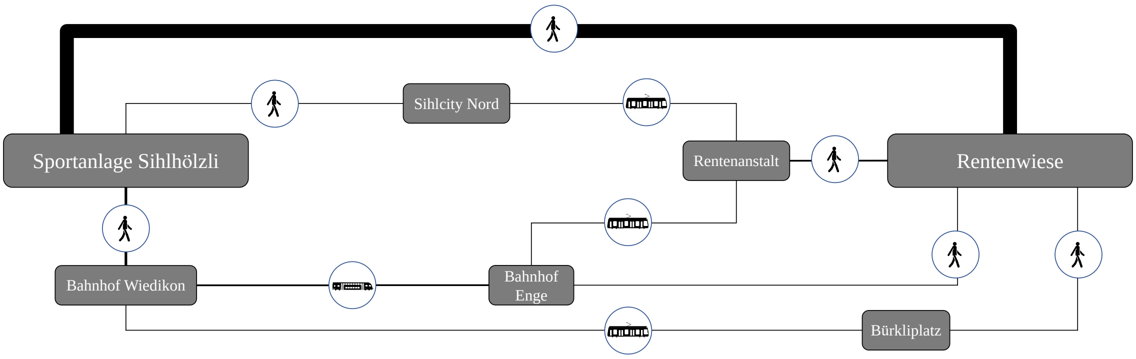


Figure 20: Flowchart of participant routes, transport mode and frequency (Task 4)

The fourth and last task visualized in *Figure 20* is somewhat different. Both start and end points in this task are only reachable on foot. 80% prefer to walk the entire distance to *Rentenwiese*. Four participants use public transportation, two of which take a train at *Bahnhof Wiedikon*, which is, in theory, the fastest but more complex and least direct way to the destination. Other public transportation connections use a combination of walking and trams, which in most cases also represent a faster option than walking the total distance. The fourth task, therefore, shows that the majority prefer walking to the last destination, despite taking a longer travel distance into account.

Summarized Travel Chain

As explained in subchapter 4.6 under *Travel Chain Approach*, the obtained information allows for a representation of intermodal travel sequences in the form of a travel chain. A travel chain can be visualized using the data documented with the travel log and screen recordings. However, generating 20 individual sequences for each of the four tasks defeats the purpose of finding common needs and strategies. The travel chains are therefore summarized according to the tasks and the most frequently used route and modes of transportation. *Figure 21 – Figure 24* display the data summarized as the four tasks.

Task 1

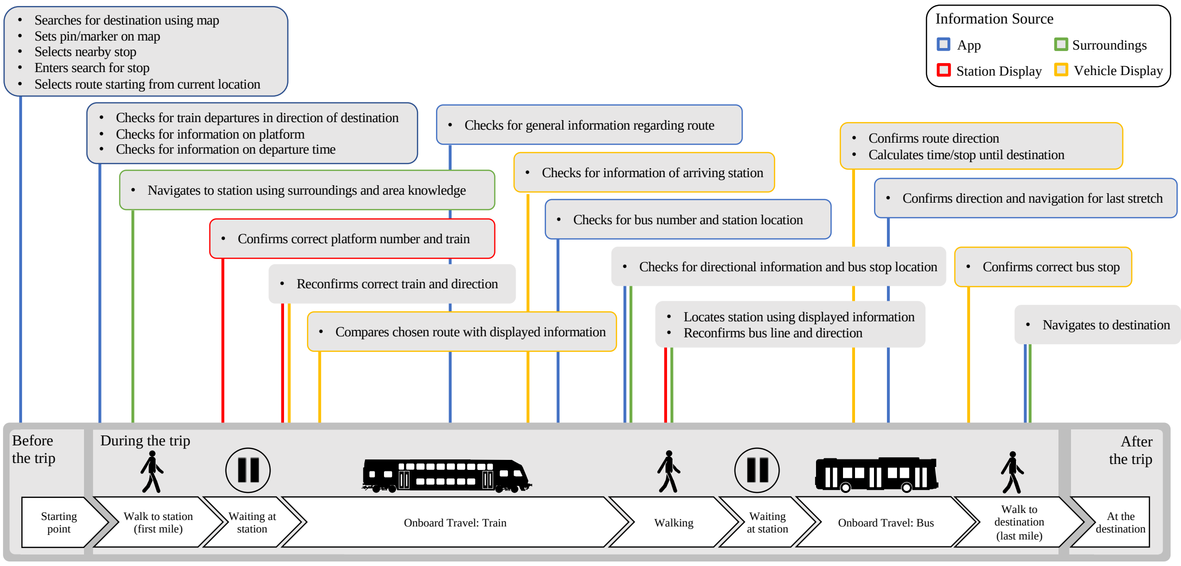


Figure 21: Travel Chain summarizing participant needs and strategies (Task 1)

The first task is the longest in terms of time and distance; thus, more notes and information is depicted (*Figure 21*). To plan the trip, participants in task 1 basically only use travel apps. The first search is mainly done with a map showing spatial information for the trip. During the first walking phase, information on the upcoming train route is collected using the app. Once at the station, the participants use the information provided by the displays or, when getting on, a combination of both. App information is during onboard travel on the train and the bus. The display within public transportation is utilized for checking and confirming the correct route. Participants frequently compare app information with display information. Walking phases often require participants to use a combination of surrounding information to navigate and the instructions provided by the app.

Across all intermodal phases, the app is consulted for most information, while the other sources are used to compare or confirm the correct route or direction.

Task 2

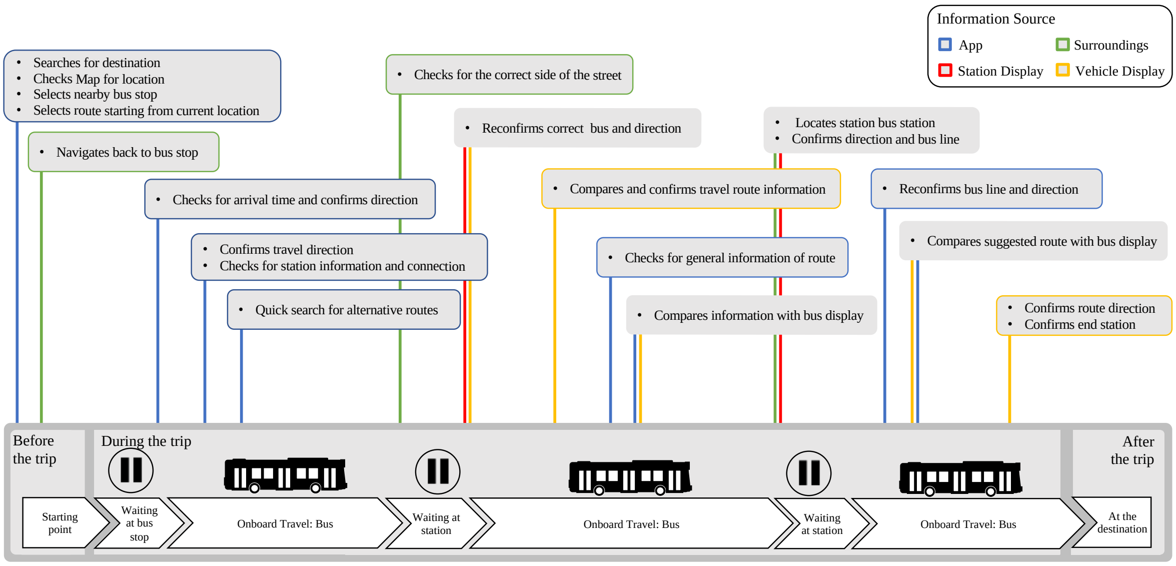


Figure 22: Travel Chain summarizing participant needs and strategies (Task 2)

Figure 22 displays how participants solved the second task. During the first travel phases, only the app is primarily consulted for information and is mostly for confirmation purposes. The station displays are used at the interchanging points to locate and confirm the correct bus line and direction. The last two onboard phases require much more information retrieval, which is done using the app and the vehicle displays. Again, these two sources are mainly used together. Participants only made use of the surroundings when it came to navigation, which occurred when locating the bus stops.

Task 3

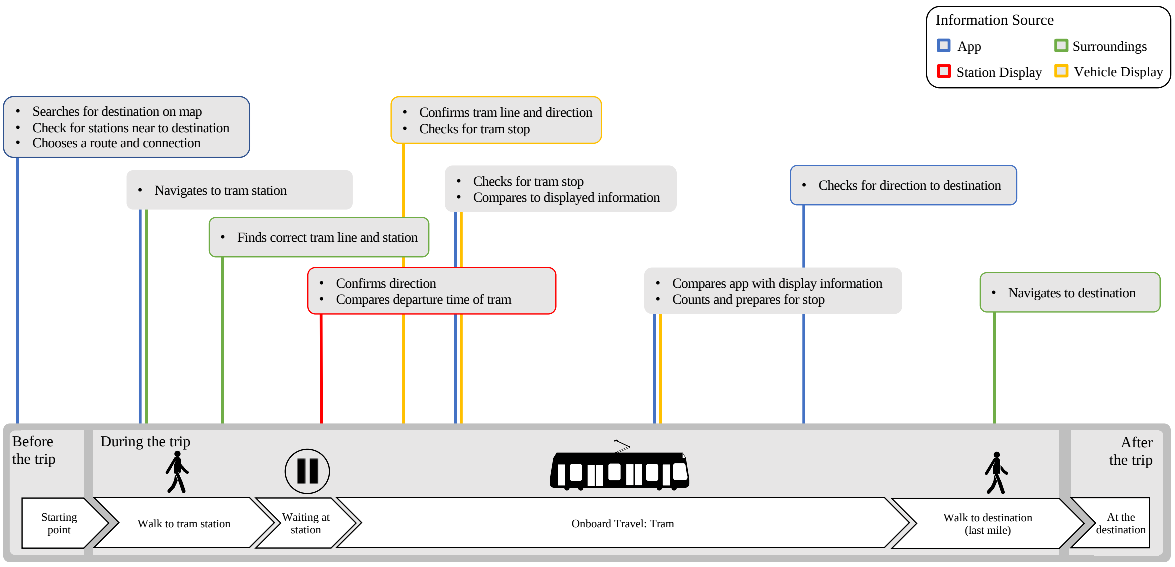


Figure 23: Travel Chain summarizing participant needs and strategies (Task 3)

Overall fewer information sources are used in *Figure 23* than during the first two tasks. The initial travel planning and walking phase use the app and surroundings as information sources. Stationary information is only consulted briefly to confirm the correct direction and departure at the tram stop. During the onboard travel phase on the tram, participants frequently used display and app information. The display informs participants of the tram stops and therefore, when to get out. This is compared twice with the app information. In the last phase, in which one walks to the destination, only brief navigational information using the surroundings is used, indicating a relatively straightforward stretch.

Task 4

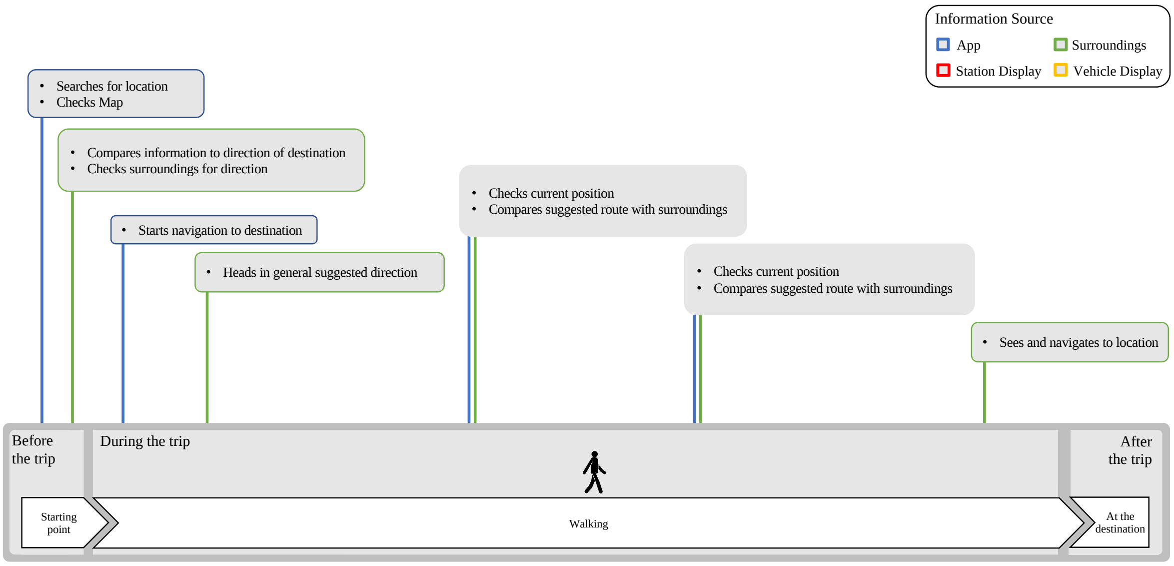


Figure 24: Travel Chain summarizing participant needs and strategies (Task 4)

The last task is summarized quite simply since walking is the predominant mode of transport (*Figure 24*). Thus, this task does not use displays at stations or in vehicles, while the primary information sources stem from the app and the surroundings. The app is only used for guidance, showing the participant where they are in space. This is initiated at the beginning, from which the general direction and route are established. Surroundings are consulted along the way, helping to confirm navigation and app information. Once the final destination is seen, which can be early on, the app is not used anymore.

5.3 Third Stage – Debriefing Results

After each session, the participants were given access to an online survey, which they must fill out. The survey consists of six question groups, each focusing on a different theme. The survey includes questions to be answered in an open format, meaning participants must write their answers and closed questions. The latter mostly being in a matrix format, which answers on a scale to multiple specifications.

Perceived Task Difficulty

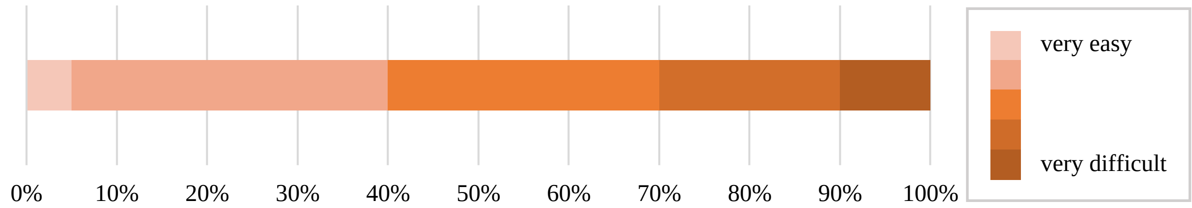


Figure 25: Difficulty of the entire stage perceived by participants

In *Figure 25*, one can see that the tasks seem to be not very difficult overall. Most participants indicate that the tasks are easy. However, just one person rates the tasks as easy while four rate them as difficult or even two as very difficult. The remaining six participants find the tasks to be neither easy nor difficult. The following diagram visualizes the perception of difficulty per individual task (*Figure 26*).

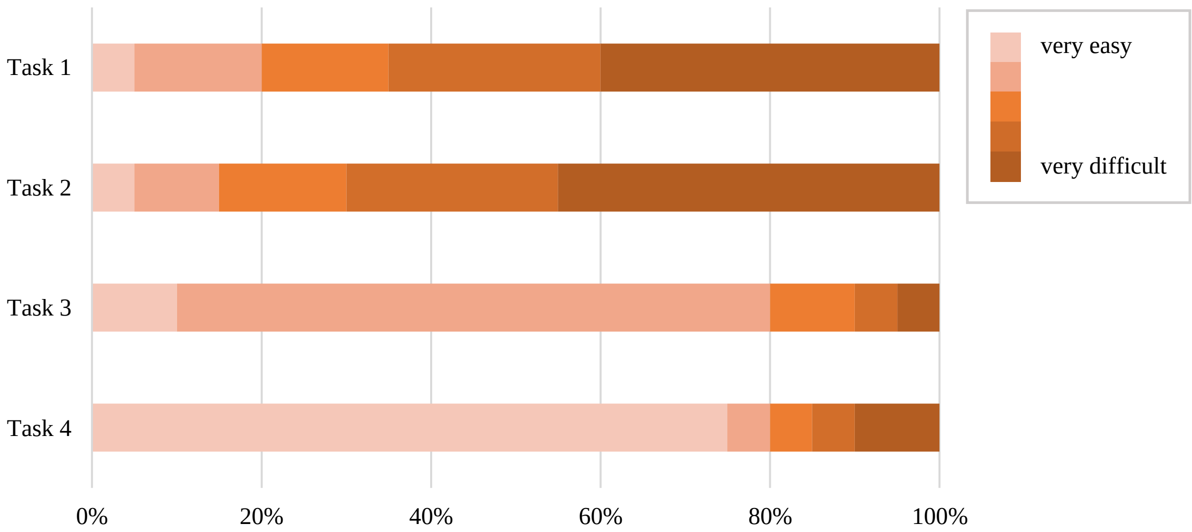


Figure 26: Difficulty of the individual tasks perceived by participants

The perceived level of difficulty tends to decrease over the tasks. The majority of the participants find the first two tasks to be *difficult* (8) or even *very difficult* (8/9). In comparison, the third task is perceived by 80% of the participants to be on the easier side. The fourth and last task seems to be the least difficult. 16 out of the 20 participants rate the fourth task be *very easy*.

Explanation of the perceived difficulty

Participants were then asked to explain briefly why this order of difficulty was chosen. Some summed their reasoning up with a few simple statements. One participant states that *the more changes are needed, the more complicated navigation becomes*. Another participant comes to a similar overall conclusion indicating that their selection reflects the complexity of the task and the number of available routes.

Across all tasks, the theme of familiarity is raised. The last two tasks take place in relatively known urban areas, while the first two do not. A participant sums their experience up by writing: *the more unfamiliar an area is, the higher the level of difficulty to travel*. Other comments regarding the difficulty were specifically reasoned from task to task:

Task 1

The main reason for selecting the first task as the most difficult was its unfamiliarity among the participants. Many find unknown destinations, and the route to get there makes the task harder. On top of that, the route is rather long and uses different modes of transport. Thus, a complex route with many interchange options in an unknown area also makes it hard. It is mentioned that not only does the unknown area make it difficult, but also the unfamiliar bus line, its stops, and the direction it follows.

Two participants emphasize that the combination of bus and train connections is tough since it can be challenging to navigate in and around a train station and find the correct connection. A further point raised is the routes proneness to disturbances and how to search and decide on an alternative route quickly. Since the name of the ending stop corresponds to the name of the destination one must travel to, the planning process requires fewer searches. However, the accuracy of information about the route is relatively small using the app, which makes it more difficult.

Task 2

Comments regarding the second task follow a similar line as the first task. Many find the task harder because different modes of public transportation are needed, and the changes between these modes can be challenging if the area is unfamiliar. The end destination is a relatively large complex accessible from different angles and has more than one public transport connection. However, some participants find it to be not indicated well enough. On the other hand, similar to the first task, the destination also corresponds with the station name, making it easier to search and find using an app.

Task 3

Participants find this task easier because it partially goes through known areas and uses familiar bus or tram lines. This also makes the decision-making process more manageable, even though different modes of transportation are used. Something mentioned by a few participants that make this task a little easier is the fact that they got to know one of the changing points in the previous task. Thus, they were able to make use of their gained knowledge. Since the route led straight through a dense urban area with narrow city structures, orientation and navigation are sometimes a little more complicated. A further point raised is that even though the end destination is a prominent and known location in the city, it does not have a specific public transportation stop. This makes the search for the optimal route more difficult for some participants.

Task 4

For almost all participants, the last task is the easiest. Many justified this through the area's familiarity and the distance the route covers. Even though it might be challenging to maintain a good sense of orientation during this route, being on foot most of the time compensates for this fact. The point that being on foot made it easier since one is free to move and one does not need to rely on public transportation connections is raised by a few participants. It is further mentioned that being in an unknown area means that one can rely on landmarks and other familiar things along the way. The choice between accessing the destination using public transportation or walking seems to be the most challenging factor of the last task.

Usefulness of Information Sources

A travel chain consists of multiple different phases, and each may have a different set of needs and therefore requires a different set of information. Participants are asked to put the information sources in the order they perceived as the most useful. This is done for all the different travel phases.

Planning Phase

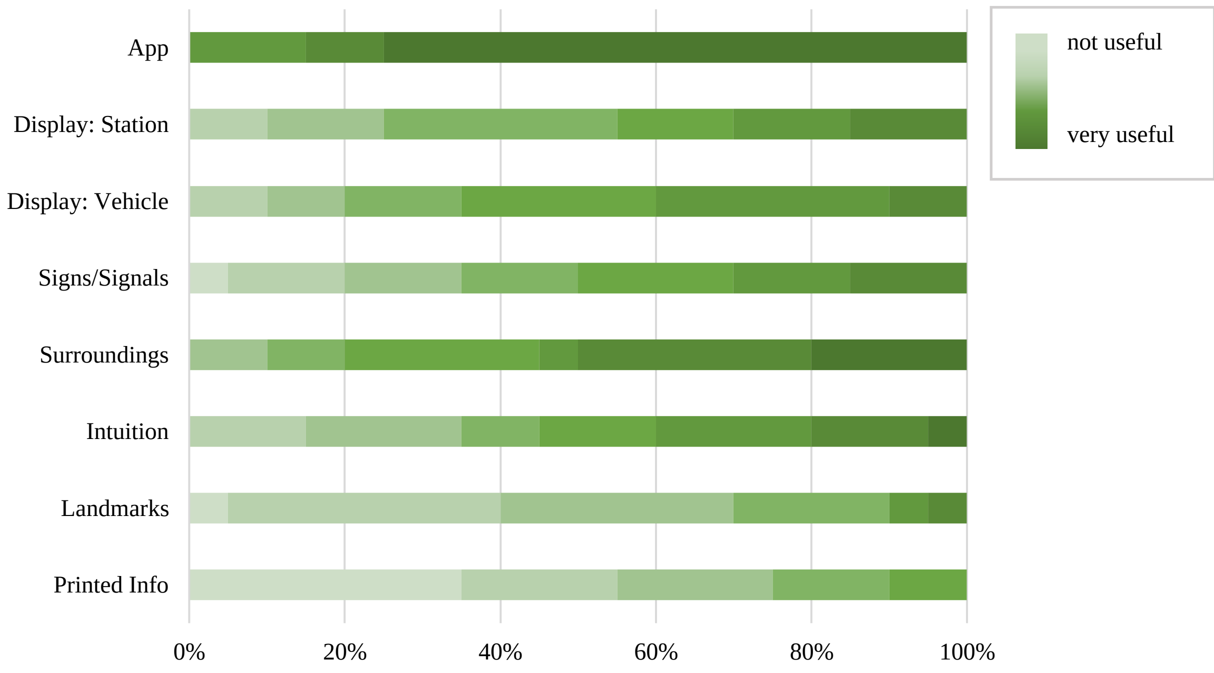


Figure 27: Usefulness of information sources while participants plan travel

When planning an urban trip (*Figure 27*), an app seems to be the most useful source of information. In fact, 15 out of 20 participants indicate that apps are *very useful* when planning travel. More than half find surroundings and intuition to be useful as well. Most participants consider landmarks and printed information the least useful. Signs/Signals and both sources of display information are neither useless nor very useful.

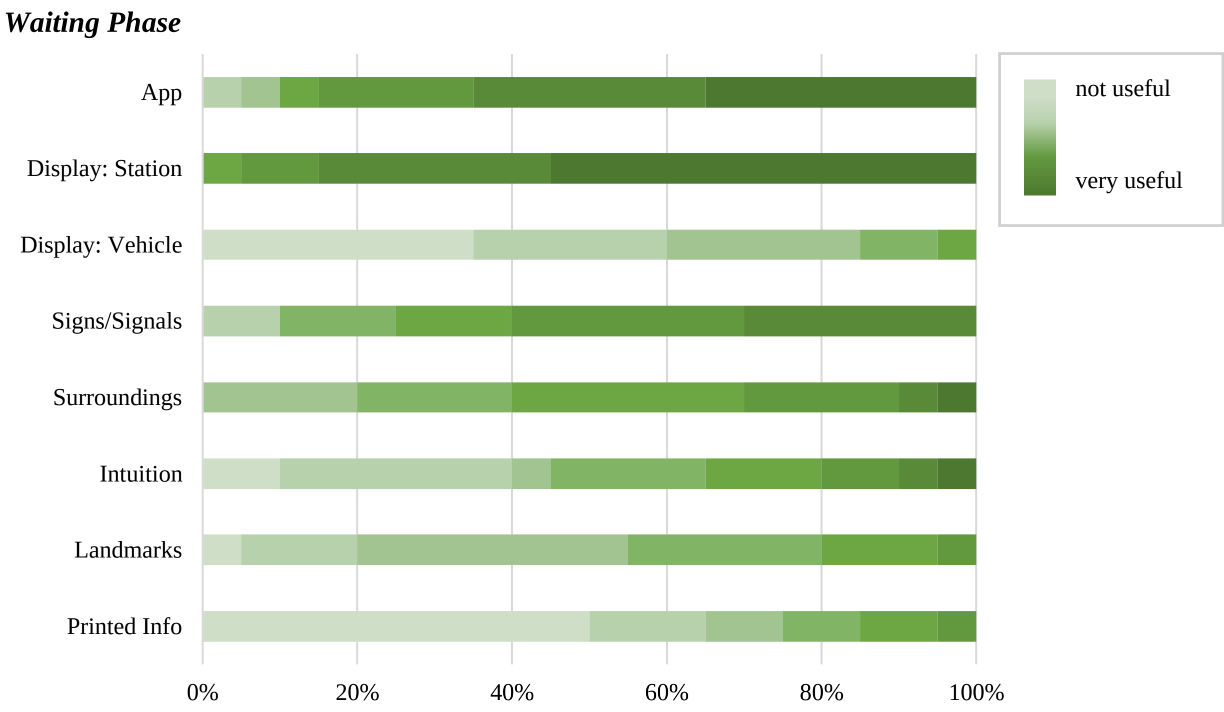


Figure 28: Usefulness of information sources while participants wait

While waiting at a station or stop (*Figure 28*), digital displays are the most useful information source, followed by the app. Participants consider station display information *useful* (6) or even *very useful* (11). Although less than while planning, the majority find the app useful during the phase of waiting. Signs/signals, intuition, and surroundings are also found to be useful to at least half of the participants. However, printed information and information displayed in public transportation are the least useful at this travel stage.

Onboard Travel Phase

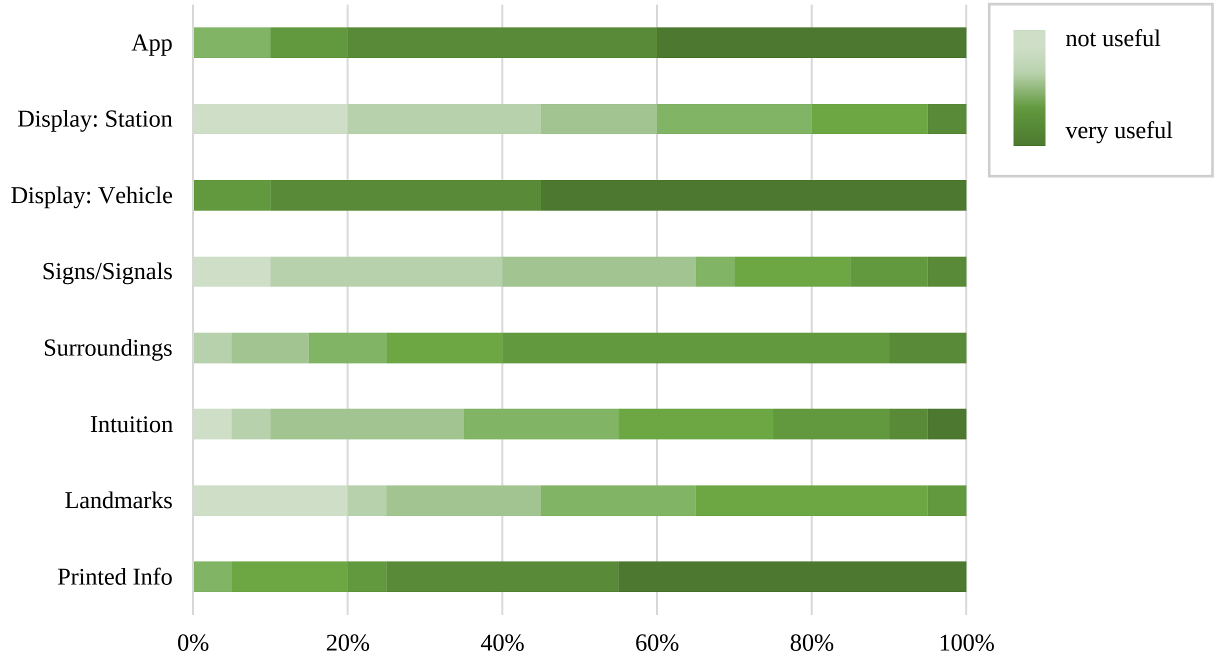


Figure 29: Usefulness of information sources while participants travel using public transportation

Figure 29 shows how participants perceive the usefulness of information sources while onboard public transportation. Along with the app, the majority find displays in public transportation very useful for onboard travel, followed by printed information. At the same time, station displays, signs and signals, and landmarks decrease in usefulness.

Travel On Foot

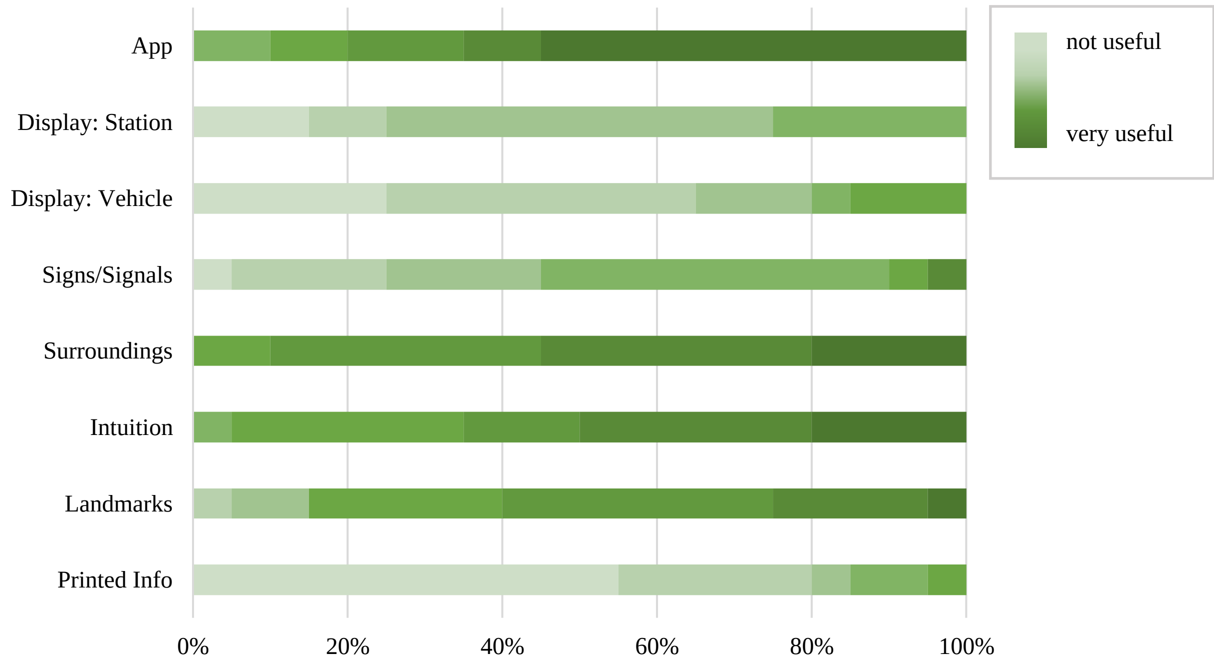


Figure 30: Usefulness of information sources while participants walk

Four information sources are considered the most useful to participants while walking: apps, surroundings, intuition, and landmarks. The other four sources seem to be adequately useful or, in the case of printed information, not useful at all (11).

Getting on or off Public Transportation

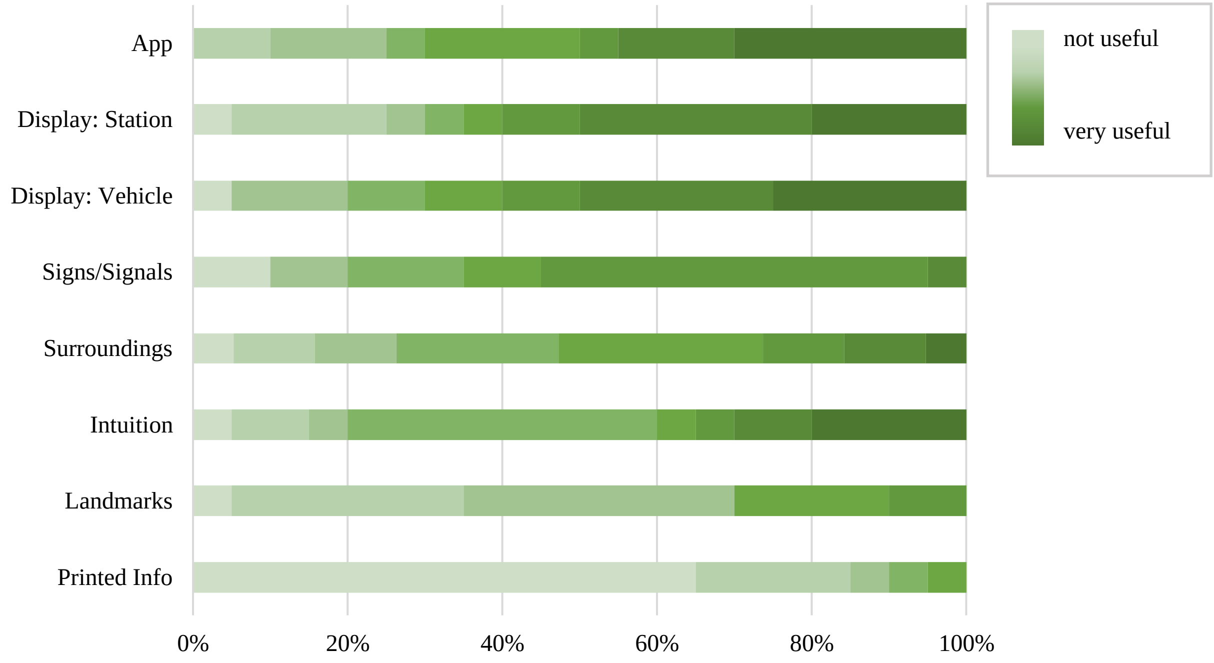


Figure 31: Usefulness of information sources while participants get on or off public transportation

The results shown in *Figure 31* do not indicate a clear trend of a dominant information source. The usefulness is therefore perceived across all participants differently while getting on or off public transportation. Around 20% perceive the app, intuition, and both digital displays to be the most useful. Perhaps the most distinct observation is that majority considers printed information not useful at all.

Perception of Reliability

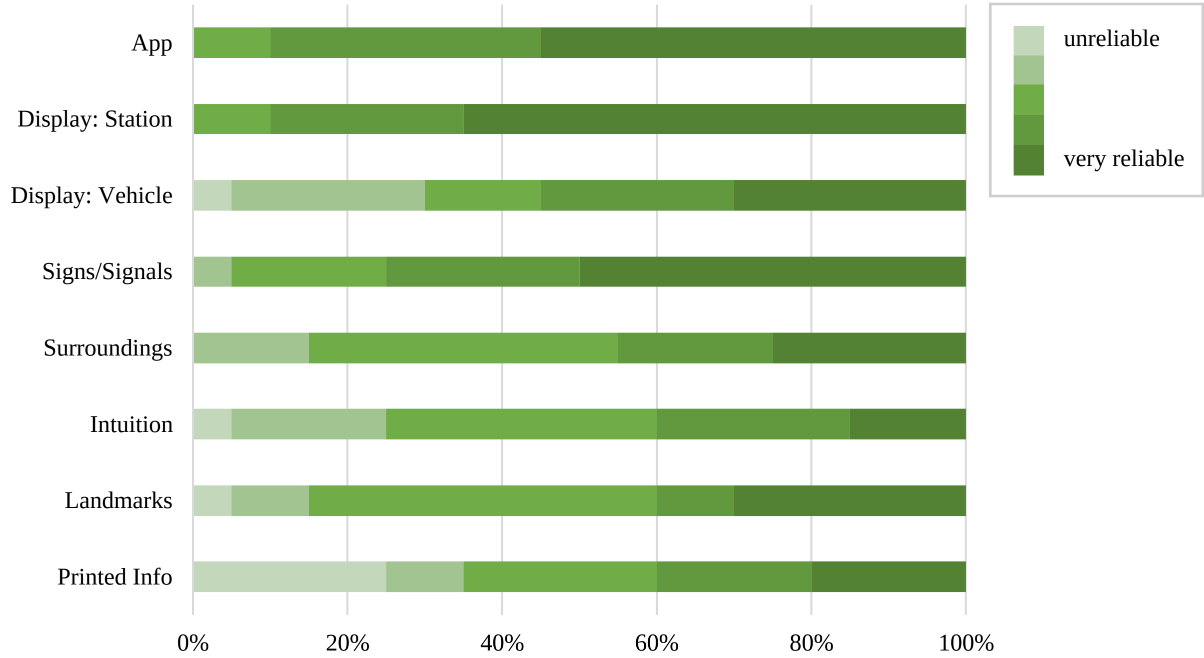


Figure 32: Reliability of information sources perceived by participants

All sources n general show high reliability perceived by most participants (*Figure 32*). Station displays have the highest reliability rating (13; *very reliable*), followed by the app (11) and signs and signals (10). Five participants find printed information are the least reliable.

Strategy

14 of the 20 participants admit to changing their strategy during the study, while six state they stick with their initial approach. Participants are then given the opportunity to justify their answer:

Participants who stuck with their initial strategy explain that their approach uses a combination of apps and switching between them works fine across all tasks, thus, no strategy change is needed.

The most mentioned reason for changing a strategy is a heavier focus on using intuition. Another strategy change was done in the last task, as participants prefer to walk to the final destination, even though the app suggests a public transportation route, which is done constantly throughout the previous tasks. However, one participant mentions in this context that the route on foot is more complex than they thought, still making them use their smartphone. Two participants indicate that they switch to using multiple apps instead of just one. Further justifications include adaptions when information seems more accurate through another source or a more efficient route, discovering a better map in another app, or adapting the search query.

In an open question format, participants were asked to describe the strategy they follow to complete the tasks. The answers participants gave mostly covered the three core topics of search strategy, using information, and decision-making.

Search Strategy

More than half of the participants say they begin with a search using a map, meaning they open an app and enter just the announced destination to see where it is located geographically. This is primarily done using Google Maps. Once it becomes more apparent in which direction the destination is and which stops or stations are nearby, a search for a connection is done.

Information Usage

All answers regarding strategy have a heavy focus on the usage of smartphone apps. A few mention that they at least try to rely on their intuition at first since they know the city. However, since not all routes are familiar, they still cannot get around using the smartphone and its apps.

Most also use a combination of apps, depending on the trip's phase. Destination and overview searches during the planning phase are done using a map-based app, such as Google Maps. Apps utilizing a timetable are used after that and consistently throughout onboard travel. One participant brings up the point that for these tasks and in a real scenario, only the usage of common and well-known apps makes sense.

Five participants mention how they use a two-step process, by which they first assume and run a general search for the destination and the route to get there, but then in a second step, still confirm their assumption using a generated timetable of an app. As a result, the SBB Mobile app is brought up multiple times to confirm. Participants tend to change their strategy when traveling on foot and either shift focus to features aiding navigation and spatial cognition or, in some cases, even rely solemnly on the information around them.

Decision-Making

Within strategy selection, many participants justify their decision. This is mainly related to the choice of the route generated by an app. Even though a few mention that the area and route is known, distinct preferences behind decisions are given. Almost all answers in this context include the term efficiency in some way. However, there is no consistent use of this term among the participants. Four consider being efficient in the sense of speed or keeping the number of interchanges to a minimum. Others generally find it efficient to spend the least time on foot or use the shortest route. This criterion leads to the choice of which route to the destination is selected. In one specific answer, the first suggested route by the app is always chosen, as long as it is never 25% longer than the next. Another answer mentions that the top three options are always considered, and then a choice is made depending on the ratio between travel time and the number of necessary interchanges.

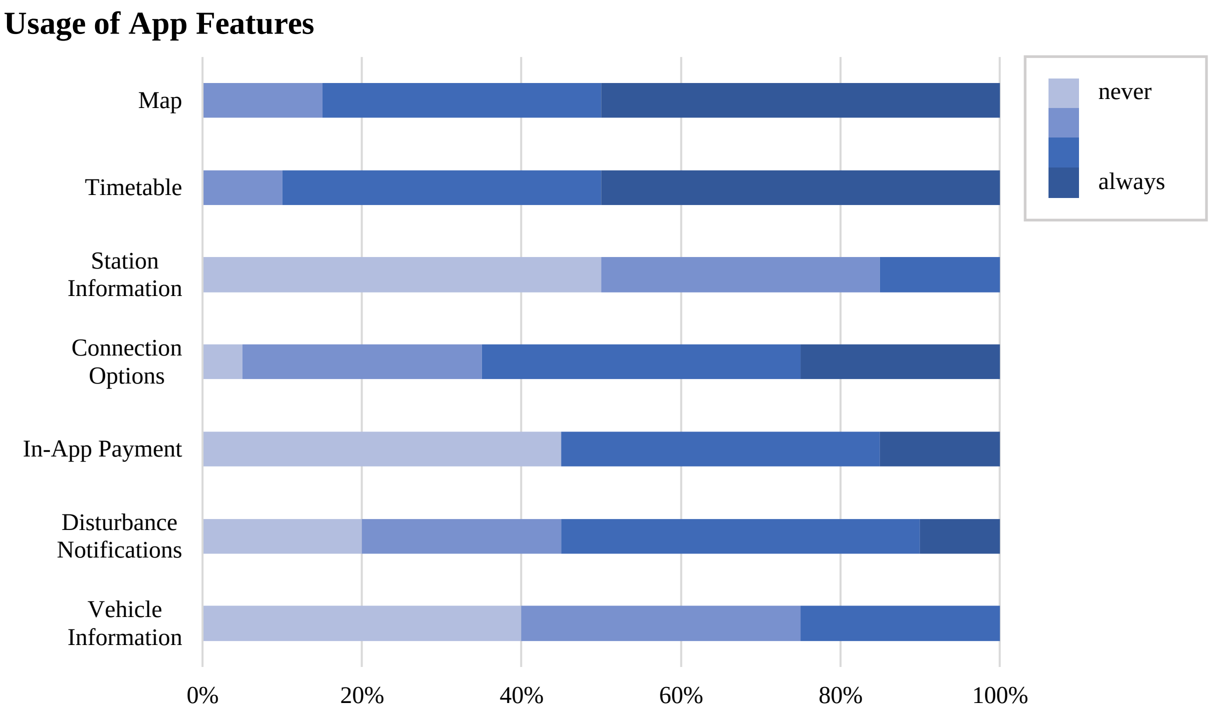


Figure 33: Participants' frequency of app feature usage

Participants are asked about their usage of features mobility apps offer, but there is no reference to a specific app. The results are represented by the diagram in *Figure 33*. The usage of maps and timetables is very high and is *always* used by more than half. Also, features showing connection options and disturbance notifications are used by most. Around half never use in-app payment, vehicle, or station information features.

Importance of App Features

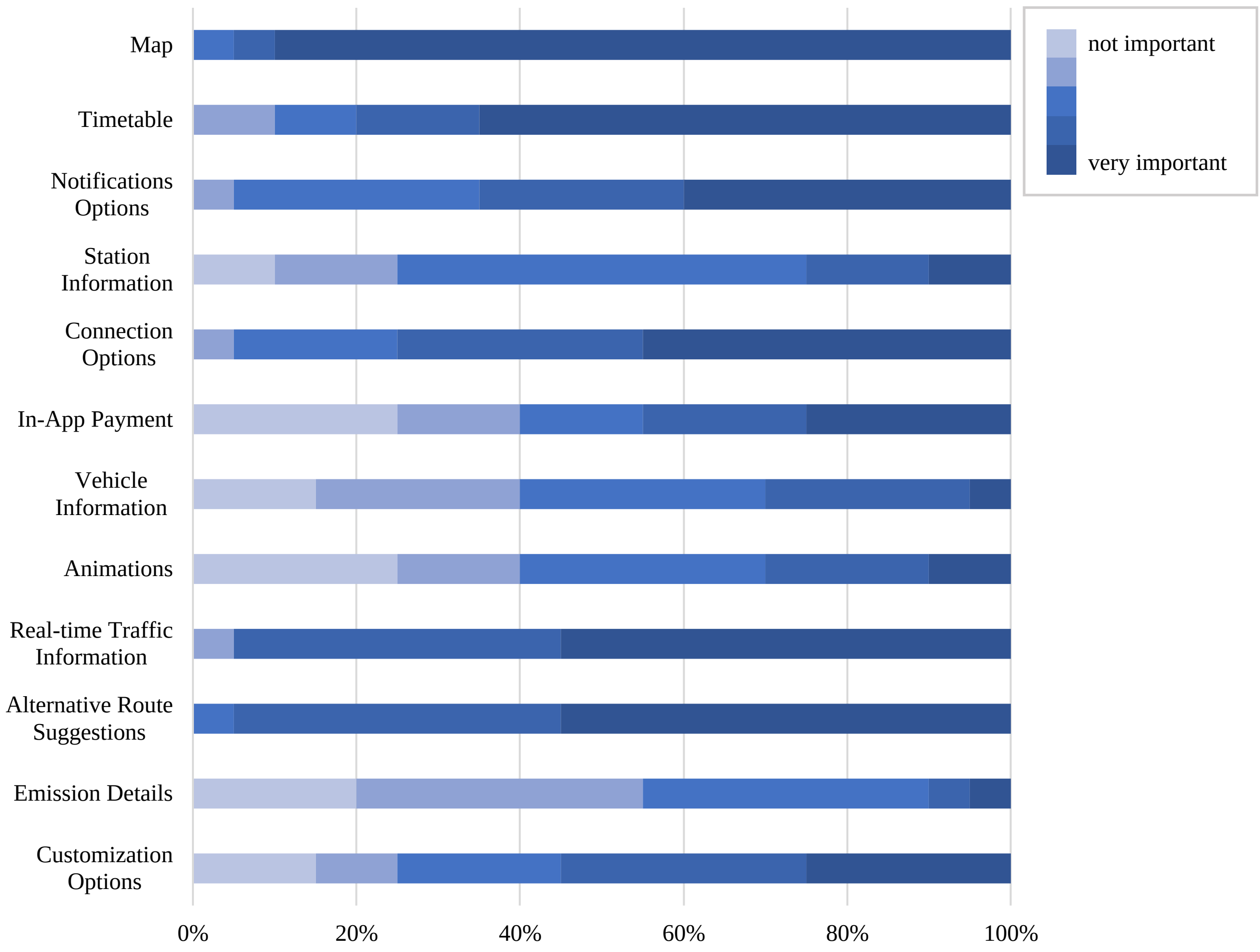


Figure 34: Importance of app features for travel perceived by participants

How participants perceive the importance of the app features for travel is seen in *Figure 34*. None of the listed features seems to be considered not important at all. Maps are clearly the most important feature an app has to offer (18; *very important*). Real-time traffic information and alternative route suggestions are highly important features. Features regarding in-app payment, vehicle information, animations, and emission details show less importance than other features but are still considered useful overall. More than half find notifications and customization options to be important as well.

Dealing with Uncertainty

Situations may arise where one is either uncertain of themselves, meaning unsure of actions or possibly even lost, or external factors such as traffic, detours or delays. Participants are asked to select all sources of information which they consider using when it comes to such a situation (*Figure 35*)

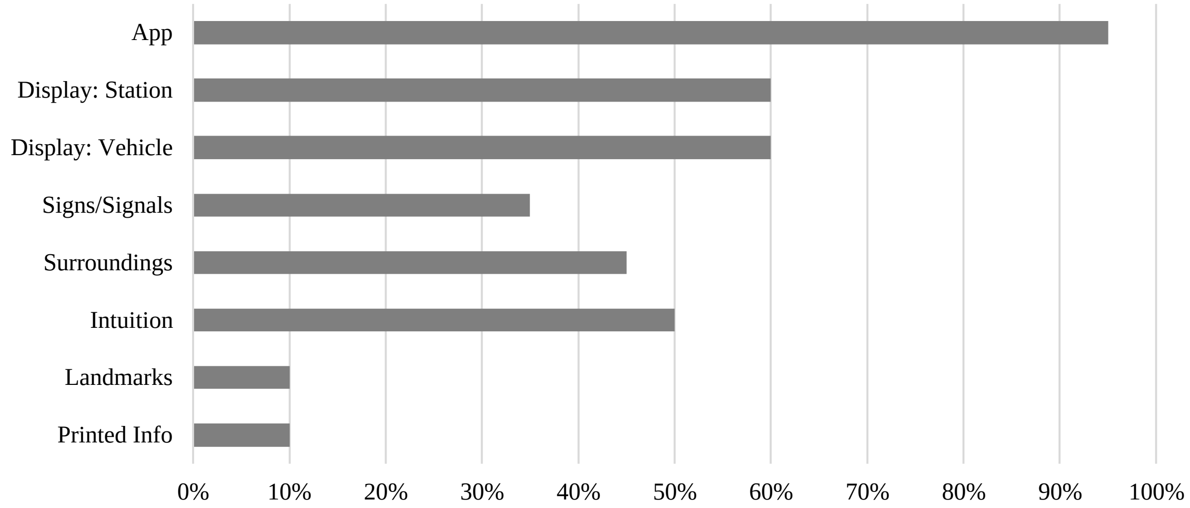


Figure 35: Participant information source usage in uncertain situations

19 participants use an app when it comes to an uncertain situation during travel. 60% also consult displays providing information, and 50% also rely on intuition. Signs/Signals (35%) and surroundings (45%) are less helpful to participants. Just two participants would use landmarks and printed information in an uncertainty. Since almost all consider travel apps to be useful when it comes to uncertainty, a look at the individual features may be interesting (*Figure 36*):

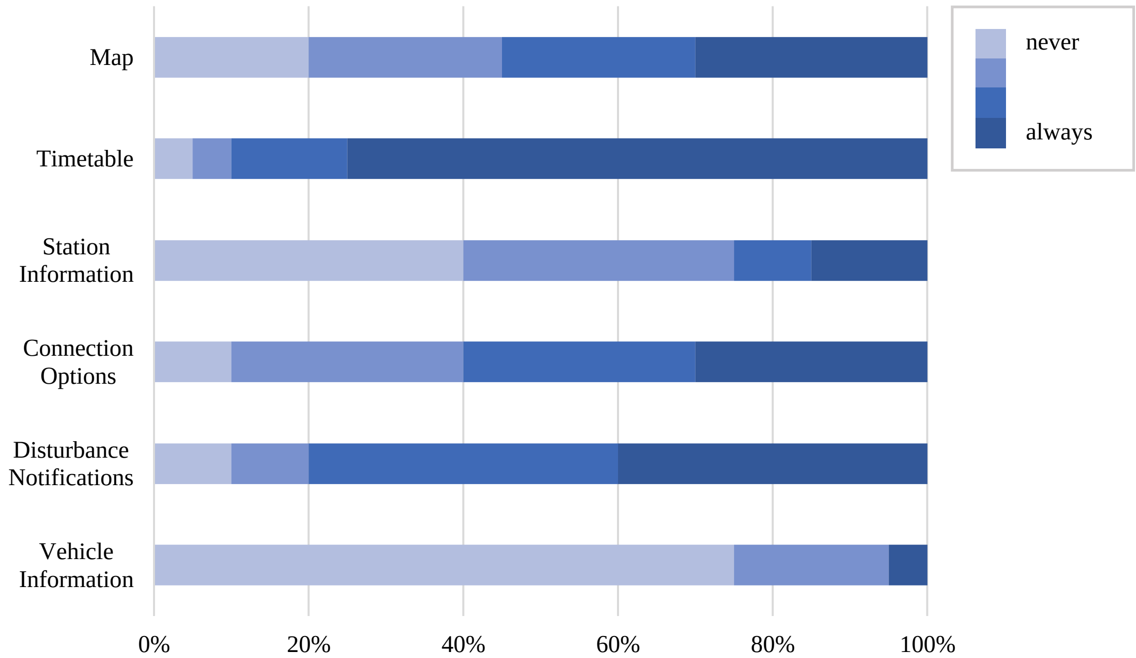


Figure 36: Diagram showing how participants perceive the helpfulness of app features

The most used feature during an uncertain situation are timetables (*always* by 15/20). Notifications on disturbances are the second most used feature, followed by maps and connection options. 40% state they *never* use station information, and 75% *never* use vehicle information features.

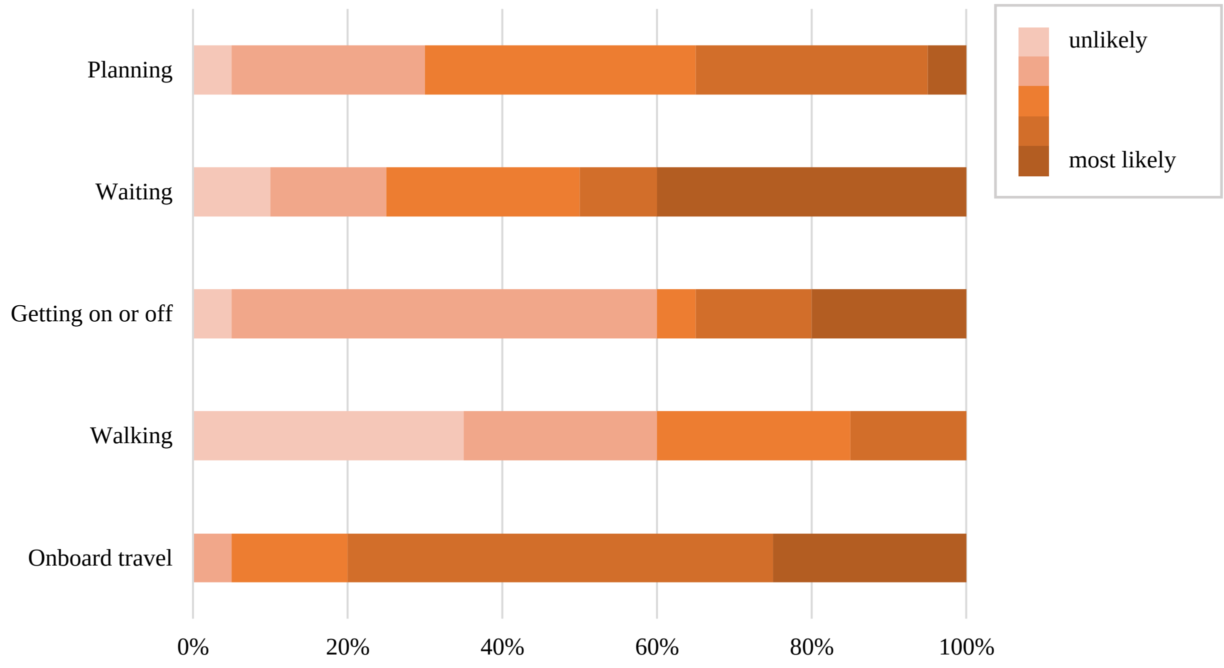


Figure 37: Likelihood of uncertainty across travel phases perceived by participants

Results from *Figure 37* show that the phase during which onboard travel takes place is perceived to be the most uncertain. Participants also perceive the phase of waiting and planning to be prone to some uncertainty, while getting on or off and walking involve less uncertainty.

Travel in an Unfamiliar Environment

Similar to previous questions, participants are asked to put the information sources in order. However, this time it should be done in regard to usefulness when being in an unfamiliar environment.

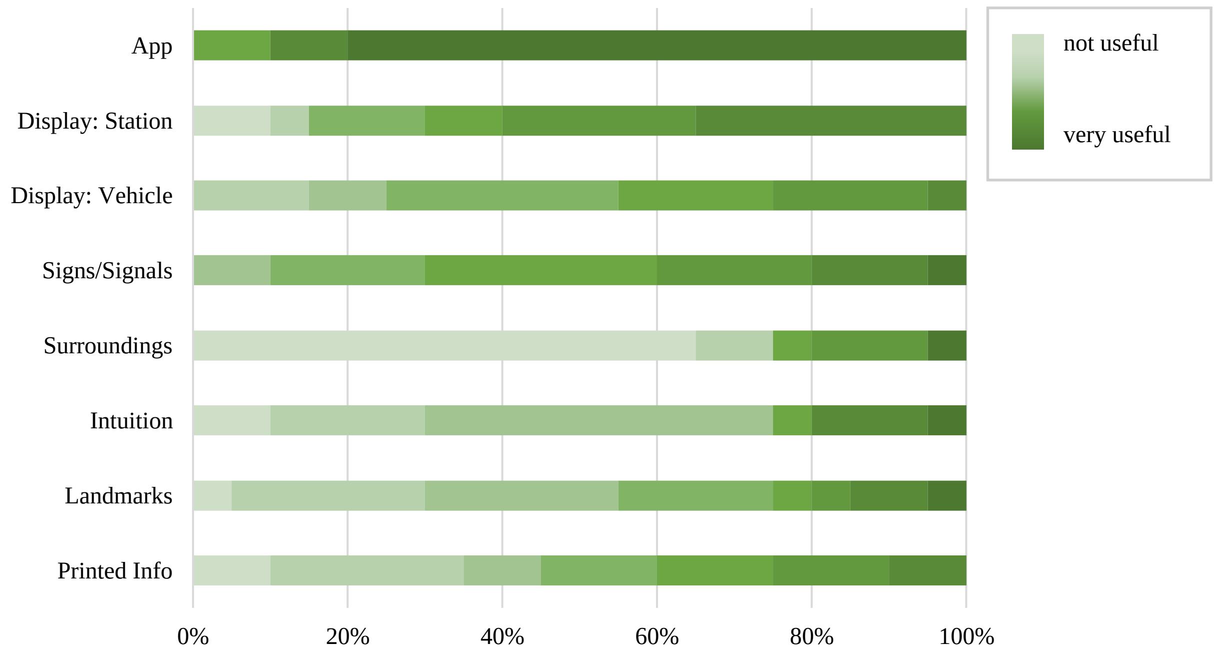


Figure 38: Usefulness of information sources while participants are in an unfamiliar environment

16 participants perceive the usage of an app to help in an unfamiliar area to be *very useful*. *Figure 38* further shows that displayed information sources are considered to be useful to most participants. On the other hand, usage of intuition, landmarks, and printed information show less helpfulness in unknown areas, while 13/20 consider surroundings not useful at all.

The following diagram (*Figure 39*) shows the degree of reliability participants require from the individual sources.

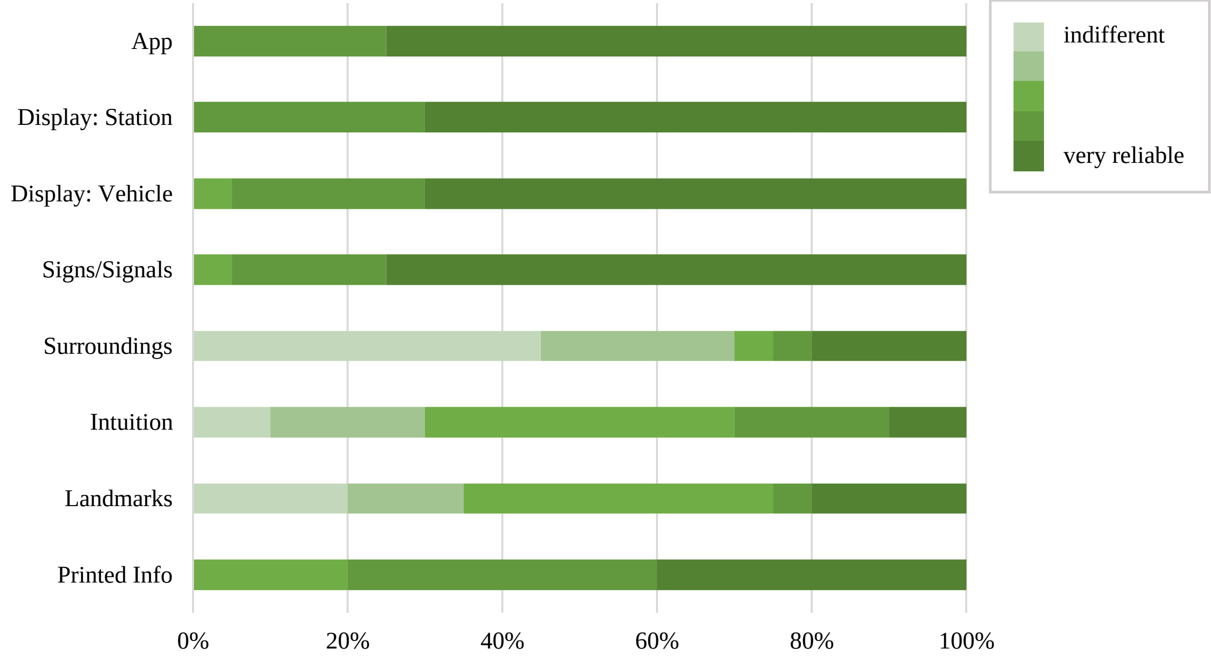


Figure 39: Required reliability of information sources by participants

Participants require network infrastructure to be more reliable than it is perceived. However, the app and non-physical information sources seem to live up to expectations. Printed information, on the other hand, requires a much higher degree of reliability for participants.

Future of Urban Mobility

To analyze the needs for future trends, participants are asked to rate each feature according to how its significance might change in the future. Three options are available to choose from; increase and decrease of significance or there will be no change.

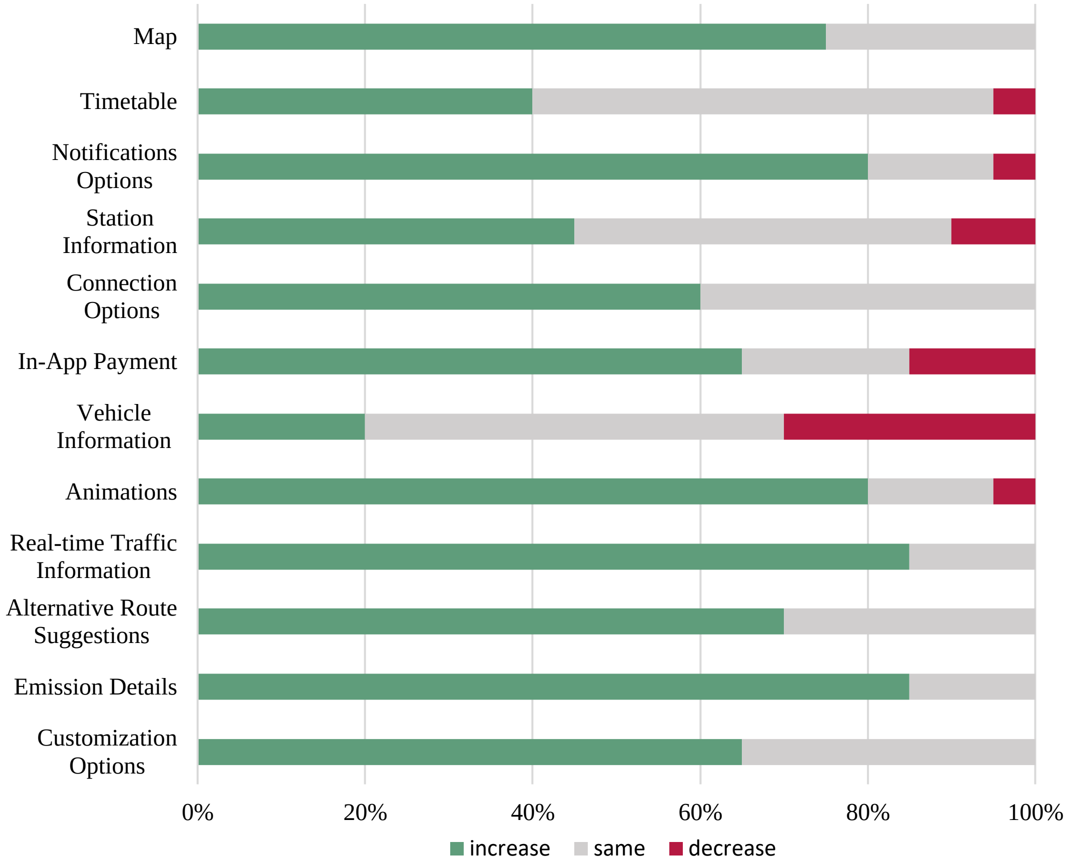


Figure 40: Change of significance for app features in the future

In *Figure 40* all listed features seem overall to be essential, meaning participants think feature significance will increase. The most evident increase can be observed in customization options, emission details, alternative route suggestions, in-app payment, real-time traffic information, connection options, notification options, and app maps. Timetable and station information also show an increase. However, it seems participants cannot agree on how the significance of vehicle information will change.

Open survey question on the future of urban mobility

The last survey question is an open question in which participants can write ideas, approaches, or thoughts about the future of urban mobility. Almost all answers include either technologies or the adaptation to individual preferences.

For example, two participants wish algorithms would be implemented so that apps automatically adjust information to personal requirements, such as walking speed, mode choice, or general simplifications. *Information given through public transport personnel is the most up-to-date and reliable, which apps need to adapt to become more trustworthy to all age groups*. Other answers are about promoting useful app features or even incorporating ones used by other urban transit networks. In particular, using a smartphone as a payment and ticketing system is a promising future trend.

6 Discussion

The following subchapters discuss the results presented in the previous chapter. Some of the discussions evolve around travel chain analysis, which is important to fully understand for the following subchapters. The described travel chains in this study define six phases of travel a user experiences: planning, walking, waiting, traveling, and getting on or off public transportation. Interchanging and any switching of transportation modes are included as well.

The discussion is structured according to the three research questions this thesis aims to answer. Therefore, the first subchapter covers the different types of travel information, focusing on apps and their features. The second subchapter discusses results related to travel strategies, such as user behavior, trip planning, and problem-solving. The third section centers around recommendations for travel information systems and a brief look into the future and finally limitations of this study are outlined.

6.1 Public Transportation Information Needs

Research Question 1

> *Which user information needs can be identified in public transportation and what is the role of apps and their features for urban travel?*

Hypothesis

> *Public transportation users have the constant need to be informed regarding problems and their progress along the route. Information related to space and time are of particular need to passengers. Travel apps represent the most helpful information source across all travel chain phases, especially due to features providing real-time data.*

Public transportation users require adequate information regarding their routes to plan and implement their travel endeavors successfully. This subchapter presents and discusses the sources of information available to a user and to what degree they are helpful. In particular, travel information assistance is highlighted and how in-app features can benefit a user. Furthermore, the perception of reliability related to information needs is discussed.

Information Sources

When faced with any spatial task, a human cognitively captures and processes tremendous amounts of information (Lloyd & Cammack, 2007; Tversky, 1993). Especially, non-physical information sources, such as past experiences, knowledge of an area, or intuition, are challenging to analyze. This study considers eight information sources: apps, station and vehicle displays, signs and signals, knowledge of surroundings, intuition, landmarks, and printed timetables or maps.

Various publications suggest that providing sufficient information positively influences a passenger's travel experience (Nandan et al., 2014). A study done in Zurich investigated how the degree of information affects travel scenarios in an urban setting. The authors, Leng and Corman (2020), conclude that in the scenario, 100 % of users with no information were delayed, while users with advanced information suffered the least.

Information needs vary depending on the travel activity or, in this case, the travel phase or mode of transport. Overall, the app as an information source was the most useful to participants, while printed information was consistently perceived as the least useful (*Figure 27 – Figure* 31). This result is similarly reflected in relevant publications, highlighting the significance and reliability of travel apps and how they evolved into the favored source of travel information (Casquero et al., 2022; Roth, 2019). Nevertheless, results also show that the usefulness of travel information highly depends on the travel phase. While waiting (*Figure 28*), displayed travel information at a station becomes a valued source of information, and apart from using an app during onboard travel, participants also consult the provided information within public transportation. These findings partially align with the needs identified by Grotenhuis et al. (2007) during the waiting and travel phases; while waiting and traveling users have the need to be informed of delays and monitor their movement through real-time information. Onboard systems can address this user need and, for instance, display the precise location on a bus along a timeline (Camacho et al., 2013). With real-time travel information, passengers can make informed decisions (Nandan et al., 2014).

On the other hand, non-digital timetables or maps are displayed at a station but rarely used because understanding the information overtaxes many passengers (Beul-Leusmann et al., 2014). Since users require real-time information, such sources cannot show travel progress or delays. However, research by Schmid et al. (2010) highlights an example in which non-digital stationary information can be useful: You-Are-Here Maps. Their results show that it is more efficient and requires significantly less interaction is needed to retrieve information when a simplified map with a set pin showing one's current is available.

Traveling on foot is, by nature, a multidimensional activity, meaning multiple directions are possible, while public transportation is usually bidirectional. This suggests that walking, which can be long distances between connections, at the beginning of a journey or at the end to arrive at the exact location, generally requires a different combination of information. Non-physical information sources such as knowledge of the surroundings, intuition, and usage of landmarks become more useful when traveling on foot (*Figure 30*). This can also clearly be seen in the travel chain visualization of task 4 (*Figure 24*). While navigating, landmarks provide salient perceptual cues for recognizing one's position and distances (Brunyé et al., 2015). In particular, landmarks are more important to pedestrians than knowing street names or distance information (Beul-Leusmann et al., 2014). Environmental cues can determine orientation and provide a cognitive map, which is the principle of landmark anchoring (Epstein et al., 2017). Although difficult to verify, the *Prime Tower*, the highest building in Zurich, could have been used as a helpful landmark during the second and third tasks[2]. Other examples could be the *Lake of Zurich* or the river *Limmat*, which can be used to determine one's approximate location. However, without landmarks, users must rely on other sources of information the environment can provide (Gardony et al., 2013).

The distinction between a regular and non-regular user is common across literature since different information needs are present. The need for information is higher for non-frequent public transportation users than for frequent users, who use habitual information instead (Grotenhuis et al., 2007).

Travel Information Assistance

The travel chain visualizing observed results (*Figure 21 – Figure 24*), reveal that across all travel activities, participants primarily consulted digital information using installed travel apps, which represent travel information assistance technology. The usefulness varies depending on the current travel phases, but overall mobile apps providing travel information are top-rated. Casquero et al. (2022) do not find this trend surprising since smartphones and their ability to reach people worldwide have made us shape our behavior and habits around such technology. At the same time, the acceptance of apps for traveling depends on high usability (Habermann et al., 2016). According to Jamal and Habib (2020), positive travel experiences are often related to smartphone ownership, which again coincides with age. Millennials, for instance, are more likely to use a smartphone for travel activities and thus see an increase in travel ease. In general, the travel category in app markets is one of the most popular (Kim et al., 2021).

Sufficient travel assistance should accompany a user throughout the entire journey and be able to offer precise information along the way. Even though users do not need every piece of information a travel app has to offer, a quick glace without any interaction should capture enough (Samsel et al., 2014). Users need access to different types of information related to travel, which an app can host in one organized domain. This also includes services a traveler may want to access, such as payment and ticketing options (Lopez-Carreiro et al., 2020). Customization features (Casquero et al., 2022) or the Take-me-Home feature (Wirtz & Jakobs, 2013) are examples of how apps employ travel assistance.

MaaS can be considered an attempt at travel information assistance since it attempts to integrate all aspects of a travel experience into a single system. Users expect to be supported and guided in a personalized way along a route (Lopez-Carreiro et al., 2020).

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[2] 9.1 provides an image of this example.

Public transportation networks work within a supply and demand model, meaning the offered services must appeal to a user and meet their demand to be willing to pay for the service. Therefore, developing sound travel information systems is also in the best interest of public transportation agencies to meet these demands. In this regard, intelligent transportation systems (ITS) are a major technological revolution. With ITS, a network can efficiently interconnect vehicles, infrastructure, and people (Camacho et al., 2013). The study results might not directly acknowledge the effect of such systems, but observations along the travel chain (*Figure 21 – Figure 24*), showed that information sources between the users, vehicle displays, or station displays were constantly being compared and verified. Camacho et al. (2013) mention other systems, such as advanced traveler information system (ATIS) and real-time passenger information (RTPI), which are developed around real-time location data of each vehicle in a transportation network using positioning sensors. Mrs. Andenmatten from ZVV's digital sales department confirms that the ZVV implements such measures and thus synchronizes all information across their local app, within busses and trams, and at stations with digital displays.

App Features

Companies and agencies that develop and maintain apps must be able to survive in a highly competitive app market. Offering the right features and consistently improving the app significantly impacts any app's success. Developers must carefully identify and address key features since it significantly impacts user rating scores (Wu et al., 2021).

The reason research does not solely analyze apps but also individual features as a travel tool, is because travel apps may seem visually similar, but provide different features which then influence trip decisions, the inclusion of other services, and even trigger a user to switch apps (Jarass & Oostendorp, 2017). Apps such as Google Maps and Apple Maps have a strong emphasis on wayfinding and navigation by visualizing information through a map interface. Features in those cases are based on providing a spatial user experience, such as address or point of interest searches, proximity estimations for different transport modes, and even integrating multimodal transportation options (Ricker & Roth, 2018). A practical but also, in a sense, a trivial feature can be the option to use and manage the app's travel information while offline. This means information is perhaps not up to date, but on the other hand, no internet access is required, and it is less stressful on the smartphone's battery (Strenitzerova & Stalmachova, 2021).

Public transportation users found timetable features to be the most useful features for urban travel (*Figure 33*). This feature is indicated to be used by more than half of the participants every time. Even though a digital timetable may seem to be a relatively simple piece of travel information, it can be precious to a user since it can accurately indicate delays and visualize an intuitive travel timeline. Wirtz and Jakobs (2013) argue that users want apps to be able to assist them and combine information throughout the entire travel scenario. Therefore, any features related to real-time information and location services benefit users. The survey results confirm this trend as participants perceive traffic information and any type of notifications regarding travel to be necessary. Such travel information can come in different forms, as Samsel et al. (2014) described. The simplest form is when app information is updated regularly, so a user can immediately acknowledge any irregularities. In-app notifications actively inform the user through a notification that something along the travel route has changed, similar to navigation systems guiding one around traffic. Such notifications need to be automatically generated and sent to affected users. Alternative route suggestions are another type of tailored information helping a user make an informed decision. The findings in this study support this notion, as users report they would welcome more features supporting alternative route suggestions (*Figure 34*).

Maps as an app feature are also rated by users clearly as an essential feature overall. 18 out of 20 participants found that maps are very important information sources for public transportation usage (*Figure 34*). Most map interactions were observed in the planning phases of travel (*Figure 14*). Digital maps have the ability to represent real-world elements relevant to travel and show geographic relationships (Ricker & Roth, 2018). Research by Bartling et al. (2021) show the same findings, with map design playing a crucial role in making travel information useful. Despite almost every functional travel app providing an interactive map, most utilize Google Maps for a geographic search. This can suggest one of two things; maps in travel apps may not fulfill user needs or Google Maps is the go-to option for most due to its simple but practical interface setup.

A feature not used by participants in this study, but still acknowledged by most as necessary during travel (*Figure 33* & *page 56*) is the opportunity to purchase a ticket within the app. However, such options are usually only available on apps serving a specific region or country, such as the app by ZVV and SBB.

Traditionally a different ticket for different transportation modes or even network operators was needed. In recent years, providers made an effort to allow travel across all spaces with just a single ticket. The most recent movement in urban travel has gone a step further by offering in-app ticket purchasing options, where a user indicates getting on and off public transportation, and the app calculates the fare for the user considering any other travel subscriptions (Li & Voege, 2017). Integrating such transportation services results in an increasingly more complex transit network and users requiring a convenient and sustainable travel experience (Gebhardt et al., 2016; Lopez-Carreiro et al., 2020).In some studies, payment and ticket options represent one of seven information classes users need to consider when traveling (Hörold et al., 2012). Modern literature on travel services frequently mentions the concept of MaaS, in which universal ticket functions also play a key role (Jittrapirom et al., 2017; Lyons et al., 2019; Polydoropoulou et al., 2020).

Recent studies reveal that the current user demands are centered around personal assistance based on their profiles, needs, and habits (Casquero et al., 2022). A common preference participants seem to share is the option to add individual information to a travel app for a personalized experience. Apart from a map and real-time information, features supporting any type of customization, such as favoring stations and stops, or setting up the layout to one's liking, are important to users (*Figure 40*). Furthermore, users are more attracted and loyal to apps that provide such features (Lopez-Carreiro et al., 2020). Defining how and when travel notifications are allowed to provide information to a user is another way of customizing the experience (Strenitzerova & Stalmachova, 2021). According to Mrs. Andenmatten, the ZVV also follows such measures by enabling app users to be notified by personalized and situation specific information. Furthermore, in the event of an incident ZVV aims to provide information as swiftly and automatically as possible.

In general, apps are increasingly developing features a user must sign into or set up themselves, which not only ties the user through personal information to the services but can simultaneously be of value for app developers (Lim et al., 2015). For example, setting up a take-me-home feature and saving other frequently used addresses (Wirtz & Jakobs, 2013) or subscribing to mobility service packages (Casquero et al., 2022).

Reliability

Apart from using landmarks and knowledge of one's surroundings as an information source, users believe all types of information to be reliable (*Figure 32*). Stationary maps, timetables, signs, and signals are considered very reliable sources of information. These sources provide basic and agency-based information, from which no wrong conclusions are made. Meyer de Freitas et al. (2019) state that due to widespread stable network service, such as in Zurich, users are able to rely on simple information sources such as timetables at the station. However, they are only reliable to the point where no sudden changes in the network are made, meaning they lack dynamic. Using landmarks as navigational points is considered reliable as well. Especially if in a familiar environment, such information sources are helpful. However, landmark reliability decreases when spatial knowledge decreases, which can trigger more uncertainty (Brunyé et al., 2015).

Digital sources, such as displays at a station or inside public transportation, can adapt, and inform travelers of these changes. Together with travel apps, these sources are perceived by participants in this study to be highly reliable (*Figure 32*) An important distinction is the type of travel activity being performed; a routine habitual user relies differently on information than a tourist. Kim et al. (2021) use an independent tourist as an example, to whom obtaining information through mobility apps is especially important. Critical travel information is available anytime and anywhere and can be easily obtained using an app, improving a tourist's experience.

Apart from different travel types, there are also different reliability types to be considered. Bruinsma, Rietveld and van Vuuren (1999) indicate that reliability relates to the quality of service or infrastructure, operating hours, passenger volume, and most importantly, timeliness. In Zurich, where travel times are short, and the transit network has a high frequency, users base their travel decisions on service reliability

(Meyer de Freitas et al., 2019). Compared to other urban public transportation networks, Zurich's is highly reliable (ZVV, 2018), which puts users in a comfortable position.

Nevertheless, users still need to be updated on possible delays and rely on real-time reporting of incidents, shaping a user's travel behavior (Casquero et al., 2022; Lyons et al., 2019).

Public transportation reliability can also be inferred by the mode of transportation. For instance, Romero et al. (2020) point out that for a long-time, bus services were perceived to lack quality and thus seen as less reliable. Although vehicles differ in age and comfort, reliability based on service quality does not seem to be an issue in Zurich. Also, in terms of delays, there are no significant differences to be observed across modes of urban transport in Zurich. Statistics regarding punctuality show that urban services in Zurich consistently achieve high scores (ZVV, 2018; puenktlichkeit.ch, 2022). Furthermore, Bruinsma, Rietveld and van Vuuren's (1999) findings show that public transportation reliability and operating times are not directly related because agencies adapt service availabilities to passenger volumes.

Summary

The need for information during each travel phase dictates the source or the combination of sources from which a user retrieves their information. Users have the need to be able to oversee and follow all steps of a trip, which is where real-time information is most useful. In phases where planning or walking is done, users require spatial information. Although landmarks are able to fulfill spatial information needs, their use is limited to situations during which a user is familiar to the area. Travel apps on the other hand, offer thorough features such as maps, navigation support or dynamic timetables, spatial information, and real-time information, making them a useful tool in any travel scenario.

6.2 Travel Strategy

Research Question 2

Which travel strategies do public transportation users follow and how are travel related uncertainties delt with?

Hypothesis

A public transportation user follows a travel information retrieval routine, from destination search and decision-making processes to travel mode choice. Strategies are therefore firmly based on habitual preferences and how well the area and public transportation lines are known, thus physical information sources are preferred. Digital information sources only become a main part of a strategy once travel related problems come up.

A public transportation user experiences a sequence of different travel phases during a trip. The phases reflect the user's activity along their journey and, depending on their composition, can make a route quite complex. The following subchapters discuss the development and implementation of a travel strategy. A strategy is meant in its simplest form of a plan, laying out actions to achieve a goal. In the case of travel this includes the steps a passenger takes to retrieve relevant information, the choice of transportation and route, and problem-solving.

In this thesis the general but distinct elements that describe or influence a user's travel strategy are their behavior, the process of planning a trip and decision-making. These are all subject to managing a travel activity using public transportation and will be explained in detail throughout this subchapter.

User Behavior

Developing a strategy for moving through time and space is different for everyone. Weisberg and Newcombe (2018) state that an approach can depend highly on spatial knowledge and ability to navigate, but in particular, motivations, preferences for traveling, and even personality shape the way travel tasks are solved. At the same time, travel expectations can be significantly heterogenous (Lopez-Carreiro et al., 2020).

Before walking in a direction, each participant's first impulse was to consult information from a smartphone app (*Figure 21 – Figure 24*). As mentioned by participants in the follow-up survey, most had a good guess of where to go and how to get there but still needed their plan to be confirmed with the support of an app (*page 49*). Jamal and Habib (2020) conclude that smartphone usage for travel significantly impacts travel outcomes and is highly influenced by attitudinal attributes. For example, individuals with a tech-savvy attitude are much more likely to use a smartphone to plan a trip. Most of the participants in this study are young and knowledgeable in using mobility apps (*page 31*). In a classification attempt by Alonso-González et al. (2020), public transportation attitude is mentioned, which explains how people perceive public transportation and the impact it may have.

The method of first assuming and gathering small bits of information and then confirming it through other information sources is something Beul-Leusmann et al. (2013) also observed. In their study, it was common for passengers only to use a smartphone to check if their intuition was correct and then continue the trip. However, some also questioned the app-based information, which also needed to be confirmed by transportation personnel. This reflects users' trust in different information sources (Beul-Leusmann et al., 2013).

Depending on the stage of the trip and personal preferences, the type of relevant information may change. Some information is consulted in a routine, anticipated manner, which applies to planning an unusual trip, while other information needs to be obtained immediately to mitigate uncertainties during travel (Romero et al., 2020).

Across all study tasks, a heavy focus on smartphone apps as an information source is observed. Although some strategies may typically be based on spatial knowledge and follow a user's intuition, being in an unfamiliar environment forced participants to adapt and adjust to relying more on smartphone apps (*Figure 38*). Other studies reveal that a user may not require the complete trip information (Samsel et al., 2014).

The travel chain analysis in *Figure 24* also shows that strategies regarding information needs on foot can change; navigational aids, spatial knowledge, and surrounding information become most valuable. In a wayfinding strategy comparison by Ishikawa et al. (2008), users with navigational aids such as GPS tend to travel longer distances and make more stops when walking than users who navigate based on experience. Using GPS to navigate was perceived as more difficult and less effective than using acquired spatial understating of the environment, which supports navigation for walking more smoothly (Ishikawa et al., 2008).

Travel behavior is shaped by the perception of time. Public transportation users aim to be as efficient as possible when traveling in urban areas, which becomes apparent through participant answers regarding travel strategies (*49*). However, efficiency does not necessarily mean the same to all. While some participants think of efficiency as using the least time, others consider it to be using the least effort, meaning using simple routes with fewer interchanges. *Figure 17* shows that in the first task users prefer a fast and direct route over comfort, which would mean fewer changes and walking. In the two tasks that followed this trend was less frequent (*Figure 18 & Figure 19*).

An analysis of travel patterns by Huang et al. (2021) shows that the most critical factor in any mobility scenario is the duration of the trip. Furthermore, even though a route is fast, it may reduce attractiveness to users when highly complex.

According to Grotenhuis et al. (2007) time-saving in public transportation travel can occur in two ways of information processing. The first is when a user acquires information from travel services and then needs to understand and complete the retrieved information. The second way is when the information is being implemented during travel, which includes tracking, comparing, and deciding on route and mode options.

Dacko and Spalteholz (2014) also make a few interesting statements on the subject of time. Firstly, even though some consider a car to be the least time-consuming option, as a direct route from location to location is possible, one forgets that traffic jams or looking for parking are major time disadvantages. Secondly, public transportation networks can also be prone to delays and be affected by road traffic. Thirdly, the time waiting at an interchange is perceived differently by individuals. For some, waiting for public transportation is a waste of time and may bear uncertainty risks. Eventually, personality factors and offerings of transport service providers determine how a user travels (Dacko & Spalteholz, 2014).

The study took place in the urban area of Zurich, which provides a reliable transportation network and uses pulse timetabling. This means connections are based on timed intervals and sometimes synchronized when interchanging and switching means of transportation (Petersen, 2016). User habits are also based on this principle, as these intervals of specific transport modes or lines are known.

Trip Planning

The solving of each task began with a planning phase. In this phase, even though unconsciously, a plan of how to proceed and solve the task is formed. Once the task was explained, the study participants began to develop a strategic plan in their minds. Although participants first consult technological information sources, in this case, the smartphone with travel-specific apps, one still intuitively follows an individual approach. Technology supporting travel planning, such as an app, aims to align its services with the different phases a user experiences. This means that when planning a trip, an app may have a specific planning view, or when traveling, the app provides the user with an assistance view (Samsel et al., 2014).

A common approach done by participants was using Google Maps to search for a destination on a map (e.g., *Figure 24*). This gave them spatial information in terms of direction and proximity of the destination. This observation shows the importance of maps in travel planning. The participants' answers emphasized this approach by indicating that planning a trip first requires general geographic information, making one aware of the journey's extent, direction, distance, and approximate duration (*page 50*). With a simple search input, a mobile map can generate a visualization showing one's position in proximity to the desired location, which therefore addresses these planning needs precisely.

This observed user approach shows a two-step strategy of retrieving geographic information before the travel plan is laid out in detail. The main results of Romero et al. (2020) suggest a similar approach of providing two levels of information. In the first level of information retrieval, general information is obtained, allowing passengers to have a broad understanding of the route. This information has value to a user, even before the journey is started, and can be covered by apps such as Google Maps. The second level of information their research identifies represents specific information and details of the journey and is commonly obtained by regular public transportation users. Such information can include travel durations or incidents along a route.

Within the planning phase of a trip, Grotenhuis et al., (2007) identify that maps are a valuable tool to establish spatial knowledge and generate a sense of direction for the destination. Nevertheless, their survey findings also suggest that routine travelers only use any information prior to a trip if it is an unfamiliar route.

Naturally, one wants to find and implement the fastest route possible. This becomes apparent in the open survey answers regarding travel strategy, as participants mention that their approach is based on travel duration and efficiency. According to most participants, these factors influence decision-making during travel planning 50).

Decision-Making

At many points during the tasks, using the retrieved information, participants were confronted with the decisions of which route and mode of transportation to take. However, due to the nature of the tasks, the routes to decide on are based on the different combination of transportation modes. Thus, the key variable of decision-making processes in the course of the study is choice of transportation mode.

The four modes of transportation available to users during the study were: bus, tram, train, and walking. Each of the tasks required a different route through the urban environment and consequently also ask for a different combination of transport modes. For example, the route to the first destination consists of a particular bus travel leg at the end since the location only is reachable by bus or on foot (*Figure 17*). The third destination is located in an area that is near the city center but does not have a direct adjacent station or stop, meaning the *last mile problem* is applied (*Figure 19*).

The level of service a transportation network can offer a user often affects travel behavior and, thus, how a transportation mode is chosen (Beirão & Sarsfield Cabral, 2007). The highest impact on a travel sequence in terms of reaction are rerouting and mode choice (Rieser-Schüssler et al., 2016). A survey conducted by Habermann et al. (2016) identified a user's main three reasons for choosing a specific mode of transportation. The top reason was to reach a destination as quickly as possible but is closely followed by punctuality and the availability of the mode. Factors such as cleanliness and accessibility did not seem to influence the choice.

In the first task, the most chosen routes used trains to move through the city (*Figure 19*). Many perceived this as the *most efficient* way to solve this task (*50*). As mentioned, travel time is important to the user and can consequently impact mode choice. Furthermore, the complexity of a chain or route can also affect a travel mode choice (Huang et al., 2021). Apart from the general benefits and disadvantages of specific transportation means, Digmayer et al. (2015) also mention that mode choices depend on the complexity of a route. This complexity is assumed through the high number of available transportation modes and their combination. Urban mobility allows for a lot more flexibility thanks to the combination of transportation means, but at the same time, it can be challenging for a user to manage (Digmayer et al., 2015).

This study shows that there is a motive in some cases to choose a longer route with one single mode of transportation to avoid a complex but faster connection. However, this was not consistent with all participants. In fact, some even remained persistent in using the routes arriving the earliest, even though it meant the mode of transportation needed to be changed multiple times. Participants decided to take a train or combination of trains in the first and second tasks (*Figure 17* & *Figure 18*). Many later admitted that mode changes at train stations represent the most complex part of traveling due to the distance and location between the train platform and bus or tram stop (*page 44*).

Furthermore, navigating through larger stations such as the train station in Oerlikon or the central station can become tricky, even more so if a user is unfamiliar with the area. Results in a study by Digmayer et al. (2015) reveal that the likelihood of travel uncertainty increases when several means of transportation are combined, which is in accord with this study's findings. When it comes to changing modes of transportation, inconvenience and uncertainty are more critical to a user (Meyer de Freitas et al., 2019).

Related literature often suggests that public transportation choice depends on personal characteristics (Huang et al., 2021) and psychological factors (Beirão & Sarsfield Cabral, 2007). Although this study did not analyze the participants to this depth, demographics show a rather diverse selection of participants. A consensus among this study's results and related literature is that walking is considered the least complex mode of transportation and is therefore favored whenever possible. The last task displays this statement quite well, as the majority chose to walk despite being more time-consuming (*Figure 20*). One can argue that the LMP concept does not apply here, as it reflects the general issue of not being close enough to the nearest public transportation point. However, the results indicate that users still prefer to walk even if the LMP could be solved in a complex way. Moreover, Huang et al. (2021) mention in this regard that mitigating walking distances in a public transit network makes it attractive to users, who will adjust to it.

When choosing a mode of transport, a user is not necessarily required to go through a rigorous process of assessing all options. Since travel can be based on behavior and habits, choosing means of transportation can also become an automatic or even mindless action (Kenyon & Lyons, 2003).

Problem-Solving

Passengers may be faced with delays, route changes or other possible forms of irregularities. Strategies of dealing with such events are considered here to be called problem solving processes. Therefore, this subchapter discusses such uncertainties in urban travel and how passengers handle them.

Addressing travel uncertainties in public transportation is particularly important, as it may mean a change in mobility strategy (Brunyé et al., 2015) or even shift users towards using a car (Rieser-Schüssler et al., 2016).

During travel using public transportation, different types of problems can occur. This can be external factors such as disturbances in the transportation network making users adapt their travel route or a user's insecurities, including disorientation or doubts about their actions. Digmayer et al. (2015) highlight two possible disturbances in a transportation network: a planned route becomes unfeasible (e.g., missed connection, traffic jam), and the user lacks the knowledge of how to perform activities.

The first two tasks were suggested to be unfamiliar to most and thus considered the most difficult (*Figure 26*). To most participants, the route of the first task was new and, at the same time, rather complex (*page 44*). These factors and the fact that longer routes are more prone to disturbances relate to travel uncertainties.

Limited knowledge of the environment one moves through can be described as spatial uncertainty. The research by Brunyé et al. (2015) explains that users in an unknown area begin to retrieve other sets of information than when traveling in a familiar setting. Spatial uncertainty triggers one to adapt to cognitive information sources, meaning complex problems are simplified, learned spatial information is recalled, and any visible information sources such as landmarks become important (Brunyé et al., 2015).

The study results in *Figure 37* show that the onboard travel phase is perceived as the most uncertain while getting on and off public transportation and walking are less likely to be an issue. Consequently, uncertainty can also be perceived differently within the travel chain.

Brunyé et al. (2015) conclude that users tend to rely on just their surroundings, such as landmarks, or use technology to help them navigate, with the latter being the more favored option. The overwhelming majority in this study consult the app as the first source of information for problem-solving. Other digital information sources such as displays at the station or inside of public transportation help, while using landmarks to navigate is not common (*Figure 38*). On the other hand, results shown in *Figure 39* suggest users want information sources provided by agency infrastructure to have a higher degree of reliability.

When an app is utilized for problem-solving, features that share information on network disturbances or show timetable information are perceived to be the most useful to participants. These results align with the travel chain assessment by Digmayer et al. (2015); users want to be able to monitor the trip and frequently check on the status of possible delays and follow steps to be taken. Specifically, visual representations showing a travel timeline and alerts telling a user when to get off the vehicle are features mentioned in their study to reduce uncertainty. In fact, Romero et al. (2020) state that changing a route during travel is 12% due to passengers receiving notifications of an alternative option or possible issues in the transportation network. Such in-app elements are referred to as travel-assistant features (Digmayer et al., 2015).

Generally, cognitive difficulties in travel, which mainly include anxiety and stress, can be mitigated by mobility systems in the form of an app that provides real-time information (Kim et al., 2021). Travel-assistant features even have the ability to decrease unpleasant waiting times and make travel planning easier. The main ingredient of such features, which helps in uncertain situations, is access to real-time information (Jarass & Oostendorp, 2017).

Thus, related research sees the solution to travel uncertainty in improving interchange information (Barcik & Bylinko, 2018), providing YAH maps (Schmid et al., 2010), and developing suitable travel-assistant features (Digmayer et al., 2015; Jarass & Oostendorp, 2017; Kim et al., 2021).

Providing information for public transport assistance helps users plan their travel, make decisions, and reduce uncertainty. However, providing appropriate information at the right time is tricky. In this regard, Samsel et al. (2014) refer to the implementation of context awareness in travel information technologies. The aim is to deliver information tailored to the user's phase or activity. By knowing the exact location and mode of transportation, the system can detect whether a user is waiting at a stop or entering or exiting public transportation. This enables an app to provide ideal travel information specifically for that activity and travel phase (Samsel et al., 2014).

Summary

Even though user needs and habits can be heterogenous, a few distinct behaviors are identified. Travel strategy is highly influenced by time, meaning it is shaped by the urgency and the motivation behind the trip. Deriving and implementing a strategy depends on a travel app's help. Especially when users plan to travel, apps are the primary source of information. To a user, the planning phase is essential to establishing general spatial information for travel, which can be done with an app. This information includes direction, approximate duration, and proximity to the destination. Duration and efficiency are the most critical factors when a trip is planned. This also has its influence on the choice of transportation mode. Although no consistent strategy in this regard could be identified, users are faced with two options: a fast route that requires multiple interchanges at complex points or fewer changes, but travel takes longer. To reduce complexity, train stations ought to be avoided, while walking is perceived as flexible and preferred whenever a suitable alternative. Travel strategies thus based around the usage of travel apps, accounting for personal preferences such as time and comfort, and acknowledging travel aspects prone to complexity when planning.

6.3 Recommendations for Travel Information Systems

Research Question 3

How can service providers in the City of Zurich improve their travel information systems to ensure easy urban travel?

Hypothesis

Public transportation agencies need to find a way to address all user needs in a single and easy-to-handle app. As urban mobility becomes more complex, the need for technologies to advance and incorporate suitable alternatives grows. There is a demand for all digital information sources to be synchronized and reinforce each other during travel.

Much literature focuses on tackling this issue from a technological angle. Since public transportation in urban areas represents not only the most sustainable way of travel but also likely the most efficient, it has always been crucial to identifying network improvements and increasing attractiveness (Beirão & Sarsfield Cabral, 2007). This is a two-way street, as users and potential users need to familiarize themselves with modern travel assistance, while transportation providers need to manage and use novel technologies to improve digital infrastructure (EWP & Schweizerischer Städteverband, 2019)

Essentially modern public transportation providers operate in two ways. On one side, they provide and maintain a network of vehicles serving a region to use for travel; on the other, they need to provide a system of information, primarily digitally through an app or infrastructure. Both sides show room for improvement in the case of the urban region of Zurich. However, it is always important to remember that usage patterns and implementation barriers differ from country to country (Altay & Okumus, 2021), which is why a universal recommendation is difficult.

Nevertheless, the following subchapters suggest in relevance to the study’s findings how user demands can be met, which improvements can be made from a systematic perspective, and perhaps how future trends might be a factor.

Meeting User Demands

Public transportation users manage travel information differently, meaning travel needs are very heterogeneous. No one information source is consulted, but a combination of different types is utilized in planning and decision-making processes. This needs to be considered from the supply perspective for travel information, meaning urban travel networks and agencies should develop their systems around the availability and synchronization of all information sources. In an urban mobility assessment by Lerner et al. (2011), the lack of collaboration across platforms and diverse stakeholders is seen as a shortcoming. However, although Switzerland hosts and coordinates over 30 transportation companies, collaborative issues seem minor (ZVV, 2022).

In-app purchasing systems for public transportation users are offered by both ZVV (Check-in Ticket) and SBB Mobile (EasyRide). Both also let users sign in with an account to which already purchased travel subscriptions are integrated (SwissPass). Although the ZVV app does not offer many other options for personalization, both apps successfully meet user demands in terms of customization (*Figure 34*). Essentially, providing an interactive design to a user with sufficient features improves the travel experience and the transportation company's image (Beul-Leusmann et al., 2013). Other apps may reduce customization features due to their core purpose being navigational tools (Google Maps, Apple Maps). In contrast, others may be restricted through their private developer status (Wemlin, Stations, öV Plus, Sojo), or international implementation cannot individually account for each local transit subscription (Moovit, CityMapper). It is assumed that these reasons are responsible for app knowledge and usage results derived in this study.

Schmitz et al. (2016) relate *information fit to task*, focusing on systems and services delivering relevant information at any time. Thanks to location-based data implementation, most apps can offer real-time information, which most perceive as a valuable aspect of urban travel (Altay & Okumus, 2021). In addition to location-based information, data coupled with an accurate timetable keeps users informed when network irregularities occur.

A travel chain does not only consist of public transportation elements. A journey starts and ends with walking, which sometimes is not ideal and results in using personal motorized transportation instead (Digmayer et al., 2015). Therefore, travel information systems must address this issue, known as LMP (Shaheen et al., 2016; Wang & Odoni, 2016). One can argue that travel apps deal with this issue by allowing searches to be done by address and not only by station, thus giving the user options to the nearest connection points. Some apps such as Google Maps and Apple Maps can integrate multimodal travel options such as car sharing services and scooter or bike providers. Apps such as Moovit or ZüriMobil, which is developed locally, serve precisely the purpose of giving all options to fill public transportation gaps. Therefore, these gaps or LMP can be bridged by shared mobility (Shaheen et al., 2016) and thus deserves more attention from more prominent local app providers such as ZVV and SBB.

Not everyone sees and can handle a mobile device as a beneficial tool, and it can even be a frustrating or constraining experience for some. Although not directly affected by this, some participants mention that apps are not user-friendly to older generations. The *mobile first* approach addresses and removes such constraints for users by optimizing the design, including making information more visible and improving processing power and battery life (Roth, 2019). It is recommended that travel information apps to implement *mobile first* elements, for instance, by giving the user an egocentric map view and providing thematic symbolization and an organized interactive interface.

According to ZVV, their app is aimed at the entire population and to make travel for everyone as simple and user-friendly as possible. To achieve this, extensive user research is necessary over multiple stages (ZVV Interview).

All apps available in this study have an interactive map. Users considered this integration the most valuable feature of a travel app (*Figure 34*). Implementing a good app feature is one of the main reasons people download an app, but at the same time, the absence of that feature results in users abandoning the app (Lim et al., 2015). Thus, travel information providers must include a suitable map as an app feature. However, as maps are becoming more and more pervasive, the design in relationship to user expectations, engagement, and usability needs to be better understood, and user studies intensified (Abraham, 2019).

Many of the described user demands could be met by implementing MaaS concepts. Integrating intermodal transportation, personalized features, pay-as-you-go, and real-time information notifications are elements of MaaS addresses (Polydoropoulou et al., 2020). Therefore, considering adapting aspects of MaaS concepts to any urban transportation network is recommended.

System Improvements

Apart from meeting user needs, public transportation and the companies operating them also need to improve the user experience from a systematic point of view. A frequent demand is the availability of real-time data (*Figure 34*), which gives users the potential to increase awareness of available travel alternatives and facilitate more informed decisions (Lopez-Carreiro et al., 2020).

As Samsel et al. (2014) describe, implementing context-aware technology could benefit this cause. It would mean an app's system recognizes when the user boards public transportation, for instance, and deliver travel information specific for that mode of transport along that route, such as delay estimations and the exact duration or number of stops until interchanging. Travel phases and activities would, therefore, also be accounted for, and thus a different set of relevant information for each of them, as seen in the study results, can be shared.

Indirectly the deployment of such app features could feed critical data back to public transportation providers, which then can inform other affected users. Google applies such measures in their map app by using the locations of devices using google services to predict traffic models, which then can help other users (Hilpert et al., 2021).

In a sense, this recommendation aligns with crowdsourcing approaches such as Nandan et al., (2014) propose. Via an app, a user can provide information on punctuality and quality of the mode of transportation, and other users can profit from such information in real-time. Furthermore, the authors propose that knowledge regarding passenger volumes throughout the day can help transportation companies schedule services accordingly.

Transportation networks can also be improved from an infrastructural point of view (*Figure 39*). Displays at stations are considered helpful as an information source during travel. However, only certain interchanges provide such displays. At the same time, displayed information inside public transportation is also useful and available in every vehicle. During the study, it was observed that some of the systems were either not working or, in the case of one participant, showed real-time data of a completely different line. In order to reduce uncertainty, displayed information should be accurate because participants perceive such systems to be very reliable. Dacko and Spalteholz (2014) bring up the subject of accessibility, meaning that it is important for everyone to be able to use public transportation. This includes constructing stations to make any user's interchange convenient. At the Seebach or Oerlikon train stations, users seemed frustrated with the inconvenience of catching a bus in time due to obstacles such as stairs and ramps (*Figure 21* & *page 44*). Nonetheless, signs and signals at such interconnections seemed to be satisfactory.

In the case of Zurich, three guidelines for implementing public transportation in urban infrastructures are generally followed (Menendez & Ambühl, 2022). Firstly, where public transportation and private vehicles meet, the highest priority should be given to public transportation. Consequently, cars are allowed, but congestion needs to be avoided. Secondly, 20% of lanes are dedicated to public transportation, which buses can use bidirectionally. Third and last, signaling prioritizes pedestrians and public transportation, meaning the latter can run on its individual system.

Future Public Transportation Research

Digital channels have become much more important in recent years, and due to the Corona pandemic, this digital shift has been accelerated and will continue. However, adequate alternatives will continue to be offered for user groups that cannot or do not want to use digital channels (ZVV Interview).

The development of future urban mobility is coupled with technological advancements. Electrification and automation have already shaped how mobility systems operate and will likely intensify in the future (Miskolczi et al., 2021). The study results shown in *Figure 40* and on *page 56* indicate that users see an increase in the importance of features supporting real-time traffic information, notifications, connection, customization options, and details on emission.

Much literature regarding mobility calls for sustainability issues to be addressed, for instance, by focusing on emission reduction (Jones, 2020), implementing urban operational measures (Menendez and Ambühl, 2022), or recognizing the potential of MaaS (Matowicki et al., 2022).

One of four key shortcomings of urban mobility developments identified by Lerner et al. (2011) was the absence of a vision of leaders and relevant stakeholders, who have failed to devise a common mobility concept. The European Court of Auditors (2020) stated in a report that there is no clear indication that European cities have fundamentally changed their approach toward sustainable urban mobility. Furthermore, despite cities instigating some initiatives to improve the quality and quantity of public transportation, no significant reduction in private car usage can be observed. How cities intend accomplish sustainability goals in terms of public transportation developments is an exciting subject to follow in the future.

Li and Voege (2017) see a shift in the role of public transportation agencies from a provider to a promoter of their services. Efforts to make sustainable mobility, particularly public transportation, more attractive are a further trend observed in this matter (Casquero et al., 2022). Nevertheless, the demand for a high-quality and integrated solution for public transport services is likely to increase (Miskolczi et al., 2021). Moreover, research on innovative transport and communication systems is becoming more popular. Such developments may include the integration of augmented reality and a 5G network (Abraham, 2019), virtual reality aiding navigation (Weisberg and Newcombe, 2018), and advanced RTI using crowdsourcing (Nandan et al., 2014; Romero et al., 2020).

Summary

Public transportation apps are responsible for providing users with information to help them decide on a route and means of transportation. This information comes from real-time data, maps, and in-app features addressing customization needs. Public transportation in the urban area of Zurich is not only very reliable in terms of punctuality and quality of service, but the local providers, with the help of apps, also make the travel experience very straightforward. The locally preferred apps ZVV and SBB Mobile incorporate most of the user needs, leaving no considerable improvements to be identified. However, implementing intermodal options, such as MaaS offers, might have to be considered in the future.

The transportation system itself also has only minor flaws. Mode changes at major train stations can be improved by better signaling and additional navigation. Real-time information can even be taken to the next level by implementing crowdsourced and context-aware data to predict passenger volumes and suggest alternatives in the case of delays.

Collaboration amongst stakeholders, addressing sustainability issues, and widespread integration of modern technologies are the areas where urban mobility will likely see the most development in the future.

6.4 Limitations

This study researched how public transportation users apply travel strategies, which information needs exist, and how public transportation information systems can be improved. This study used a mixed method approach of three stages in which 20 public transportation users took part. However, there are some limitations to this method.

Although 20 participants generate more than enough detailed information on public transportation behavior, it may not represent all public transportation users well enough. The participants were mainly relatively young, tech-savvy, and familiar with urban public transportation. The study, therefore, primarily reflects those strategies, needs, and behaviors, while user groups such as tourists or occasional city visitors are not included. This limits the study results and recommendations for public transportation systems to only those users, who are still the majority user group.

In the second stage of the study, in which the four tasks needed to be solved, the selection of session time impacted the outcome and travel experience. For instance, the government still had a work-from-home recommendation in place during the first sessions due to the pandemic. This possibly decreased passenger volumes, especially during rush hour. Although difficult to verify, public transportation capacities and frequencies may have been reduced. Conversely, one could also argue that by chance, any of the offered time slots might be affected by any possible irregularities, even on an average day.

The perhaps most important limitation of this study's outcome is that it focuses solely on the urban area of Zurich. Perception of public transportation and travel behavior differs from country to country or even from city to city. This study used common approaches and concepts, but the results are derived from a well-functioning and reliable transportation network. Thus, outcomes around sustainability, promotion of public transportation, or understanding user behavior may be contrained.

7 Conclusion

The goal of this thesis was to answer three core questions in the context of public transportation behavior research. Using a mixed method approach, a three-stage study with 20 participants took place in the urban area of Zurich. The study consisted of four tasks, which all needed to be solved with the help of public transportation. Later, each participant answered a series of online questions about their experience. The results were then discussed in conjunction with relevant literature and the initial objectives of the thesis.

First, the information needs of public transportation users and the role of app features are identified. The hypothesis was that users must be informed of spatial and temporal information. Furthermore, travel app features can fulfill this need using real-time data.

The thesis results confirm this hypothesis. It is revealed that across any public transportation travel chain, users have the need to monitor progress constantly. This means information on points in time and space is an essential element of travel. However, requirements vary depending on the travel chain phase. Planning requires spatial information, giving public transportation users a general narrative of the upcoming travel situation in terms of direction, duration, and distance. Users also expect to be able to access spatial information when walking is involved during travel, which can be at the beginning or end of a route or at points where a change of transportation mode occurs. For the latter situation, however, users struggle to navigate efficiently at complex train stations. This suggests an area for improvement for service providers. Landmarks can satisfy spatial information needs to the extent that an environment is familiar to the traveler.

A tool most public transportation users rely on to meet their demands is app features. Users expect local app services to provide adequate and reliable travel information with the help of suitable features. These include maps, navigation, dynamic timetables, and real-time information.

The second objective is to expose users' public transportation strategies and how travel-related issues are handled. It was hypothesized that users base their travel approach on habits and routines. At the same time, physical information is the most important, and digital sources only become relied upon when travel-related problems arise.

The thesis results do not verify this hypothesis. Travel strategy can indeed be based on habits and mobility preferences, but no universal principle supports this. Even if habits and routines dictated travel strategies, the critical component of any travel approach in this study was the usage of apps, meaning users are accustomed to digital information sources. Mainly during travel planning, actual strategic approaches can be seen. Apps play a vital role in this process, providing real-time and map-based travel information. Once all relevant information is retrieved, users decide on a travel route suggested by app features. This decision is primarily based on selecting the shortest route in terms of time and overall efficiency of the route. Users are confronted with a tradeoff between duration and complexity.

Furthermore, when it comes to the choice of transportation mode, trains tend to be avoided, despite being the faster travel option. These all factor into a traveler's strategic decision when a specific location needs to be reached. In some cases, complexity is avoided altogether by opting to walk a longer distance instead of using public transportation. Users deal with uncertainty by focusing on digital information sources, which can provide real-time information on the situation.

The third and last thesis objective is to identify areas for improvement regarding the information supply of the local public transportation network. The hypothesis assumed that all needs could be met with a single and easy-to-handle app as an information source. Also, there is a demand for information sources to be synchronized across all travel phases.

The thesis results confirm this hypothesis and uncover additional related aspects of interest. Since there is high reliability in apps supporting public transportation users, this domain needs to be of increased priority for service providers. This is the case with local transportation apps, as their development meets most users' general demands. As users need real-time and customization features, apps attempt to address this by offering up-to-date vehicle locations and the opportunity to combine personal information with the app.

There are two measures which could be taken in order to improve the information system. The first is the implementation of crowdsourced data, which would provide a user with information to an even more tailored and detailed degree. Secondly, the harmonization between the app and recognition of the travel phase could lead to a more customized and efficient public transportation experience.

The identified travel needs, strategies, and information system improvements relate to MaaS. Therefore, urban public transportation stakeholders looking into the future could consider the fundaments of the MaaS approach. Nevertheless, the issues likely to be increasingly addressed include sustainability, system automation, and full information integration across all sources.

Since the study is conducted with a relatively unique set of methods in the City of Zurich, individual outcomes may only apply to local users and service providers. Nonetheless, this thesis has produced many informative insights into public transportation user behavior and successfully linked travel needs to the phases of travel with the help of the travel chain model. Travel approaches are therefore better understood and explained using Zurich as a stage of urban public transportation. The results can support city officials and public transportation agencies in recognizing the challenges users in urban areas face and how system improvements can address them. By doing so, public transportation and thus sustainable mobility has the chance to gain popularity in cities. Lastly, this thesis invites urban mobility research to shift focus to understanding more about the public transportation user and how networks can be made more appealing.

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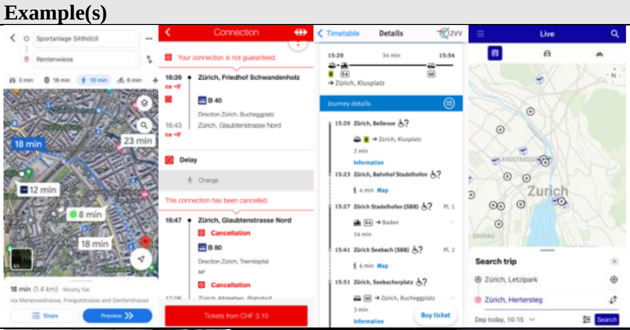
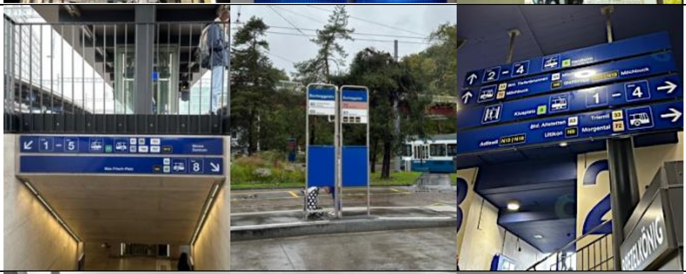
9 Appendix

9.1 Physical Information Sources

Table 5: This list shows examples of all information sources considered in the thesis

Source	Description	Example(s)
App	Many different types of apps relevant to travel exist. Some are primarily map-based and provide navigational and spatial data, while others have the purpose of presenting exact travel routes. (Examples: Google Maps, SBB Mobile, and ZVV)	
Information Displays	***Station displays*** show travel information at a bus, tram, and train stations. They are stationary and provided by the local transportation service. Since they are digital, information can be dynamically adjusted in the case of any changes. (Examples: *Altstetten*, *Bellevue* and *Oerlikon*)	
	Vehicle displays show travel information within public transportation. They share the same information properties as station displays but are generally just focus on the current transportation line. (Examples: Bus Nr. 72, S-Bahn 72 and Bus Nr. 83)	
Signs or Signals	Apart from digital displays there are Apart from digital displays, there are also standard signs at stations and stops. These can show directional information, modes of transportation, and platform or line numbers. (Examples: *Oerlikon*, *Bucheggplatz* and *Hardbrücke*)	
Landmarks	Landmarks often stand out in a city. This can be due to size or just the uniqueness among urban structures. Although commonly subdivided in natural and built, here landmarks are categorized as a whole. (Examples: *Prime Tower*, city construction crane, and *Limmat* + churches)	
Printed Timetable or Map	Transportation agencies provide information in printed form. Often this can be at a station showing the location's departure times or, in some cases, maps as a poster can be found within public transportation. (Examples: *Station Irchel*, map in S-Bahn Nr.8, and *Station Oerlikon* timetable)	

9.2 Study Script

Invitation Phase

Table 6 (a – e): Each individual step a participant experiences is described: invitation (a), Phase 1 (b), Phase 2 (c), Phase 3 (d) and the end of the study (e)

1. Email	This email is sent to all potential participants. It includes general study information, objective, and participation requirements. Furthermore, it consists of a signup link, which directs the participant to a doodle form, where they can select a suitable and available time slot for the study run. For this signup process name and email address are required.
2. Email	First, people who signed up for the study are thanked for their interest and participation. Secondly, more information is provided regarding meeting point and requirements. The email contains a link to a survey, which ought to be completed beforehand, and a specific participant number (PN) is given. Participants answer a few simple demographic and general mobility questions in the survey and enter their given PN. Additionally, the email includes the form of consent, which they will be signing before the study can begin and can therefore review beforehand.

Phase 1 (10 – 20 min)

Form of consent	Participants already received this document before the study in an email and (ideally) have reviewed it. The form includes the study's purpose, general procedure, potential risks, and how confidentiality is dealt with. Participants are asked to sign the document, agreeing to participate under the stated conditions. At any point during or after the study, it is possible for participants to withdraw, for which any type of data collected will be deleted.	(5`)
Survey	In the case that the participant has not filled out the survey, it is at this point that this can still be done. The PN is added as well.	(5`)
Introduction/ explanation	Once again, I explain the study's purpose and objective and describe what will happen in the next phase. This means participants are informed that for the next 1-2 hours, they will receive a smartphone for four tasks. In each task, a destination must be reached, which will be revealed at the beginning of each task. Once the destination is reached, and the task is therefore completed, the following location is revealed. During the time that the participant is working themselves through the tasks, I will be collecting data in two ways. The first data source comes automatically through the given smartphone, which records what happens on the screen (screen recording). The second data source is the documentation of the participant's behavior observed throughout each task (observational analysis). It is explained that during the study, communication between the participant and me is acceptable as long as it does not affect the outcome of the task. There is no right or wrong, no time limit, and only, if necessary, I will intervene.	10`
Study setup	The smartphone has a full charge battery and is set up so that only specific apps and features are available (defined focus mode for the study). Further, no personal data is or can be stored on the phone, and previous search histories and system preferences are removed beforehand.	2`
Testing	The participants are given a few minutes to get used to the smartphone and test general features such as: switching between apps, closing and launching apps, searching within the app, and lastly, ensuring the video recording is active, and the network connection is stable.	3`

Phase 2 (4x 15 – 25 min)

Start	Device	• Screen recording is manually started.
	Participant	• Receives smartphone and location.
	Study organizer	• Reveals location • Starts screen recording
During tasks	Device	• Creates a video clip of everything happening on the screen. • The duration of the task is clocked by screen recording time.
	Participant	• Uses given a smartphone to search, find and travel to the location.
	Study organizer	• Observes the general reaction and interaction of participant. • Observes behavior and interaction with the smartphone. • Observes behavior and interaction with the surrounding. • Documents all observations using predefined tags on a tablet. • Significant interactions/observations are highlighted and timestamped. • Interference protocol is strictly followed.
End of tasks	Device	• Screen recording is stopped. • Video file automatically saved.
	Participant	• Confirms/announces that location is reached. • The device is handed over.
	Study organizer	• Manually stops screen recording and names file according to PN. • Reveals next location. • (At the last location, announces the end of the phase)

4x

Phase 3 (20 – 40 min)

Introduction	Participants are informed that this last part of the study is a further survey. It is done in the same format as ten first one and does not ask for personal information. If there is anything not clear or a question comes up, ask for guidance at any time.
Survey	The survey questions and their order are consistent among all participants. Questions are grouped into seven themes: 1. Open and closed questions regarding the previously solved tasks 2. Ranking the usefulness of the resources and their reliability 3. Open question on strategic approaches to the tasks 4. Questions regarding the features of the used apps 5. How uncertainty is dealt with 6. The unusefulness and reliability of resources in unknown environments 7. Changes and ideas on how the future of mobility might look
End	At the end of the survey, participants have the option to receive the study's results.

End of study

Acknowledgment	Participants are thanked for their participation and for helping provide data for the thesis.
Feedback	Perhaps participants have inputs regarding the study or any sort of valuable information which could be considered or help improve the thesis.
Follow up info	Contact information can be provided if a participant wants to be informed about the study or thesis outcome.

9.3 Form of Consent

Thank you for your interest in participating in this study. Detailed information on the study is provided below. You are free to choose whether to participate in the study or not. Your participation does not affect your academic performance at the University.

Study Purpose

The study is conducted by Jakob Knöpfel as part of his Master's thesis at the University of Zurich in the field of "Geographic Information Visualization and Analysis" (GIVA). The general objective is to research how people interact with a smartphone and apps while using public transport. In order to analyze these interactions between a human, their mobility apps, and their surroundings in an urban environment, the city of Zurich was chosen as a study location. The master thesis is supervised by Tumasch Reichenbacher at the Institute of Geography at the University of Zurich.

Study Procedure

The study's duration will not take longer than three hours and is divided into several different stages. In the first stage, a short questionnaire is filled which is to derive simple demographic data, as well as previous knowledge of the subject. Afterward, a short introduction to the second part will take place. In the second part of the study, the participant is given a specific location in the city of Zurich, which should be reached using public transport. As assistance, a smartphone with preinstalled mobility apps will be provided. Four locations and thus four routes are traveled. In the third and last part of the study, you will be asked a few questions about your experiences and preferences regarding mobility in the form of a detailed survey.

Risks

The study does not involve any fundamental dangers and risks. However, because tasks must be solved in public and busy spaces, a certain degree of attention throughout the study is necessary.

The study adheres to the current Covid-19 measures; masks and distance requirements are followed, as well as in the case of any relevant symptoms, participation is reconsidered.

Data Confidentiality

All data collected in this study will be treated confidentially. In order to relate the three parts of the study, they will be identified with the same participant number but without personal information. The study is structured so that there is no possibility of identifying participants by results. In the event of a request from a third party, any data collected will only be passed on with your express permission. With your signature, you agree that the study results may be published.

Study Results

If you would like to be informed about the results of the study, you can leave your email address. A copy of the study results or the master thesis can then be sent to you at a later date.

You are free to decide whether you want to participate in the study or not. You are also free to discontinue at any time during the study. Please do not hesitate if you have any questions!

With your signature, you confirm that you have read and understood the above information and agree to participate in the study under the conditions described therein.

signature participant

full name (block letters)

signature study organizer

full name (block letters)

place, date

Withdrawal of Consent

I hereby wish to withdraw my consent to participate in the study described above. This will remove and delete any information collected so far for the study.

signature participant

full name (block letters)

place, date

9.4 Participation Requirements

Table 7: List describes all criteria required for the study to take place and how its verified

Criterion	Description	Verification
Participant lives in or around the City of Zurich.	The study objective is to examine people with a general sense of the area. Analyzing participants who never or rarely spend time in the City of Zurich might skew the data output since their knowledge of the area and ability to navigate throughout the city is lower. This criterion ensures comparable results, even if tools, information preferences, and strategies differ.	This requirement is touched upon and justified during the selection process of potential participants. Participants must indicate that they either frequently spend time or commute into or throughout the urban area of Zurich. The distribution and recruitment process for participants is done with the help of the University, and thus, by nature, this criterion is, in most cases, automictically met.
Participant knows their way around a public transportation system.	Like the previous criterion, the implementation of this requirement aims to select participants who not only move through the city but additionally do this using public transportation. Since the focus is to study public transportation usage, this should be met as a prerequisite. Less experienced public transportation users obtain information and apply strategies and routines differently than users who know their way around public transportation (Meyer de Freitas et al., 2019).	(1) In the process of signing up for the study, this requirement is specifically listed, indicating that participation is only possible if one frequently uses public transportation. (2) The participant survey in the first stage asks which type of public transportation pass one has. In the case that one selects the option "no pass", "holiday pass" or a type of irregular transportation pass, a short follow-up inquiry is made, whether the criterion is still met. (Even if one has not resubscribed or renewed their pass due to the pandemic, the criterion can still be met)
Participant frequently uses technology such as a smartphone to get around.	Digital information sources are at the core of the study. Therefore, the usage and knowledge of the general way to use a smartphone for tasks are important.	At multiple initial stages, it is made clear what the topic and research objectives are. Thus, users who know their way around a smartphone and frequently use it for navigation, for example, are a must.
Permission to collect, compare and analyze data	Taking part is only possible if the produced data is allowed to be collected, analyzed, and potentially publicized as a research paper.	Potential participants are given a form of consent to read in advance. Before the study starts, the data collection process is explained again, and any related questions are answered. By signing the form of consent, one agrees to allow the data to be collected, analyzed, and potentially publicized in the form of a research paper.
Participant acknowledges that precautions apply.	The study is done in an urban environment using public transportation. Since, throughout the second stage of the study, one is tempted to use a smartphone and other sources of information, distractions are therefore likely. Thus, one must remain observant and move with caution once one's full attention is not on the traffic situation.	As with the previous criterion, potential participants are informed on this topic through the form of consent. Signing the consent form acknowledges that one must always remain observant.
Participant needs to follow health and safety measures.	When the study was launched, the Swiss federal government had several Covid-19 rules. This included social distance and mask regulations while using public transportation.	The consent form acknowledges these rules and must be followed throughout the study.
The study takes place in dry conditions	The weather should be dry to make the study as pleasant as possible for participants. In addition, since a smartphone is carried around and one glances at it frequently, any type of precipitation is not ideal.	The weather conditions were always checked in advance and monitored. In the case of rain, participants were informed, and an alternative date was scheduled.
The study takes place during the daytime.	Transportation Networks tend to have different schedules depending on the time of day. To somewhat keep consistency across participants, the study should be done the latest by 19:00 (7 pm).	Specific timeslots were predefined for participants to choose from. This requirement was communicated beforehand if another day or time needed to be set.

9.5 App Selection Survey

The following two diagrams stem form an online survey conducted throughout November of 2021 by the same author of this thesis. 32 people in and around the city of Zurich took part.

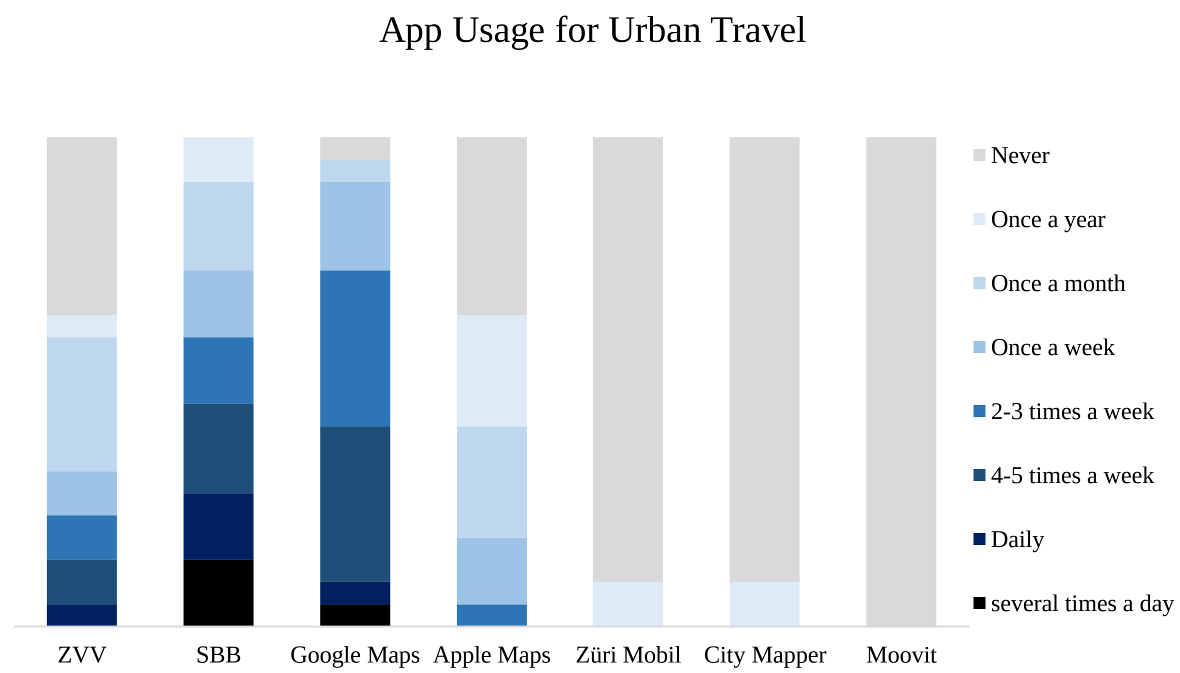


Figure 41: Results of individual app usage (survey November 2021)

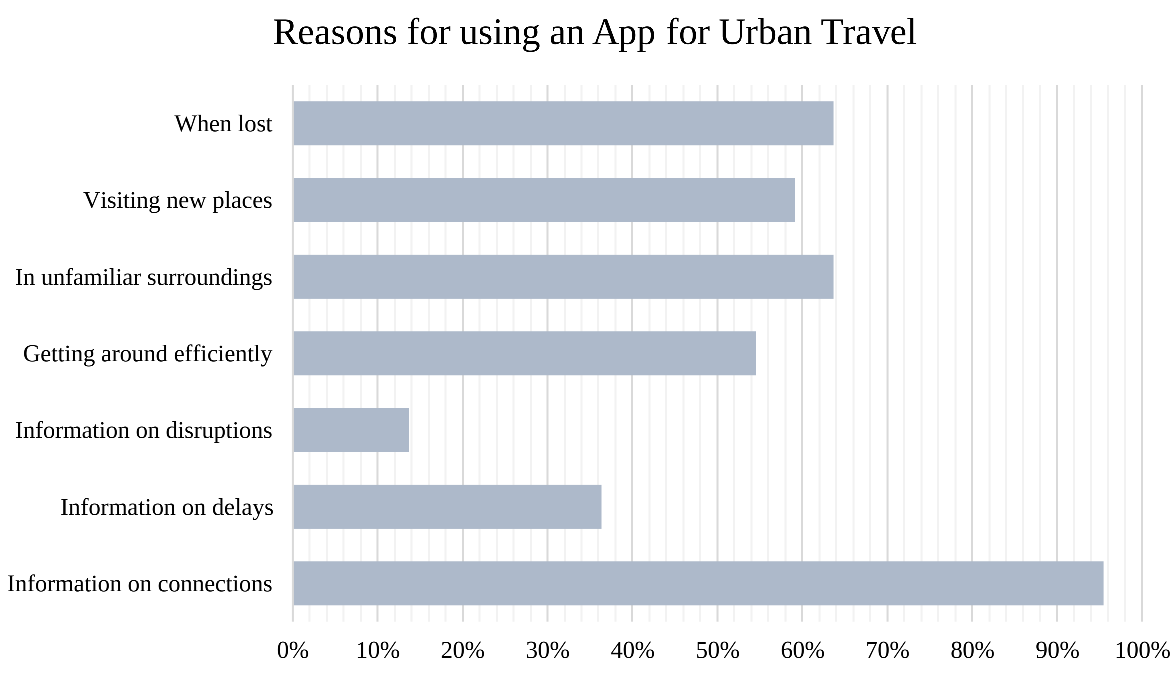


Figure 42: Reasons for using an app for urban travel (survey November 2021)

9.6 App Selection

Table 8: Details of the twelve provided apps for the second stage

	App Category	Ranking (Nov. 2021)	App Developer*	Description	Reason for Inclusion in Study
Moovit	Navigation (7)	7	Moovit App Global LTD (UK)	App for all urban mobility and different transportation modes.	Popularity Study relevance (intermodal)
Google Maps	Navigation (1)	1	Google LLC (USA)	Provides worldwide multi-layer map and navigation.	Popularity
ZVV	Travel (18)	18	Zürcher Verkehrsverbund (ZVV)	Timetable and ticket app based on transit area of Zurich.	Popularity Local-based
Citymapper	Navigation (10)	10	Citymapper Limited (UK)	Travel and navigation app for urban mobility.	Study relevance (urban-based)
ZüriMobil	Travel	-	Verkehrsbetriebe Zürich (CH)	Provides options for intermodal travel connections for the region of Zurich.	Local-based Study relevance (intermodal)
SBB Mobile	Travel (2)	2	SBB AG (CH)	Timetable and Ticket app for the Swiss transport network.	Popularity
Apple Maps	Navigation	-	Apple (USA)	Multi-layer map and navigation app.	Popularity
Wemlin	Travel	-	Netcetera AG (CH)	Timetable and station information app for Swiss German regions.	Local-based
Swisstopo	Navigation (3)	3	swisstopo (CH)	Map-based navigation app for outdoor activities.	Popularity Local-based
Stations	Navigation	-	André Horstmann (CH)	App to look up specific station information.	Local-based
öV Plus	Travel	-	Bernmobil AG (CH)	Timetable and Ticket app for the Swiss transport network.	Local-based
Sojo	Travel	-	Axon Vibe AG (CH)	Provides real-time information for intermodal travel.	Local-based Study relevance (intermodal)

***Country Abbreviation**

UK – United Kingdom

USA – United States of America

CH – Switzerland

9.7 ZVV Interview

The following questions and answers are part of an interview. It was done digitally via email on May 11th with Brigitte Andenmatten, who is part of sales and digital distribution at ZVV.

Can you explain what was the motivation behind the idea to develop a mobile app for ZVV?

Basic motivation for mobile app operation:

- Adapting sales and information and service channels to the current and future needs of users.
- Ensuring the nationwide and efficient provision of consulting, sales and services (24x7)
- Simplification of public transport use.
- Commitment and orientation for public transport users by means of a consistent presence of the ZVV as the body responsible for public transport in Zurich in conventional and digital channels.

Strategic goals of merging the two existing apps into a new ZVV app

- Consistent continuation of the digitization strategy
- Further simplification of access to the system
- Increase in customer benefit
- Reduction of sales costs
- Better positioning of the app on the market
- More cost-efficient and effective marketing of the mobile channel
- Better visibility of the ZVV brand in the digital world
- More flexibility in development
- Enabling new innovative features

Were there specific goals that the transport association wanted to achieve with an app?

Targets in the mobile channel were defined in terms of the number of active users and the market share in the ZVV / Z-Pass area.

How do you see the positioning of the ZVV app in the mobile app market and are there also goals in terms of market share?

Value proposition of the ZVV app:

The ZVV app is the compact solution for the entire customer process in public transport (focus on the core business and mapping of all relevant processes). It is primarily geared to the needs of passengers in the greater Zurich area. Thanks to the clear focus on the relevant core features and ranges, the targeted linking of features and the clear user guidance, the app is outstanding in terms of simplicity and user-friendliness. The ZVV app offers targeted regional added value and facilitates orientation in the system through visual identification on site and direct communication options with the ZVV. Advertising and the use of customer data are deliberately avoided. This positioning distinguishes the ZVV app from alternative offers.

How were user needs taken into account during development?

The new ZVV app was designed and developed from scratch. The focus was consistently on user needs. The fact that the ZVV app, as a public transport app, is aimed at the entire population presented a particular challenge in its conception and development. In order to meet the needs of as many user groups as possible, extensive user research was carried out right from the conception stage:

- Results from market research studies
- Findings from pilot projects (timetable pilot app)
- Focus group surveys with younger and older target groups
- User experiences with existing apps
- Extensive usability walkthroughs and usability tests were conducted throughout the project (from conception to implementation). In various iterations, the UX concept was thus constantly reviewed and refined, and the various areas were optimally aligned with user needs.

Can you explain how the app was developed and tested step by step as a network?

The project to realize the new ZVV app was carried out in four stages over 4 years:

2019: Phase 1 - conception (with agency competition and design concept).
2020: Phase 2 - implementation (technical specification and development)
2021: Phase 3 - Test operation of the new app with parallel operation of the existing apps and ongoing further development, bug-fixing and stabilization
2022: Phase 4 - Definitive introduction of the app and replacement of the existing apps.

After the functional conception, the individual features were technically specified and documented. The development was then packaged in numerous iterations (so-called sprints), with testing of the newly developed features being carried out after each sprint was completed. Before the go-live of the app, a large final round of testing was carried out on all features. In addition to the departments and friendly users from the ZVV environment involved in the testing, two external testing companies and a foundation for the promotion of accessibility were also involved.

To what extent were other apps used as inspiration for the development of individual features?

The analysis of mobile apps in public transport nationally and internationally and also the analysis of comparable offerings from other industries and the identification of best practices and new, promising approaches are among the ongoing tasks in the (further) development of the app channel**.**

In and outside of the means of transport, one can use timetables, maps and digital displays etc. to help. Is the ZVV app also adapted to these?

Yes, the app basically uses the same data sources as the other ZVV channels. Via the national data hubs, ZVV exchanges timetable data and real-time information (delays, cancellations, detours) with most transport companies. This data is also offered publicly via the Mobility Switzerland open data platform. The data offering will be expanded in the coming years. In order to meet customer demand for fast and comprehensive information in the event of an incident, ZVV will push ahead with the automation of the recording processes and examine synergies with national data and services.

How do you see the role of the ZVV app when it comes to situations such as cancellations, detour, delays or similar?

The ZVV offers its passengers travel-related information from a single source. Its passenger information channels simplify access to public transport and are present throughout the entire travel chain. Digital channels offer the potential to provide even more personalized and situation-specific information than before. In the future, information in the event of an incident should be created and communicated as automatically as possible. The increasing number of connection queries underlines the growing importance of digital publication channels in passenger information.

Are there plans to further develop the digital offering, such as the app, and how will feedback and suggestions from users be taken into account in this process?

The app is constantly being optimized and further developed. The main drivers in this regard are:

- Customer requests and feedback
- New offers / features
- National developments in tariffs and sales
- New technological developments
- various technologies already help public transport users to find their way around the city.

Do you think that in the future everything will be made available only in digital form?

In recent years, digital channels have become much more important. The digital shift has accelerated again due to the Corona pandemic in the last two years and will continue. Adequate alternatives will continue to be offered for user groups that cannot or do not want to use the digital channels.

9.8 Interference Protocol

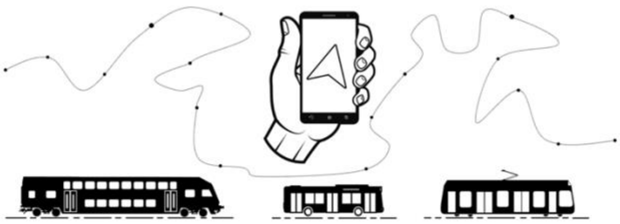
Table 9: Description of all possible issues during the study, their type and how to interfere

Type of issue	Description	Possibilities	Interference
General	All issues regarding the overall study, the topic, or the thesis itself.	Concerns regarding data/privacy	The session is paused. The participant is informed about confidentiality and study setup.
		Safety concerns raised	The session is paused. The situation will be assessed. Health and safety are the priority.
		General questions	It can be answered on the fly during the run if there is no effect/influence on the outcome.
		Study objective	It can be explained on the fly during the run if there is no effect/influence on the outcome.
Usability	Not properly using the app or device. Difficulties in operating an app or device.	Operational Questions	Simple/fast: can be dealt with on the fly. Complex/essential: session is paused, and questions are answered.
		Multitouch/Swipe/Gesture difficulties	The session is paused. Short explanation and testing are done.
		Feature cannot be found	Minor issue: dealt with on the fly. Major issue: run is paused, and assistance and short instructions are provided.
		Questions/difficulties regarding search and keyboard	Minor issue: dealt with on the fly. Major issue: session is paused, assistance and short instructions are provided.
Environment	Hindering of a direct route through external influences.	Extreme weather condition	The session is paused or even aborted. Health and safety are the priority. Seek shelter.
		Delay (traffic, accident)	Delay < 20 min: run followed through as usual. Delay > 20 min: Run will be assessed for an alternative. If there is no other possibility: Skip to the next task or abort.
		Detour/rerouting (Demonstration, construction)	Detour delaying task less than 20 min: run followed through as usual. Detour delaying task longer than 20 min: interference and assessment for alternatives. The task is skipped, or in the worst case, the session is aborted and rescheduled.
Directional	An incorrect route/direction is chosen by the participant.	Walking in opposite/incorrect direction	After 5 min tolerance: intervention (vocal indication)
		Getting on tram in opposite direction	1 Stop tolerance: intervention (vocal indication + explanation)
		Getting on bus in opposite direction	1 Stop tolerance: intervention (vocal indication + explanation)
		Getting on train in opposite direction	No tolerance: intervention when getting on (clue to reevaluate choice)
Action	An incorrect vehicle or line is taken.	Incorrect tram line taken	3 Stop tolerance: intervention (vocal indication + explanation)
		Incorrect bus line taken	3 Stop tolerance: intervention (vocal indication + explanation)
		Incorrect train line taken	No tolerance: intervention getting on (clue to reevaluate choice)
Technical	Malfunctioning of screen recording, app, or device.	The smartphone battery runs out	The session is paused. An external battery (power bank) is used
		Screen recording is stopped/paused	The session is paused until the issue is dealt with
		Insufficient or no network service	Reconnection on the fly if no effect on the outcome
		Insufficient or no location services	Reconnection on the fly if no effect on the outcome
Temporal	The duration of the task/study is too long.	A single task is taking too long	10 min above average: vocal indication and participant is informed
		Overall study run is taking too long	The participant is informed of timeliness
		A decision is taking too long	1 - 2 occurrences: no interference Two or more: Participant is informed of timeliness

9.9 Online Survey

Introduction

Language: English - English Change the language



You receive this survey to participate in the main study of my master thesis. Thank you for showing your interest and support in my study!

This survey is being conducted as part of my Master's Thesis at the University of Zurich in the field of "Geographic Information Visualization and Analysis" (GIVA). The objective of the study is to investigate how people behave and interact with technology when using public transport in an urban environment. In order to research this area, a qualitative analysis will be done, in which you are asked to fulfill several tasks within the city of Zurich, during which your behaviour and actions will be analized.

All information and answers are kept completely confidential and are only used for the purpose of this study. Furthermore, all stages of the study are only joined by participant number, while no private information is ever obtained in any of the processes, hence complete anonymity is guaranteed.

Now you will take part in a short survey in which you answer a few general questions about yourself and your mobility habits.

If you have any suggestions or questions, please do not hesitate to contact me.

Study Organizer: Jakob Knöpfel (jakob.knoepfel@uzh.ch)

Supervisor: Tumasch Reichenbacher (tumasch.reichenbacher@geo.uzh.ch)

I have read and understood the terms and conditions.
Show policy

Survey data policy

Risks

The study does not involve any fundamental dangers and risks. However, because tasks must be solved in public and busy spaces, a certain degree of **attention** throughout the study is necessary.

The study adheres to the current **Covid-19 measures**, i.e. masks and distance requirements are followed, as well as, in the case of any relevant symptoms, your participation needs to be reconsidered.

Confidentiality

All data collected in this study will be treated **confidentially**. In order to relate the three parts of the study, they will be joined by a participant number, but in no relevance to your identity. The study is structured so that there is no possibility to identify participants by results. If the opportunity arises, data may be published in an anonymised form.

Agreement

You are free to decide whether you want to participate in the study or not. You are also free to discontinue at any time during the study.

By checking the box and continuing the study, you confirm that you have read and understood the above information and agree to participate in the study under the conditions described therein.

Accept Close

Demographic Questions (First Stage)

Please enter your participant number in the field below.

If you don't have a number, please contact the study organizer.

Only numbers may be entered in this field.

✱ To which of the following age categories do you belong to?

ⓘ Choose one of the following answers

- ○ 17 or younger
- ○ 18 – 20
- ○ 21 – 29
- ○ 30 – 39
- ○ 40 – 49
- ○ 50 – 59
- ○ 60 or older

Please select your gender.

ⓘ Choose one of the following answers

Please choose...

✱ Where do you spend the most time?

	1 – never	2	3	4	5 - daily
in the city	○	○	○	○	○
on the countryside	○	○	○	○	○
in the agglomeration	○	○	○	○	○

How well do you know and use the following apps?

	Knowledge						Usage						
	1 – never heard of it	2	3	4	5 – know it very well		1 – never	2	3	4	5 – use it daily		No an-swer
Moovit	○	○	○	○	○		○	○	○	○	○		◉
Google Maps	○	○	○	○	○		○	○	○	○	○		◉
ZVV	○	○	○	○	○		○	○	○	○	○		◉
CityMapper	○	○	○	○	○		○	○	○	○	○		◉
ZüriMobil	○	○	○	○	○		○	○	○	○	○		◉
SBB Mobile	○	○	○	○	○		○	○	○	○	○		◉
Apple Maps	○	○	○	○	○		○	○	○	○	○		◉
Wemlin	○	○	○	○	○		○	○	○	○	○		◉
Swisstopo	○	○	○	○	○		○	○	○	○	○		◉
Stations	○	○	○	○	○		○	○	○	○	○		◉
öV Plus	○	○	○	○	○		○	○	○	○	○		◉
Sojo	○	○	○	○	○		○	○	○	○	○		◉

* Please select the type(s) of transportation pass you have at the moment.

Check all that apply

- [ ] No pass
- [ ] GA Travelcard
- [ ] Half Fare Travelcard (Halbtax)
- [ ] Point-to-Point Travelcard
- [ ] Regional Travelcard
- [ ] Modular Travelcard
- [ ] Leisure Travelcard
- [ ] Multi Travelcard (digital or paper form)
- [ ] Other:

* Please select how often you use public transportation.

Choose one of the following answers

- ○ never
- ○ once a year
- ○ once a month
- ○ once a week
- ○ 2 – 3 times a week
- ○ 4 – 5 times a week
- ○ daily
- ○ multiple times a day

Debriefing Survey Questions (Third Stage)

1. Question Block: Tasks

* How would you estimate the difficulty of the entire tour with all four tasks?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

1 = very easy
5 = very hard

* Now that you have completed all tasks, please rank them according to their difficulty.

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 4 answers

Your choices	Your ranking
1. Route	
2. Route	
3. Route	
4. Route	

Most difficult at the top.

* Briefly explain why you chose this order.

* Select for each of the following apps if you know and used it during the tasks.

	Known			Used	
	yes	no		yes	no
Moovit	○	○		○	○
Google Maps	○	○		○	○
ZVV	○	○		○	○
Citymapper	○	○		○	○
ZüriMobil	○	○		○	○
SBB Mobile	○	○		○	○
Apple Maps	○	○		○	○
Wemlin	○	○		○	○
Swisstopo	○	○		○	○
Stations	○	○		○	○
öV Plus	○	○		○	○
Sojo	○	○		○	○

2. Question Block: Information Sources

* Select **all** information sources that you used.

Check all that apply

- ☐ App
- ☐ Digital display at station/stop
- ☐ Digital display in vehicle
- ☐ Natural and built landmarks
- ☐ Knowledge of surroundings
- ☐ Signs and signals at station/stop
- ☐ Printed timetable or map
- ☐ Own intuition
- ☐ Other: ______

Rank the usefulness of these information sources at the time you were **planning your route.**

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or map	
Own intuition	

Most useful at top

* Rank the usefulness of these information sources at the time you were **waiting at a stop/station.**

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or map	
Own intuition	

Most useful at top

* Rank the usefulness of these information sources at the time of your **travel using public transportation.**

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or map	
Own intuition	

Most useful at top

* Rank the usefulness of these information sources at the time you were **travelling on foot.**

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or map	
Own intuition	

Most useful at top

* Rank the usefulness of these information sources at the time you were **getting on or off of public transportation.**

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or map	
Own intuition	

Most useful at top

* How reliable was the information of the following information sources during the time of the tasks?

	1 – very unreliable	2	3	4	5 – very reliable
App	○	○	○	○	○
Digital display at station/stop	○	○	○	○	○
Digital display in vehicle	○	○	○	○	○
Natural or built landmarks	○	○	○	○	○
Knowledge of surroundings	○	○	○	○	○
Signs and signals at station/stop	○	○	○	○	○
Printed timetable or maps	○	○	○	○	○
Own intuition	○	○	○	○	○

3. Question Block: Strategy

*

Did you switch or adapt your strategy at any time during any of the tasks?

Briefly justify your answer.

Choose one of the following answers

○ Yes

○ No

Please enter your comment here:

* Briefly describe what kind of strategy you followed in order to complete the tasks. Did you follow a specific pattern?

4. Question Block: App Features

* Think about your most used mobility apps. Which of the following functions and features within the apps do you use?

	never	rarely	sometimes	every time
Map within App	○	○	○	○
Timetable	○	○	○	○
Touch-Timetable	○	○	○	○
Station information	○	○	○	○
Connecting options	○	○	○	○
Take-me-Home function	○	○	○	○
EasyRide, Check-in-Ticket or similar	○	○	○	○
Ticket information	○	○	○	○
Zone allocation	○	○	○	○
Disturbance notifications	○	○	○	○
Vehicle information (Occupancy, WC, etc.)	○	○	○	○

* In your opinion, how important are the following functions and features in order to have the perfect fictive mobility app?

	1 – not important at all	2	3	4	5 – very important
Map	○	○	○	○	○
Timetable	○	○	○	○	○
Touch-Timetable	○	○	○	○	○
Animations	○	○	○	○	○
Alert notifications	○	○	○	○	○
Station information	○	○	○	○	○
Connecting options	○	○	○	○	○
Realtime traffic information	○	○	○	○	○
Alternative route suggestions	○	○	○	○	○
Emission details	○	○	○	○	○
Take-me-Home function	○	○	○	○	○
EasyRide, Check-in-Ticket or similar	○	○	○	○	○
Ticket information	○	○	○	○	○
Map customization	○	○	○	○	○
Layout customization	○	○	○	○	○
Zone allocation	○	○	○	○	○
Disturbance notifications	○	○	○	○	○
Vehicle information (Occupancy, WC, etc.)	○	○	○	○	○

5. Question Block: Uncertainty

* When an uncertainty during travel using public transportation arises (detours, congestion, outages or other changes), which information sources do you use the most?

Check all that apply

- ☐ App
- ☐ Information Display at Station/Stop
- ☐ Information Display in Vehicle
- ☐ Natural and built landmarks
- ☐ Knowledge of Surroundings
- ☐ Signs and Signals at Station/Stop
- ☐ Printed Timetable
- ☐ Own Intuition
- ☐ Other: ________

* When an uncertainty during travel using public transportation arises, which app functions do you use the most?

	never	rarely	sometimes	always
Map	○	○	○	○
Timetable	○	○	○	○
Station information	○	○	○	○
Connecting options	○	○	○	○
Zone allocation	○	○	○	○
Disturbance notifications	○	○	○	○
Vehicle information (Occupancy, WC, etc.)	○	○	○	○

* At which point does one perceive the most uncertainty when travelling with public transportation?

	1 – least likely	2	3	4	5 – most likely
During planning	○	○	○	○	○
Waiting at station/stop	○	○	○	○	○
During travel	○	○	○	○	○
Getting on or off	○	○	○	○	○
On foot	○	○	○	○	○

6. Question Block: Unfamiliar Environment

How does the usefullness of these information sources change when travelling in an uknown area? Rank the usefulness of these information sources.

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at most 8 answers

Your choices	Your ranking
App	
Digital display at station/stop	
Digital display in Vehicle	
Natural or built landmarks	
Knowledge of surroundings	
Signs and signals at station/stop	
Printed timetable or maps	
Own intuition	

Most useful at top

* If you are travelling in an unknown environment, how reliable should these information sources be?

	1 – indifferent	2	3	4	5 – very reliable
App	○	○	○	○	○
Information Display at Station/Stop	○	○	○	○	○
Information Display in Vehicle	○	○	○	○	○
Natural or built landmarks	○	○	○	○	○
Knowledge of Surroundings	○	○	○	○	○
Signs and Signals at Station/Stop	○	○	○	○	○
Printed Timetable or Maps	○	○	○	○	○
Own Intuition	○	○	○	○	○

7. Question Block: Future of Urban Mobility

* In your opinion, how would the **significance** of the following functions and features change in the future?

	Increase	Same	Decrease
Map within App	○	○	○
Timetable	○	○	○
Touch-Timetable	○	○	○
Animations	○	○	○
Alert notifications	○	○	○
Station information	○	○	○
Connecting options	○	○	○
Realtime traffic information	○	○	○
Alternative route suggestions	○	○	○
Emission details	○	○	○
Take-me-Home function	○	○	○
EasyRide, Check-in-Ticket or similar	○	○	○
Ticket information	○	○	○
Map customization	○	○	○
Layout customization	○	○	○
Zone allocation	○	○	○
Disturbance notifications	○	○	○
Vehicle information (Occupancy, WC, etc.)	○	○	○

If you have any further ideas, approaches or thoughts on the future of mobility, you can write them in the field below.

Personal Declaration of Independence

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

Zurich, September 30th, 2022

Jakob Knöpfel