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Mapping Public Transport Stops in Smartphone Apps: Dynamic Information Visualization in the Context of Hiking

GEO 511 Master's Thesis

Author
Michael Förster
17-707-761

Supervised by
Dr. Tumasch Reichenbacher
Dr. Karsten Pippig (karsten.pippig@swisstopo.ch)

Faculty representative
Prof. Dr. Sara Irina Fabrikant

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Department of Geography, University of Zurich

Abstract

Public transport (PT) offers an efficient and environmentally friendly way of transportation. However, especially for leisure activities only a small fraction of the total distances traveled are accomplished with PT. One way to promote public transport usage is to improve the provision of respective information.

Smartphones have revolutionized information access, allowing users to access context-specific data anytime and anywhere. Currently, diverse PT apps are available, often focusing on temporal information, particularly in urban areas. Few cater to outdoor leisure activities, and those that do often provide static transit-related data.

Information needs to be tailored to individual user needs to simplify PT usage for leisure activities. Therefore, improving the visualization of PT stops in maps and their respective information is addressed in this thesis. For specification, the scenario of a hiker who wants to find a fitting PT stop to get home was chosen.

A mixed method approach was applied to analyze the specific context; find possible visualization options by comparing apps; and evaluate the effectiveness of suggested improvements with a qualitative user study.

Results show that current apps do not sufficiently provide dynamic visualization of information for outdoor activities. Information related to the spatio-temporal proximity of PT stops and their connections was found to be particularly effective for the decision-making process. The results suggest that even more additional information could enhance the experience by enabling users to decide according to their personal preferences.

Keywords: *Public Transport, Geographic Relevance, Geovisualization, App Design, Hiking*

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Table of Contents

Figures

Tables

1 Introduction

Public transport (PT) is an efficient and environment-friendly way of mass transportation. To enable sustainable mobility for everyone, the paradigm is to encourage people to switch from private cars to other modes of transport like buses and trains. However, the car is often perceived as a more convenient way of transportation (Steg, 2003). Exact departure times or the way to the next stop do not have to be considered when commuting by car. In Switzerland the most important mobility purpose is leisure. Almost half of all distance traveled (43%) is for leisure activities. However, from the leisure-induced distance of travelers, only 16% relied on PT to do so. This is even more concerning when compared to education and work as transportation reasons. Here PT is used for 24% and 51% of the distances respectively (BFS, 2023). This emphasizes the pressing need for proactive measures to increase the attractiveness of PT, particularly in the context of leisure activities. To make the switch to PT easier, it is important to minimize the burdens for the user. Improving the communication of information is therefore essential to increase the attractiveness and accessibility of PT.

With the advent of smartphones, the way users obtain information has changed considerably. Information can be accessed at any time and any place. Furthermore, information that specifically fits the user’s context is now available. This change in the consumption of information leads to new opportunities and challenges. To satisfy the needs of users, the displayed information must be relevant to them and visualized in an appealing way. Real-time information (RTI) is an integral part of information provision and is also expected by most users in a transit context (Lopez-Carreiro et al., 2020). It can have a positive impact on the waiting time, travel time, transit use, and satisfaction of the user (Brakewood & Watkins, 2018). Adapting information according to the context of users enables them to make decisions effectively and facilitates the usage of PT. For this purpose, not only the temporal but also the spatial component is important. Smartphone applications are perceived as most suitable for providing this kind of spatio-temporal information (Harmony & Gayah, 2017, p. 92).

Currently, many apps with different targeted user groups and designs are available. A lot of them only focus on temporal information like arrival and departure time. Others, which also consider the spatial context and contain extensive map features, are often designed for an urban context. Of course, some apps focus on leisure activities that take place outdoors. However, if transit-related information is present in these apps, it is usually displayed very statically. In most cases, this is demonstrated by the lack of additional information provided after interacting with points of interest (POIs) on the map. However, adapting POIs with contextual information like distance to a stop or arrival and departure time can make the selection of the right stop easier.

Deciding which information is relevant is a complex task that requires careful consideration of the users' needs and the context of use (Reichenbacher et al., 2016, pp. 2620–2621). There is no one-size-fits-all answer to this question, as the best approach will vary depending on the specific situation. The more use cases there are, the harder it is to accommodate everyone's requirements (Bartling et al., 2022, p. 237). Therefore, analyzing the use case as specifically as possible provides the basis for a useful app design. To further optimize the positive impact on the user experience, it is crucial to understand how different visualizations of maps with POIs influence the user's perception, cognitive processes, and decision-making. With my master's thesis, I want to help improve the user experience for information retrieval regarding PT, especially for non-commute trips. More specifically, the focus is set on the scenario of a hiking trip. Tackling the challenge of optimizing the visualization of map apps, can increase the attractiveness of PT for such activities. To accomplish this, the following key questions are addressed:

1. What information contributes to the geographic relevance of PT stops?
2. How can identified information help to improve the visualization of PT stops in map apps?
3. How can an improved visualization of PT stops support users in their planning, decision-making, and sense-making processes?

As a first step, a context analysis will be conducted to precisely identify the needs of the user. For this matter, reviewing the literature for fitting concepts is necessary to describe the user context, identify tasks, and reveal relevance criteria. In the second step, several apps with a transit-related focus will be compared. Through this, an overview of commonly implemented features will be gained. Examples of how to visualize relevant information can be gathered and compared to the design principles of the literature. Finally, a prototype will be designed based on the findings of the context analysis and the app comparison. Different variations are then tested in a qualitative survey. Participants will solve tasks and answer related questions. Through this, it is possible to gain insight into how visualized information on map apps supports users in their planning- and decision-making process.

This thesis introduces a set of methods to improve current mapping apps depending on the chosen scenario. Specifically outdoor-related apps can benefit from the findings of this thesis. Furthermore, the approach suggested in this thesis can also be applied to other scenarios, where a wider group of users can benefit from.

2 Background

This section is divided into three core components. First, it is examined how relevance can be assessed from a geographic perspective. Following that, theories and concepts are introduced to describe activities in time and space. Finally, the last section centers on the visual representation of relevance in mobile maps using elements such as *visual variables* and key design principles.

2.1 Relevant Information from a Geographic Perspective

To help the user in the planning, decision-making, and sense-making processes, it is necessary to decide which information is relevant. Geographic relevance is a key concept that helps to understand how users search for mobile information. Therefore, it will be discussed in the next section. Subsequently, research regarding the needs of users in connection with PT is investigated.

2.1.1 Geographic Relevance as a Concept

Assessing the relevance of information is a difficult task. Consequently, the doctrine has dealt with it extensively. We as humans intuitively know what we consider relevant, without having a clear concept in mind (Reichenbacher, 2007, p. 232). Depending on the discipline, relevance can be defined differently. One important distinction lies between objective and subjective relevance (Reichenbacher, 2007, p. 233). The objective relevance is determined independently from the user by a system. Concerning information seeking, objective relevance is not sufficient, as the context of the user must also be considered. The context can change and is unique to every user. Information related to the user's context is therefore considered subjective.

In the beginning of research about information retrieval, the focus was set on text search. In this early stage, the importance of the context was already recognized (Wilson, 1973). Identifying relevant information requires knowing about the subjective relevance of the user in addition to the objective relevance. Regarding text search, assessing the relevance was particularly difficult. A text contains characteristics and elements that are not explicitly stated or directly mentioned but can be deduced by the reader. Identifying what is relevant requires a deeper understanding of the language and content of the text. Therefore, it is difficult to identify a hierarchy of importance for the user regarding text search (Vakkari & Järvelin, 2005, p. 124). This is different for geography and history since space and time are indexing features that are useful in representing situational relevance (Raper, 2007, p. 837). A situation in a geographical context includes a spatial and temporal component, which requires the concept of geographic relevance (GR). The concept of GR was developed to handle the challenge of communicating geographic information effectively and efficiently (De Sabbata & Reichenbacher, 2012, p. 1496). It can be understood as an extension of already existing concepts of relevance employed in information science. Not only a text search but also the decision to which bus stop to walk differs depending on the context. In this geographical context, the spatial and temporal components can be used for indexing and thus for defining some sort of relevance value. In the end, the relevance of a map object refers to the real-world entity which can therefore be easier understood compared to text search (De Sabbata & Reichenbacher, 2012, p. 1496). However, the information-seeking process using GR is no trivial task either.

Geographic information seeking (GISk) implies that there are geographic information needs (GINs) and geographic information objects (GIOs). A GIN can vary depending on the intentions or tasks of a user and on what the user is focusing on. Subjective relevance is sometimes more and sometimes less important in comparison to objective relevance. The objective relevance is for example important when looking at a tube map to know where to switch trains. The representation does not need to be adapted to fit the GIN of the user. If a user wants to know where a suitable option for eating is, the context and thus the subjective relevance is more important: What are the food preferences and which locations are close for example. In this case, the representation needs to adapt to the specific user preferences and context. Therefore, each user needs their own individual map representation for optimal usefulness. (Raper, 2007, pp. 840–843)

A GIO is a place with potential interest to the user and a defined extent. One example would be a POI. The user needs informational support if prior knowledge is not sufficient to satisfy the GIN. In the context of GISk, mobility information in the form of maps and directions provides this kind of help. By looking at a map, the user can figure out where to go. Giving the right information to accomplish the user's tasks is the major goal of geographic information science. (Raper, 2007, p. 843)

The GISk process is driven by a GIN to acquire and use GIOs, or in other words: Depending on the need of the user, different locations are considered relevant. Both, the GIN and the GIO are required to assess the GR. The GIN determines the extent of the area the user pays attention to. The GIO requires space and has a varying spatio-temporal influence. The GR arises from the intersection of the attention of the user and the influence desired objects have. An example could be the use case of this master thesis: A user on a hiking trip who searches for a PT stop. The attention of the user would be rather spatio-temporally large since there is no other reasonable option to get home. Even if the distance to the PT stop is far, it is relevant as long as there are useful connections available. As a result, the user would consider the influence of a PT stop as small, if it would not offer any connections on the same day. (Raper,

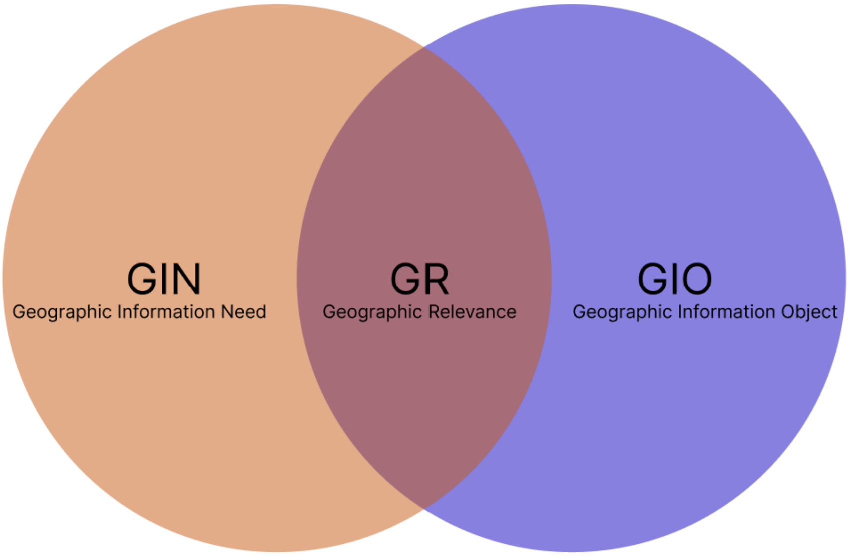

Figure 1: Venn diagram showing the GR as intersection of the GIN and GIO

2007, pp. 845–848)

GR always has an objective and a subjective component, as the GIN depends on what the user's goal is. Consequently, a GIO is not equally relevant to everyone. As mentioned above, it is essential for the definition of relevancy to know the context of the user and the properties of map objects. However, the interaction between the user's attention and the influence of the map objects is abstract and subjective. This makes it difficult to assess the GR. To overcome this, one can look at specific criteria of relevance for information retrieval. De Sabbata & Reichenbacher (2012) investigated a broad range of them and their suitability to assess GR:

Many relevance criteria were already defined in traditional information retrieval (IR) and can be transferred to GR. *Topicality* and *spatio-temporal proximity* are key criteria defined by IR and apply to GR. Nevertheless, users might consider additional criteria to evaluate the relevance of geographic entities. Next to traditional relevance criteria De Sabbata & Reichenbacher (2012) defined five additional criteria, which specifically refer to the geographic environment. Table 1 shows a summary of them. Furthermore, De Sabbata & Reichenbacher (2012) identified three categories of criteria after conducting two experiments with users.

Table 1: List of criteria for GR from De Sabbata & Reichenbacher (2012)

Properties	Geography	Information	Presentation
Topicality	Spatial proximity	Specificity	Accessibility
Appropriateness	Temporal proximity	Availability	Clarity
Coverage	Spatio-temporal proximity	Accuracy	Tangibility
Novelty	Directionality	Currency	Dynamism
	Visibility	Reliability	Presentation quality
	Anchor-point proximity	Verification	
	Hierarchy	Affectiveness	
	Cluster	Curiosity	
	Co-location	Familiarity	
	Association rules	Variety	

The first category includes the so-called *fundamental criteria*. These criteria filter out options that do not fit the user's needs in terms of interest or mobility limitations. Criteria, that belong to this category, are *topicality* and *spatio-temporal proximity*. When the objective is to locate hospitals, theaters may not be pertinent to the user, illustrating the criterion of *topicality*. An instance of the *fundamental criterion* of *spatio-temporal proximity* arises when an entity cannot be accessed within a specified time frame.

The second category including *primary criteria* determines how relevant a feasible option is. These criteria include for example *co-location*, *cluster*, and *hierarchy*. They promise to make a significant difference between multiple options of available locations.

The third category consists of *secondary criteria*. According to the conducted experiment, *presentation quality* and *visibility* are *secondary criteria*. They help to distinguish between two similar entities, but they do not have a major impact on the overall relevance.

2.1.2 User Information Needs in Public Transport

In this section, studies about the information needs of PT users are reviewed, to further investigate which information is relevant.

There are several sources of information available to PT users, including printed timetables, information signs at stops, network maps, websites, or apps. The value of them can vary depending on several factors like frequency of PT usage, the stage of the trip, socioeconomic characteristics, or travel habits (Mulley et al., 2017, pp. 129–130). Overall, several studies found that PT users prefer digital information sources, more specifically mobile apps (Harmony & Gayah, 2017; Macedo et al., 2021; Mulley et al., 2017). They are one of the main information sources that influence the users' levels of satisfaction with the trip (Mulley et al., 2017, p. 129). Positive travel experiences were even found to be often related to smartphone ownership (Jamal & Habib, 2020, p. 8). This can be explained by considering the benefits that such dynamic informational tools offer in contrast to conventional information sources.

While printed timetables and signs at PT stops mostly provide static information, apps can keep the user up to date with real-time data. An app is particularly important to users when planning (Harmony & Gayah, 2017, p. 96), but is also frequently used in the stages of the trip followed afterward (Mulley et al., 2017, p. 120). Users expect to be supported and guided throughout their route (Lopez-Carreiro et al., 2020, p. 8). For apps to fulfill this demand, the integration of various services is demanded. The mobility solutions need to be customizable by the users to fit their individual needs. Such digital interfaces can therefore be understood as a service provided to the user, which is necessary to to make the use of PT as pleasant as possible (MaaS Alliance, 2022). Many mobile applications can integrate multiple services like mapping features, to provide users with a comprehensive view of their travel options. They are accessible at any time and place, making them a convenient option to instantly receive the desired information.

Besides individual customization, multi-mobile mobility, and map features, RTI is a key component of PT apps, which users expect (Lopez-Carreiro et al., 2020, p. 6). Participants in the user study of Fulgêncio et al. (2022, p. 127) considered RTI as a differentiating factor compared to other applications that do not include this information. RTI is implemented in multiple features, which are of importance to public transport users. The survey of MacEdo et al. (2021), focuses on the following features using RTI: vehicle location map, arrival/departure time, seating availability, trip planning, and bike sharing availability. The most important feature for users is RTI about arrival and departure times. Other studies that conducted similar surveys support this finding (Fonzone, 2015, p. 19; Harmony & Gayah, 2017, p. 91). Another important user activity that also requires RTI is the planning of trips in general. Next to trip planning features and arrival/departure times, users also consider information on unplanned service disruptions and emergency information as important. The vehicle location was less important but still popular and only one-third of the respondents considered the seating availability as valuable. The bike-sharing availability was the least preferred information (Harmony & Gayah, 2017, p. 91). Even though information on accessibility features like available ramps or the state of escalators often seems irrelevant to the majority (Harmony & Gayah, 2017, p. 91), they are of great use to disabled people and should not be neglected.

The use of apps and RTI have many positive effects. Users can plan their trips more effectively, considering the most up-to-date information on departure and arrival times, route information, and unplanned disruptions. The most common positive finding in the literature is the saving of time (Brakewood & Watkins, 2018, p. 332). Especially for longer, non-routine trips users tend to consult more information in advance (Berggren et al., 2021, p. 525). By arranging the trip according to RTI, the actual and perceived waiting times can be reduced at first boarding stops as well as transfers (Berggren et al., 2021, p. 524).

RTI has not only a positive impact on perceived and actual waiting time but also leads to psychological advancements. One aspect of this is reduced stress or anxiety. Knowing that the information about the journey is up to date can help users feel more relaxed and less anxious (Bian et al., 2022, p. 87). This affects the perceived reliability of the service and leads to an improved positive impression of PT in general. The reduced uncertainty, that comes with RTI, can also affect the perceived safety (Bian et al., 2022, p. 87; Brakewood & Watkins, 2018, p. 345). Users may feel vulnerable without knowing the actual waiting time at a stop. Access to RTI while waiting enables users to leave a stop that feels unsafe until the vehicle arrives.

With all those positive effects, it stands to reason that the use of RTI also leads to a generally higher level of satisfaction with the overall transit service (Brakewood & Watkins, 2018, p. 343). The enhanced experience of PT, which comes with RTI and app use, was also shown to be related to an increased usage of such services and the attraction of new riders (Brakewood & Watkins, 2018, p. 342). Improving services that provide RTI is therefore a key task to contribute to a more sustainable way of travel.

2.2 Theories & Concepts for Activity Description

The concepts of *Activity Theory and Time Geography* and the *Mobile Usage Context* are introduced in the next sections. These concepts enable a description of the user's activity and context. These concepts provide the basis for optimal visualization of map elements since the current situation of a user influences the relevance of map objects.

2.2.1 Activity Theory and Time Geography

Activity Theory is a theoretical framework and a helpful tool to describe human behavior and actions within the context of social and cultural environments. It focuses on goal-directed actions that individuals carry out (Victor Kaptelinin & Bonnie A. Nardi, 2006). As the spatio-temporal component is of major importance for this thesis, *Time Geography* is also a central concept, because it addresses the interrelationship between time, space, and activity. The central question is how these relationships create constraints or enable possibilities for the activities (Crease, 2012; Hägerstrand, 1970; Miller, 2004). To have an analytical model, that helps to understand the user's goals and motivations, the linkage of *Activity Theory* and *Time Geography* is suggested (Crease & Reichenbacher, 2013, p. 507). A concrete description of an activity using both frameworks follows later in this thesis.

Crease & Reichenbacher (2013) describe *Activity Theory* as follows: A need or a goal-directed towards an object drives an activity. This goal has a hierarchical structure and is divisible into sub-goals. By having this layered structure, different levels of detail can be observed. Understanding the hierarchical structure allows the creation of tools and technology that support users at different levels of the activity. An activity consists of both internal mental processes and external physical processes that need to be considered together (Kofod-Petersen & Cassens, 2006). For example, the activity of hiking consists of a planning phase (mental process) and the actual hike (physical process). Tools can mediate an activity to help users focus on their goals more easily. The tool of a mobile map app supports the user to find a PT stop by displaying related information according to their GR.

Miller (2004) introduces several aspects of *Time Geography*: As already mentioned, it is a conceptual framework that helps to understand the interrelationship between time, space, and activities. The model categorizes an activity into three dimensions: two of them are assigned to space and one to time. Within this framework, the movements of people through time and space can be modeled. However, three major constraints come with such movements:

1. Capability constraints: These limitations arise when an individual does not have access to certain travel modes. For example, the unavailability of a bicycle.
2. Authority constraints: These are restrictions imposed by social or cultural rules, such as the requirement to arrive or depart at specific times.
3. Coupling constraints: These arise due to the need to spend a certain amount of time participating in an activity.

By analyzing the activity and its constraints, it is possible to determine which activities a user can perform within a certain time budget. Performing this activity requires the user to move in space and time. This movement is represented as a space-time path, while the space-time prism encloses the area that can be accessed by an individual. Such a space-time prism can be seen in Figure 2. It represents the potentially reachable path space and results from the individual time budget, the spatial constraints, and the travel velocity. A spatial constraint comes from an activity that has a fixed location that determines the travel destination that is reachable within a given time period (Wu & Miller, 2001, pp. 3–4). For instance, catching a bus is an activity that requires being at the PT stop before the bus departs, and is therefore fixed in time and space. Multiple activities and their constraints can be organized side by side inside the space-time prism. Through this, it is possible to see which activities can be fitted into the spatio-temporal constraints. This helps to find the most fitting options of activities which support the overarching goal of the user.

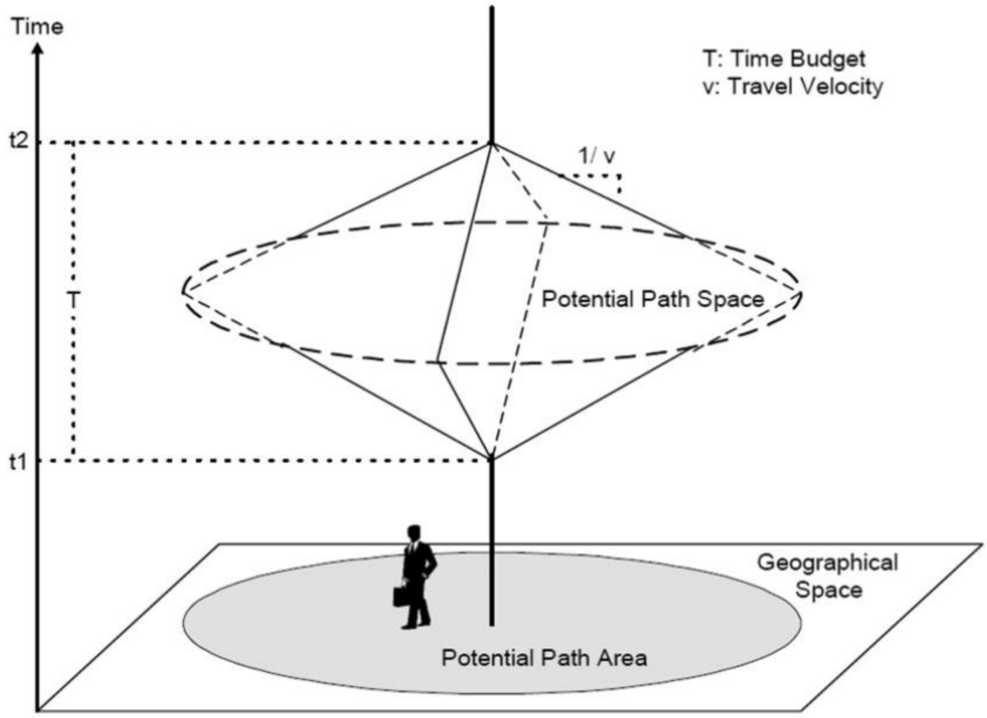

Figure 2: Space-time prism which shows the potential path space an activity can take place by (Wu & Miller, 2001)

2.2.2 Mobile Usage Context

In addition to the description of an activity on different hierarchy levels, the situation in which the user requests information from the app is also important. The mobility of a user leads to different and changing usage contexts (Reichenbacher, 2008, p. 679). A mobile map app has the advantage that the visualization of information is adaptable to fit the users' needs. Two types of adaptation can be distinguished (Bartling et al., 2022, p. 238): If users can adjust a map app by themselves based on their preferences, this is referred to as "adaptable map design". If the map itself without the instruction of the user changes the visualization, it is called "adaptive map design". Both types of adaptation support users with their activities. The concept of the *Mobile Usage Context* helps to identify in what way a visualization needs to be adapted.

Reichenbacher (2008) introduces the concept of the *Mobile Usage Context*. The concept describes four different dimensions. The dimensions are connected to each other and have to be considered together. They are characterized by different contextual factors and constrain the user's activities. The dimensions are the following:

1. *Physical Space*
2. *User Space*
3. *Information Space*
4. *System Space*

The user's position in space and time primarily defines the dimension of *physical space*. The nature of the physical environment and how a user can move inside it further contribute to describing the *physical space*. An example would be the surrounding hiking trails and the user who is traveling on foot. The user is therefore constrained to those paths and the time needed to reach destinations is limited by the walking speed.

The *user space* includes factors related characteristics of the current user. This can be individual preferences, planned activities, or the user's knowledge. Sticking to the example of hiking, some users might have a faster walking speed than others or know about paths that are not on the map. This again might result in different preferences.

The *information space* covers the availability of information concerning a particular user situation. A missing internet connection or not available RTI for specific modes of transport are examples of factors in the *information space*. It is essential to observe which information is available and if it covers the needs of a specific user, as missing information constrains the fulfillment of the respective needs.

The *information space* is also related to *system space*, which includes technological factors such as network bandwidth, capabilities of the mobile device, or size of the display. These factors constrain what can be visualized with the used device.

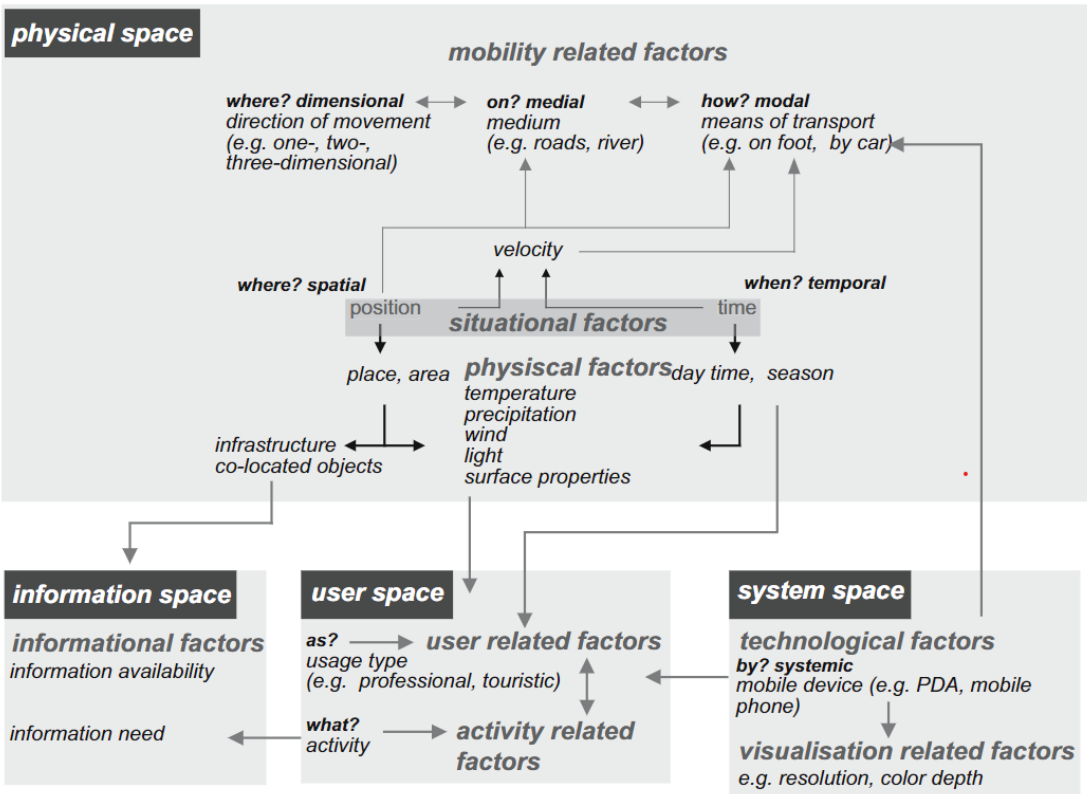

Figure 3: Example of the four dimensions of the Mobile Usage Context by (Reichenbacher, 2008)

2.3 Visualization of Relevance in Mobile Maps

Suitable visualizations allow users to effectively process geographic information. Therefore, the attention of users must be guided according to the relevant information and context. The contextual relevance a user would assign to map objects should consequently coincide with the display of those objects. This enables the user to quickly locate and decode relevant information. Designing useful cartographic applications requires an analysis of the capability of *visual variables* to communicate relevance. The following section deals with this. Furthermore, general context and map-related principles of displaying relevant information are reviewed.

2.3.1 Visual Variables

Map symbols like POI come in different variations. To describe those perceived differences in map symbols the term *visual variable* is commonly used. They were proposed by Bertin (1983). *Visual variables* are essential for designing a geovisualization, which can guide the attention of users to relevant objects. In this section, literature regarding *visual variables* is evaluated. Table 2 provides an overview of all the *visual variables*, their descriptive characteristics, and suitability to communicate relevance.

Table 2: Visual variables and their characteristics

Visual Variable	**Suitability to Communicate Relevance between POIs**	**Descriptive Characteristic**
Location	Not suitable	*no attribute information*
Texture		Qualitative
Orientation		
Shape		
Color Hue		
*Motion**	Unclear	Quantitative
Color Value/Saturation	Suitable	
*Transparency**	Very suitable	
Size		

**No original variable of Bertin (1983)*

Bertin (1983) suggested describing the *visual variables* according to four perceptual characteristics. In this thesis, a similar but slightly simpler description used from Slocum et al. (2022, pp. 67–70) is applied: *Visual variables* can be used for qualitative or quantitative phenomena. A *visual variable* is suitable for qualitative phenomena if it reflects a nominal level of measurement. Therefore, it is possible to categorize POIs into different categories using *visual variables*. A *visual variable* is suitable for quantitative phenomena if it reflects an ordinal or numerical level of measurement. With *visual variables*, POIs can be distinguished and ordered inside a group. In addition to ordering POIs, some *visual variables* enable a user to even quantify the difference between POIs.

The work of Bertin (1983) did not include any empirical research that verifies the assignment of the previously mentioned characteristics to the *visual variables*. Therefore, additional literature is used to verify the descriptive characteristics of different *visual variables*. Furthermore, the suitability to communicate the relevance of POIs is addressed. In addition to the originally identified seven *visual variables* by Bertin (1983), *motion* and *transparency* are added to the list since they are prominently mentioned in the literature and potentially interesting to visualize relevant information. (Cláudio et al., 2011; Oliveri & Reichenbacher, 2021; Roth, 2017; Slocum et al., 2022; Wolfe & Horowitz, 2004)

2.3.1.1 Location

Location is the position of a map object on the map relative to a coordinate frame. In cartography, it represents the spatial component of information and usually no other attribute information (Roth, 2017, pp. 2–3). It can be considered an indispensable *visual variable* to display any kind of geographic information. However, this *visual variable* is not further discussed in this thesis since other *visual variables* are needed to describe further attributes of a POI and the *location* is inevitably set through the position of the POI on the map.

2.3.1.2 Texture

Texture, which is one of the originally proposed *visual variables* of Bertin (1983), was often used to distinguish surfaces in choropleth maps (Roth, 2017, p. 4). It is visualized by changes in distance between marks, which make up the map symbol. POIs however are small map symbols. Therefore, *texture* is an inappropriate *visual variable* to communicate their relevance. This might also explain why it was not included in further reviewed literature.

2.3.1.3 Orientation

Orientation can be explained as the degree of rotation compared to the normal orientation. Slocum et al. (2022, p. 69) argue that this *visual variable* is most appropriate for representing nominal data. This argument is similar to Bertin (1983) who stated that the *Orientation* is associative. In an associative *visual variable*, variations in the visual dimension are perceived with equal weight, enabling the eye to perceive all map symbols with the same variation as a group (Roth, 2017, pp. 5–6). Even though (Wolfe & Horowitz, 2004, pp. 5–6) discovered that *orientation* is a well-suited *visual variable* to guide the users' attention, the effectiveness of communicating relevance is low compared to other *visual variables* (Garlandini & Fabrikant, 2009, p. 209).

2.3.1.4 Shape

S*hape* is the external form, which can be for example the outline of a map object. This *visual variable* is essential to display qualitative point symbols (Roth, 2017, p. 3). It is best suited for nominal data (Slocum et al., 2022, p. 69), which helps the user to decide between different groups of POIs. In the field of neuroscience and psychology, *shape* is considered to guide the users' attention (Wolfe & Horowitz, 2004, pp. 5–6). Special is the case where *shape* was investigated as a *visual variable* with a quantitative effect. An assignment of relevance was made possible by different *shape* variations (Cláudio et al., 2011, p. 6). For example, a star was displayed with a frame line of varying thickness. This variation of the same *shape* was an effective *visual variable* to communicate relevance. However different forms of outlines of a POI do not communicate relevance well.

2.3.1.5 Color Hue

The dominant wavelength of a map symbol is a description of *color hue*. In the literature, it is primarily known as a qualitative *visual variable* (Bertin, 1983; Roth, 2017; Slocum et al., 2022). Using *color hue* for relevance assessment between one group of POIs is therefore not recommended. However, it is possible to use hue with i.e., traffic light colors to distinguish relevancies. This was also tested regarding efficiency and effectiveness (Cláudio et al., 2011; Oliveri & Reichenbacher, 2021). Compared to many other *visual variables color hue* performed worse in most cases. The differences between *color hue* and other color-related *visual variables* like *color saturation* or *value* were not that strong in all reviewed studies (Cláudio et al., 2011, p. 14; Garlandini & Fabrikant, 2009, p. 209; Oliveri & Reichenbacher, 2021, p. 2).

2.3.1.6 Motion

Motion is a *visual variable* with great potential since movements of the real world can be represented on a map (Slocum et al., 2022, p. 449). It is clear, that attention is quickly drawn towards a moving feature (Wolfe & Horowitz, 2004, pp. 5–6). However, POIs mostly represent static locations like restaurants, museums, or transit stops. A blinking map symbol is one variation of *motion*, which can be applied to such static POIs. Compared to other *visual variables* participants performed worst in classifying the relevance of locations with differently fast blinking objects (Cláudio et al., 2011, p. 13). Therefore, *motion* can be considered as an efficient but not effective *visual variable* to display relevance, especially not for static objects.

2.3.1.7 Color Value/Saturation

Both *visual variables* can be used for quantitative phenomena and are components of color (Bertin, 1983; Roth, 2017; Slocum et al., 2022). *Color value* refers to how dark or light an object with the same *color hue* is, whereas *color saturation* can be described as the amount of grey mixed into a *color hue*. For simplicity's sake, both *visual variables* are listed together. *Color value/saturation* is considered likely to guide users' attention in a psychological and neuroscience context (Wolfe & Horowitz, 2004, pp. 5–6). Several studies confirmed that these *visual variables* are detected fast and are also capable of communicating relevance (Cláudio et al., 2011, p. 14; Garlandini & Fabrikant, 2009, p. 209). However, the *visual variables transparency* and *size* performed even better according to the reviewed literature (Oliveri & Reichenbacher, 2021, p. 2).

2.3.1.8 Transparency

Transparency refers to how clear the background is visible through the map object. Only Oliveri and Reichenbacher (2021) investigated this *visual variable* in a user study. Displaying relevancy worked best with *transparency* compared to *color hue* and *color value*. It was detected faster and ordered correctly by relevance most often by participants who searched for a specific POI on a mobile map. Therefore, *transparency* seems to be an efficient and effective *visual variable* for visualizing differences inside one group of POIs.

2.3.1.9 Size

The larger the *size* of a map symbol, the more space it occupies. Bertin (1983) listed it at the top of his list since it is the only *visual variable* where differences cannot only be ordered but also quantified. *Size* draws the attention of a user (Wolfe & Horowitz, 2004, pp. 5–6). It was also found to outperform all other *visual variables* in effectiveness, although it needs to be considered that none of the studies was carried out with mobile devices (Cláudio et al., 2011, p. 14; Garlandini & Fabrikant, 2009, p. 209). Participants from these studies favor the *visual variable size* and most often assigned it to the correct relevance.

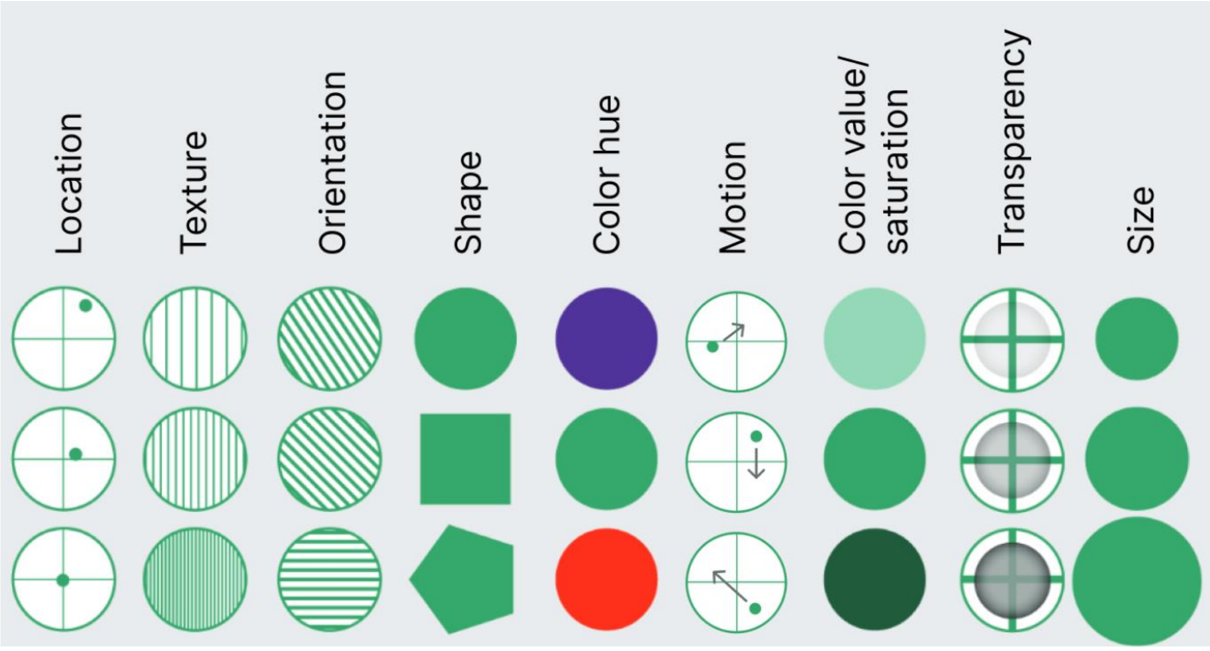

Figure 4: Visualization of the visual variables as done in Roth (2017)

2.3.2 Visualization of Relevance in Mobile Maps

Representations extend the cognitions of users by using a set of symbols. *Visual variables* can be applied to optimally guide the user's attention to the most relevant features. The central objective is to understand the relationship between the cognition of users and the representations on the map. The effectiveness and efficiency of reading a map are influenced by the visualization. Different representations of the same information influence the computational offloading. The user's computational offload is high if many cognitive tasks can be transferred onto the representation. By using familiar structures, reading a map is facilitated. However, if the representation is poorly designed, it can lead to misinterpretation. Therefore, relevant information needs to be translated into suitable representations that fit the cognition of users. The map design should let users easily locate and decode relevant information. (Crease & Reichenbacher, 2011, pp. 3–4)

Swienty et al. (2008) propose a framework for attention-guiding geovisualization. A key task is to reduce the complexity without omitting essential reference information. In addition, the users' attention should be guided to relevant features. The three design principles to accomplish those tasks are:

1. *Simplicity*
2. *Visual Hierarchy*
3. *Conciseness*

2.3.3 Simplicity

Simplicity in cartographic design refers to reducing visual complexity. Finding relevant information on maps requires filtering out less important information. Users have limited resources of attention and select information based on global and local processing modes. The global processing is about getting an overview. The local processing is the attention on specific relevant features like POIs. Maps quickly appear cluttered due to too many POIs displayed (Kamilakis et al., 2016, p. 9). Such visual clutter on maps must be minimized to enhance readability. This is particularly important on small screens, where background information can be occluded by POIs in the foreground (Setlur et al., 2010, pp. 1–2). Apart from too many map elements, the displayed phenomenon itself or the number of different types of elements can also add to the complexity (Crease & Reichenbacher, 2011, p. 6). Therefore, it is crucial to find the right balance between providing enough information and avoiding computational overload. (Swienty et al., 2008, pp. 231–233)

This is possible through filtering and generalization techniques (Kamilakis et al., 2016, p. 9). Irrelevant features should be filtered out and important ones displayed more prominently compared to other map objects (Crease & Reichenbacher, 2011, p. 7). Map objects can be generalized through simplification or aggregation, but also by grouping very specific categories and classes to reduce the semantic complexity (Crease & Reichenbacher, 2011, p. 7). Another way to reduce the visual complexity of maps is to provide optional layers (Setlur et al., 2010, p. 1). Like this, the user has some control over the amount of information displayed.

2.3.4 Visual Hierarchy

Visual hierarchy involves organizing and structuring information into layers that support the visual scanning process. In most cases, there are two visual layers. The background and the foreground. This design principle is based on the center-surround mechanism, where the user processes the background in a more global mode and relevant information in the foreground in a local mode. The background should provide the context and give an overview of a larger territory. It can act as an external form of memory. The user does not need to memorize the provided information, since the map already displays it (Crease & Reichenbacher, 2011, p. 4). The foreground includes the most relevant information and attracts the attention of the user. (Swienty et al., 2008, pp. 231–233)

The background should not act as a visual distractor and should be encoded in the least salient way. Simultaneously it is necessary to avoid the loss of too much global information. Sufficient and detailed background information is required for users to orient themselves on the map. The lack of descriptions like street names can make the orientation harder (Bartling et al., 2021, pp. 17–18). To support the users' visual search further, the contrast should not be too low between the foreground and background, since this can increase the search time (Setlur et al., 2010, p. 1).

2.3.5 Conciseness

The design principle of *conciseness* translates to displaying important information in a salient way. *Visual variables* and other attributes help to guide attention to objects in an easy way needing few processing resources of users. A user should be able to order objects like POIs according to their relevance. A classic design for a POI is a point-shaped symbol, which is displayed in the foreground (Yu et al., 2013, p. 174). It is necessary to consider different characteristics of map symbols to display relevant information saliently. (Swienty et al., 2008, pp. 231–233)

Apart from the already introduced *visual variables*, labels and semantics can support the highlighting of relevant information (Yu et al., 2013, pp. 173–174): Even though a symbol might attract attention, the user still needs to understand what information is displayed. Familiar design and commonly known semantics are therefore crucial to implement. Labels also help to explain the symbol and give the necessary context to the user.

3 Methods

The goal of this thesis is to determine how the information supply of apps for PT users in a hiking context can be enhanced. Three research questions were previously set up for that matter. To examine them, multiple approaches were chosen which are explained in this section.

The first approach helps to investigate what information contributes to the geographic relevance of PT stops. Therefore, the gathered information from section 2 needs to be applied to the scenario of hiking using a context analysis.

How this information can contribute to improving the visualization of PT-related POIs, is another question, which is investigated. By comparing multiple apps, which are widely used in the context of PT and hiking, it is possible to draw conclusions about the usefulness of different display methods.

Finally, it needs to be examined how an improved visualization of such POIs supports the users in their hiking activity. For that matter, different versions of a prototype were designed and tested with a survey. Participants need to solve simple tasks and answer questions, which gives insight into their planning, decision-making, and sense-making processes.

3.1 Context Analysis

Defining and analyzing the specific context of the user on a hiking trip is a necessary task to determine what is relevant to the user. Concepts introduced in section 2 were applied to analyze the context of the user.

As a first step, the scenario in which the user is situated was defined and described. Using the concept of *Activity Theory*, the overall activity was divided into sub-goals. Each sub-goal led to different constraints which were identified by modeling the activity using the concept of *Time Geography*.

Information is needed by the user to achieve such a sub-goal. The context influences which information is relevant. Therefore, the specific context was described using the concept of the *Mobile Usage Context*. The four dimensions of the *Mobile Usage Context* allowed insight into the user's situation. Knowing how the situation of the user appears, enables an adaption of the provided information according to the user's needs.

As a consequence, specific relevance criteria were identified which fit to the user's context. These were assigned to specific steps, which must be followed by the user to accomplish the sub-goal.

3.2 App Comparison

An overview of the commonly used features in this field can be obtained by comparing mobile mapping apps. The choice of apps is crucial in this regard. Furthermore, the criteria must be carefully selected to attain insightful results.

3.2.1 Selection of Apps

Many different apps have features related to the mentioned use case of hiking. The map feature is specifically important to solve the task of finding a PT stop. The way map features are implemented in apps can differ depending on the purpose and targeted user group. For some apps, the map feature is a fundamental part of the functionality and others also focus on different aspects. Therefore, not only apps that are commonly used for hiking are considered, but also transit-oriented and multi-use apps. Like this, a large variety of different implementations can be observed. However, to ensure that map visualizations and the respective functions are still comparable the choice of apps must be made carefully. Most importantly, all apps need to include some display of PT stops in the form of POIs on these map features. Furthermore, all apps must be suitable for use in Switzerland. This means that transit apps with maps of specific foreign cities or foreign regions will not be considered. The chosen apps are listed in Table 3.

Table 3: Selected apps for comparison

Selected App	**Intended Use**
Swisstopo	Outdoor activities
Outdooractive	
SBB Mobile	Transit usage
Citymapper	
Google Maps	Multi-use mapping app

All apps were compared using an Android operating system with the latest version available in September 2023. Detailed information regarding the compared apps is listed in the Appendix. *Swisstopo* and *Outdooractive* are both popular apps used for hiking, which both include POIs of PT stops as a layer on the background map. *Swisstopo* is very popular in Switzerland. The map material used in the app is commonly known since it is used by Swiss federal agencies. *Outdooractive* is probably less known in Switzerland but offers also map material for other countries apart from Switzerland and is therefore more popular overall. *SBB Mobile* and *Citymapper* focus on PT users and not on outdoor activities. While *SBB Mobile* is the official app provided by the national train agency (SBB) to check connections, *Citymapper* focuses more on map features and is more popular in the United Kingdom. *Google Maps* serves multiple purposes like navigation, local search, and real-time traffic updates. Additionally, it offers users the ability to explore various points of interest, enhancing its utility in diverse contexts.

3.2.2 Definition of Criteria

For the comparison, several criteria were defined. In total the following three aspects were compared:

1. App Features
2. *Visual Attributes* of PT-related POIs
3. Additional Information on PT stops

The first aspect is the different kinds of features, which are implemented in the compared apps. These were selected based on their ability to help the user find the fitting PT stop in the context of a hiking trip. To enable a comparison of such features, they were summarized into categories. These categories can also be related to the chosen relevance criteria and the design objectives defined in sections 2.1.1 and 2.3.2 respectively. For example, by filtering POIs according to specific groups, the relevance criterion of *topicality* is addressed. Similarly, providing a clear distinction between the back- and foreground corresponds to the design objective of *visual hierarchy*. Such a cross-section of apps provides insight into which features are commonly used. By relating these features to relevance criteria, it can be observed how the provision of features changes depending on the user group. Furthermore, it can be observed, which design principles are followed.

The second criterion of PT-related POIs is central to the objective of this master's thesis. Therefore, the *visual variables* used to display them are another aspect that was compared. From the already discussed literature, it is known how *visual variables* can guide attention. Depending on the visualization of POIs, the user's workload to process the displayed information can vary. An optimal representation of POIs can therefore enable a faster and more accurate decision-making process of the user. Different apps were compared in terms of which *visual variables* and other additional ways they use for displaying POIs. Therefore, all options to visualize POIs are described using the term *visual attributes*. *Visual attributes* enable the guidance of the user's attention. These *visual attributes* were chosen based on the *visual variables* described in section 2.3.1 and additional visualization options found in the comparison itself.

The last criterion of the comparison covers the information, which is related to the POIs but not directly displayed on the map. Additional information can be accessed by selecting a POI. Different kinds of additional information were found in the compared apps and grouped into categories. Similarly to the comparison of features, the relevant information displayed in the apps also relates to the identified relevance criteria previously identified in section 2.1.1. In contrast to the compared features, the additional information offers a deeper insight into how relevance is communicated to users. The additional information provides the specific information for the user to decide, which PT stop is most suitable to cover their needs. Therefore, the comparison of this additionally displayed information shows possibilities on how to translate relevant information into helpful visualizations.

3.3 Prototype Design and Evaluation

With a focus group survey, it is possible to gain an in-depth understanding of user preferences and how they come to this opinion. Participants who already use apps for hiking and PT can give detailed feedback about the relevancy of features and the reason for this. They can also explain how they come to this assessment. Therefore, it is necessary to design a prototype that can be used to test different variations of a potential map app. The implemented variations are based on the results of the context analysis and the comparison of the five chosen transit apps. The design of the prototype and its variations are based on the findings of the context analysis and the app comparison from sections 4.1 and 4.2 respectively.

3.3.1 Implementation of the Prototype

The prototype was implemented by utilizing the tool *Figma*[1]. This tool is suited to precisely define visual elements, layouts, and simple interactions. Different screens or windows can not only be designed but also linked together. However, the tool does not provide the option to use real-time or even timetable data in a standardized way. This means that no georeferenced map with POIs, that have coordinates or other linked information is displayed. Standardized transitions and animations are created in the prototype tool of *Figma*. Such transitions follow pre-defined paths between pages and windows. Interacting with the prototype therefore feels realistic compared to existing map apps.

3.3.1.1 General Design

The prototype design is based on a mix of different already existing map apps. It consists of multiple layers. The most obvious one is the underlying background map. Using *QGIS*[2], multiple map sections of different areas in Switzerland were created and saved as PNG files. The map of Swisstopo was chosen as the standard background, because of its popularity in Switzerland especially in a hiking context. The frame of the prototype was put on top of the aforementioned map image and clipped so that only the screen itself was visible. Since the

[1] *Figma* is a platform with the capability of creating designs for websites, apps, and other interfaces: https://www.figma.com
[2] *QGIS* is a geographic information system to create, edit, and visualize geospatial information: https://www.qgis.org

map extent is greater than the prototype's screen, navigating inside the map frame is possible by changing the location of the underlying map image.

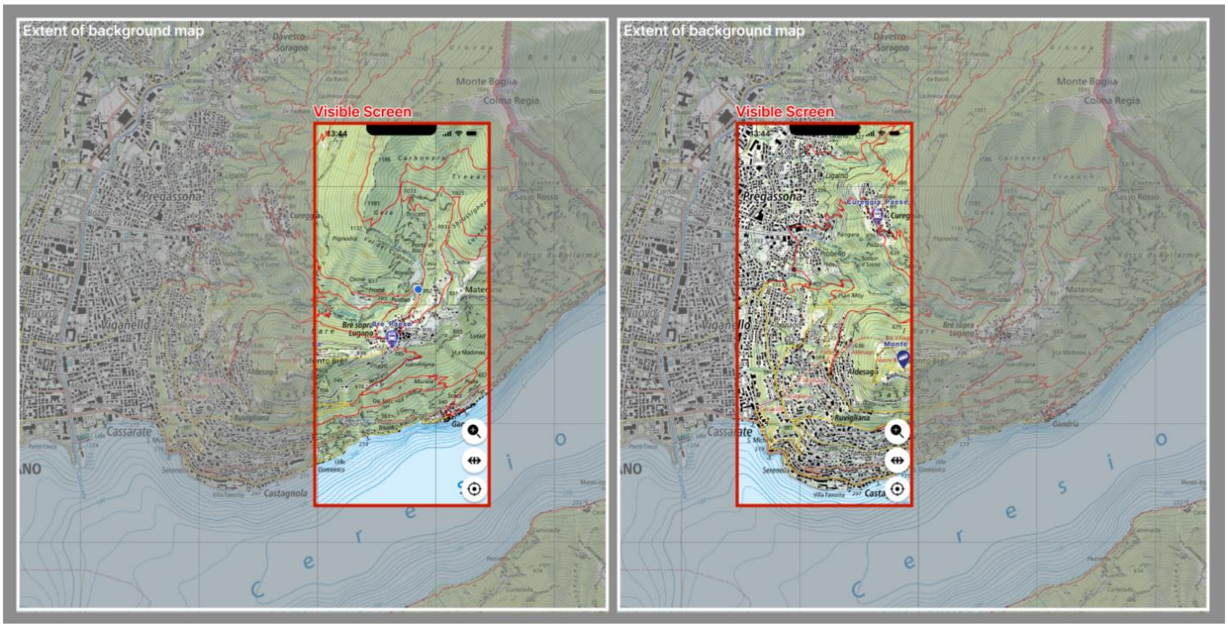

Figure 5: Visualization of the underlying background map and the actually visible screen

Displayed on top of the background map is the hiking network of Switzerland, the POIs, and the current location marker. The hiking network shows the different paths and their difficulty which depends on the color. The POIs are shown in a dark blue. This color corresponds to the official colors of SBB and is therefore well recognized by Swiss users. Therefore, Swiss users should recognize the POIs well. White pictograms within the dark blue square indicate the different modes of transport available at the PT stop. The location marker is set in a lighter blue which is very common in other map apps compared in this thesis.

Furthermore, there are user interface elements that are in a fixed position. There is the status bar at the stop which shows the time and other simulated cell phone information. At the bottom right corner of the screen are three buttons, whose design is derived from the *Swisstopo* app.

There are two types of additional overlay windows available which include further information on the POIs. The first one displays specific information about a single POI including the name of the stop, departure time, line information, and the transport mode. Below the departures, a height profile of the path from the user's location to the POI is shown. This includes distance and travel time information. Additionally, the path including travel time is also shown as an overlay on the background map. The second window summarizes basic information about all in a certain area available POIs. Therefore, all PT stops are shown in separate boxes including their name and the departure information. Waiting time for the next connection is used as a criterion to sort the PT stops, showing the transit stop with the shortest waiting time on top.

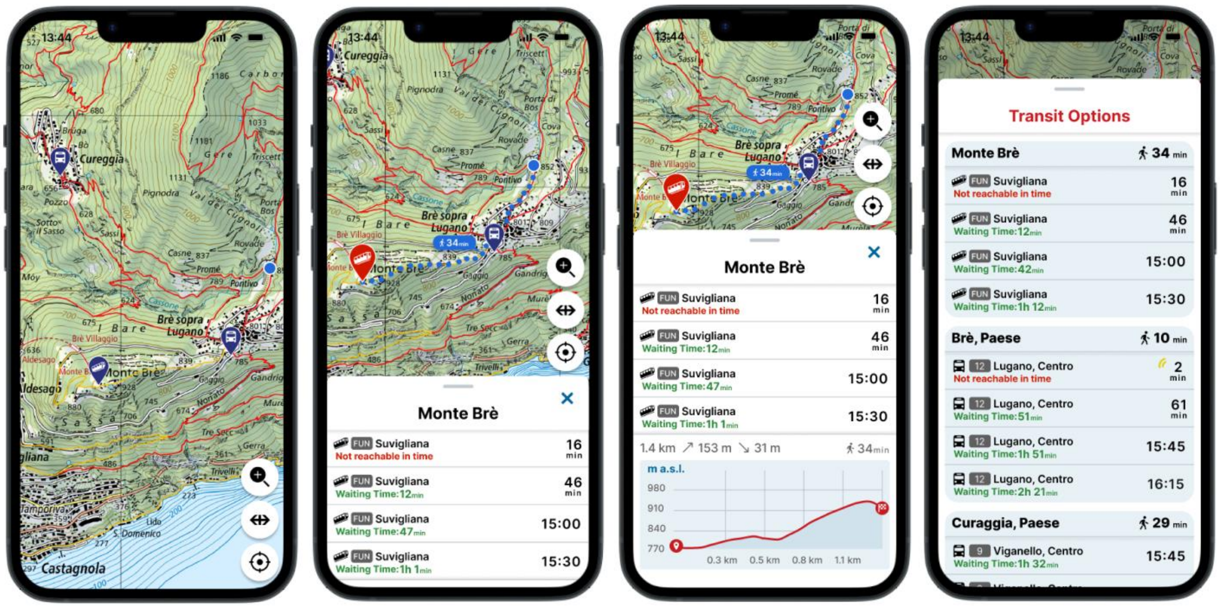

Figure 6: One version of the prototype showing the different possible variations of windows and map information

3.3.1.2 Functions and Features

As already mentioned, it is possible to navigate inside and between the different windows. On the default screen, the map is navigated with drag gestures like it is possible in other map apps. Zooming is possible with the fixed button in the lower right corner of the screen. There are two different zoom levels available. By zooming in, the background map including the hiking paths and place names gets bigger, whereas the elements on top always have the same size. This includes the POIs, location icons, and path information. With a second button, the user can center their location on the screen which can be helpful after exploring the map. The third button with the SBB logo opens a sliding window containing an overview of all available transit stops nearby. For each transit stop, a maximum of four departures is listed. This feature enables the user to see all nearby options at once. By tapping on a box inside this overview window, more specific information regarding the chosen transit stop is shown. A window slides up including more departures and a height profile. On the background map, the path from the user's location to the POI is displayed. The window can be dragged to be smaller or bigger and thereby cover different amounts of the background map. Like this, the amount of information visible inside the sliding window is changed. Another way to open this sliding window is to tap on a POI on the map directly.

3.3.1.3 Variations

In total, nine different variations of the prototype were created and tested afterward. These nine variations can be divided into groups of three. Between each of these groups, one element differs. Within the group, one specific element is differently visualized. The three following groups with the respective changes were implemented:

1. Different kinds of visualizations of the POIs
2. Different kinds of additional information included inside the sliding window of the POIs
3. Different types of background maps

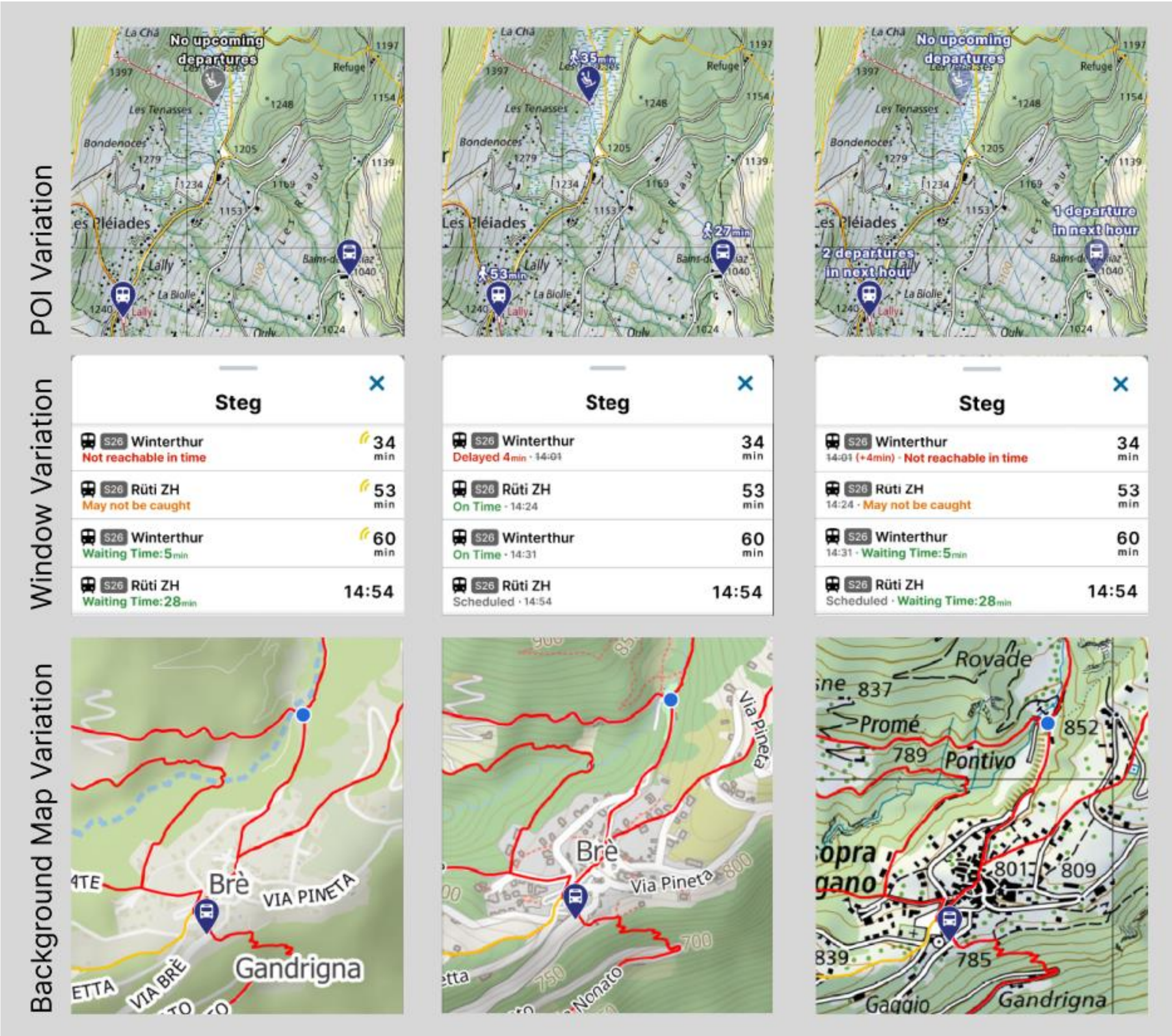

Figure 7: Overview of the implemented variations of each group

Each group addresses the same key task, but different locations are used for each of them. Only the mentioned variations make the difference inside a group. All other identical elements. A detailed description of variations is presented in Table 4.

Table 4: Description of the different variations

Group Nr.	**Location**	**Variation 1**	**Variation 2**	**Variation 3**
1	Les Pléiades	POIs with no departures are set in grey instead of blue color including a text above with the information that there are no upcoming departures.	POIs are displayed with a text of the required walking time from the user's location to the POI including a pictogram.	POIs have different *transparency* levels according to the departures in the next hour which is additionally indicated with a text above them.
2	Hörnli	The list of departures includes the waiting time a user would spend at the PT stop. It is also displayed if a connection is not reachable or may not be caught in time.	The list of departures includes the exact departure time. Additionally, it is shown if the connection is scheduled, on time, or delayed.	With this variant, a combination of the first two variants is displayed. The departures are shown with the waiting time and the information if the departure is scheduled or on time.
3	Monte Brè	The background is very simple with almost no elements displayed. No altitude lines are shown and the settlements and houses look very soft. The paths are also reduced to a minimum .	The classic Open Street Map (OSM) background contains some more elements like altitude lines and more paths. The single houses are displayed more saliently but overall, it still looks rather simple.	The third background map is from the Swiss Federal Agency of Topography (Swisstopo*)*. It contains the most map elements and therefore the highest level of detail. This includes for example camping sites, canton borders, or hospitals.

3.3.2 Survey Design

A user survey was conducted with the aforementioned prototype. The goal of this survey was to understand how specific variations in the visualization of PT-related POIs and other contextual information can improve supporting users in making informed decisions during their hiking journeys.

3.3.2.1 General Design

A focus group approach was adopted for this user study. Like this, an in-depth qualitative insight from a small but diverse group of participants was gained. Participants engaged with the prototype in a focused and interactive setting. As part of the survey, they were asked to solve tasks by interacting with the different versions of a prototype and answer questions regarding those. To obtain qualitative feedback, many of the questions were designed as open questions. The focus is therefore not lying on a quantitative statistical evaluation. The aim was rather to gain insight into how the participants came to their decision.

The study is divided into three main blocks with two additional demographic questions at the end. The first block of the survey focuses on gaining general information about the participants' hiking behaviors. These questions cover their experience with hiking in general and their usage of PT. Additionally, their knowledge and familiarity with different apps were asked.

The second block is designed to evaluate the differences between the prototype variations and explore how each version contributes to supporting the decision-making process. The focus lies on solving tasks utilizing the prototype. The task is about choosing the transit stop the participant would go to after the hiking trip. This task was repeated for different scenarios and variations of the prototype and questions were answered afterwards.

In the final block of the survey, the participants answered questions about their overall experience with the prototype. These closing questions allow the participants to provide further feedback on the importance of the displayed information and the prototype's general design elements.

3.3.2.2 Participant Requirements

To ensure the informative value of the qualitative feedback, participants should meet specific criteria. One requirement was that they have experience with both hiking and utilizing PT in Switzerland. Participants needed to be not only familiar with the activity itself but also with technical aids for this purpose. Having used hiking and transit apps before enables participants to compare their previous experience with the prototype variations of this user study. Additionally, the operation of the prototype should be easier because of its similarities with other apps and therefore result in more detailed feedback. To be able to participate in the survey, the participants had to accept the privacy policy. By agreeing, the participants were granted permission for the collection, comparison, and analysis of their responses and interactions with the prototype. A basic understanding of English or German was also required since the questions and prototype information were written in English. The participants were however allowed to answer in German and the study coordinator translated questions or information to German if necessary.

3.3.2.3 Questions

There were different types of questions included in the survey. The first block started by asking about the participant number, which made it possible to connect the recording of the prototype interaction with the survey answers. This was followed by three single-choice questions which are related to hiking including the frequency, usage of apps, and PT. The next questions cover whether the participants know and use some of the in this thesis compared apps. They were also asked to describe for which task they use these apps. They could also mention additional apps and the purpose they are used for. By knowing their hiking behaviors and for which tasks exactly the participants use apps, answers to the main question block could be set into context later. Additionally, it can be ensured that the participants meet the previously mentioned requirements.

The second block contained the main part of the survey questions. Participants used different variants of the prototype and answered questions regarding the different variations. As a first step a demo version of the prototype was presented so that participants could get familiar with its functionality by exploring it. Afterward, participants started with the main part of the survey. The basic task was always the same and repeated three times for each prototype variation group. The participants were informed about the assumption, that they wanted to end their hike and they could reach their desired location with any of the displayed transit stops and with any of the available connections at the transit stops, despite going in different directions. Therefore, the task was to choose the transit stop they would go to from the current location displayed on the screen. There were always three possible transit stops with different connections available to choose from. Each of the three tasks was set in a different location and there were three different variants to interact with for each of these tasks. In total, there were therefore nine different prototype variants the participants interacted with.

The participants were shown the three variants per prototype group as listed in Table 4. While interacting with the prototype variants, the questionnaire was filled out. The structure was the same for each of the three tasks. In the beginning, people answered which PT stop they would go to in the given scenario. The next questions cover the preferences regarding the three variants they used to solve the task. For each task, the focus was set on another variation. The first task focused on the variation of the POIs, the second on the additional connection information in the sliding window, and the third on the background map. Participants ranked the variants according to their helpfulness in solving the tasks and explained what was more or less helpful when comparing the three different variants. They were explicitly asked to only focus on the differences between the variants and not the overall prototype. If something was unclear it was always possible to mention this at the last question of each task.

The last question block covered their experience with the prototype variants overall. Participants answered how useful different kinds of information were, which were displayed in the nine prototype variants in total. Afterward, there was the option to mention specific features that stood out positively and also if other features or information would help to solve the task. Finally, they could mention if there was something else that they could not say before and were asked demographic questions about gender and age.

3.3.2.4 Data Collection

The collection of data was conducted using the *Lime Survey* tool which is provided by the University of Zurich. The time to complete the survey was estimated to take approximately 45 minutes and varied from participant to participant. In total, 26 questions were included in the survey. A controlled environment was established for the survey to minimize potential distractions and avoid interruptions from external factors. Participants were recruited selectively to ensure diversity and the fulfillment of the previously defined criteria. Care was taken to ensure that participants came from different social backgrounds, genders, and age groups. Setting up the prototype required the study organizer to be in the room during the survey. The role of the organizer was however focused on technical assistance and clarifying potential misunderstandings. Conversations were limited to those aspects to prevent influencing the participants in their decision and sense-making process. The collected data was restricted to the participants' answers and screen recordings of the prototype screen. These were matched with the assigned participant number so that the participants remained anonymous. The screen was recorded with *OBS Studio*[3]. The participants had to read, understand, and accept the privacy policy to start the survey. Interrupting and quitting the survey was possible at any moment and participation could be withdrawn at any time.

Participants were guided through the survey. Two laptops were used. On one they filled out the survey and on the other, they interacted with the prototype. The survey questions included open as well as closed questions, providing some quantitative but mainly qualitative data. The participants could navigate back and forth in the survey and between any prototype variants at any time. They had to answer certain questions to proceed to the next section to ensure that no questions were overlooked and that each completed survey could be fully analyzed. The purpose of this design was not to evaluate trends of decisions but rather to understand how the decision was made. To explain what was more or less helpful to solve the task, it is required to know which transit stop participants picked and which variant was most useful to make this decision. Similarly, participants who hike a lot might have different preferences than participants who just hike occasionally. Therefore, the hiking, transit, and app usage behavior needed to be known to better understand participant's preferences. The closed questions serve therefore not mainly as quantitative feedback but rather as necessary preparation for the qualitative open questions.

[3] *OBS Studio* is a software for live streaming and recording video content from a computer: https://obsproject.com/

4 Results

In the following sections, the results are presented. They are structured according to the methods used in this thesis. Section 4.1 shows the results from the context analysis of the chosen use case. The results of section 4.2 cover the app comparison and the last section 4.3 displays the results of the user survey about the implemented prototype.

4.1 Context Analysis

The context analysis can be divided into multiple steps. The analysis of the activity and the resulting spatio-temporal constraints are covered in section 4.1.1, the description of the *Mobile Usage Context* in section 4.1.2, and the definition of relevant criteria in section 4.1.3. In a final step, these relevance criteria are assigned to single steps a user needs to fulfill to accomplish the goal of finding a fitting PT stop after a hiking trip in section 4.1.4.

4.1.1 Hierarchy and Spatio-Temporal Constraints

There are different levels on which an activity can be analyzed. The activity itself, the action sequences, which are part of the activity, and finally the sub-actions, which are part of an action sequence. In this thesis, the whole activity would be a hiking trip. This activity consists of three actions. This is visible in Figure 8. The first action is the travel sequence to the hiking location. The second action is the walk from the starting point to the destination of the hiking trip. The last action is the journey home after the hike. In this selected use case, the focus lies on a sub-action of the last action. For the journey home, the hikers need to know which PT stop they need to head to from their current location on the hiking route.

To better understand that sub-action, it is necessary to identify the different constraints. They can be of spatial, temporal, or spatio-temporal nature. So, it may be possible that in a certain area, multiple POIs are available. Therefore, the location of a PT stop to start the trip home is not absolutely fixed. There is also no specific time by which the hikers must be at the PT stop. The starting point on the other hand is spatio-temporally fixed. The user is at the destination of the hiking trip (or at a certain point of the hiking route) at a specific moment in time. Finally, hikers must decide which PT stop to go to. Because the travel time from the location of the hiker to a PT stop is not the only relevant factor, a multicriteria relevance assessment should guide the decision. Analyzing the *Mobile Usage Context* is the first step to identifying such multiple relevance criteria.

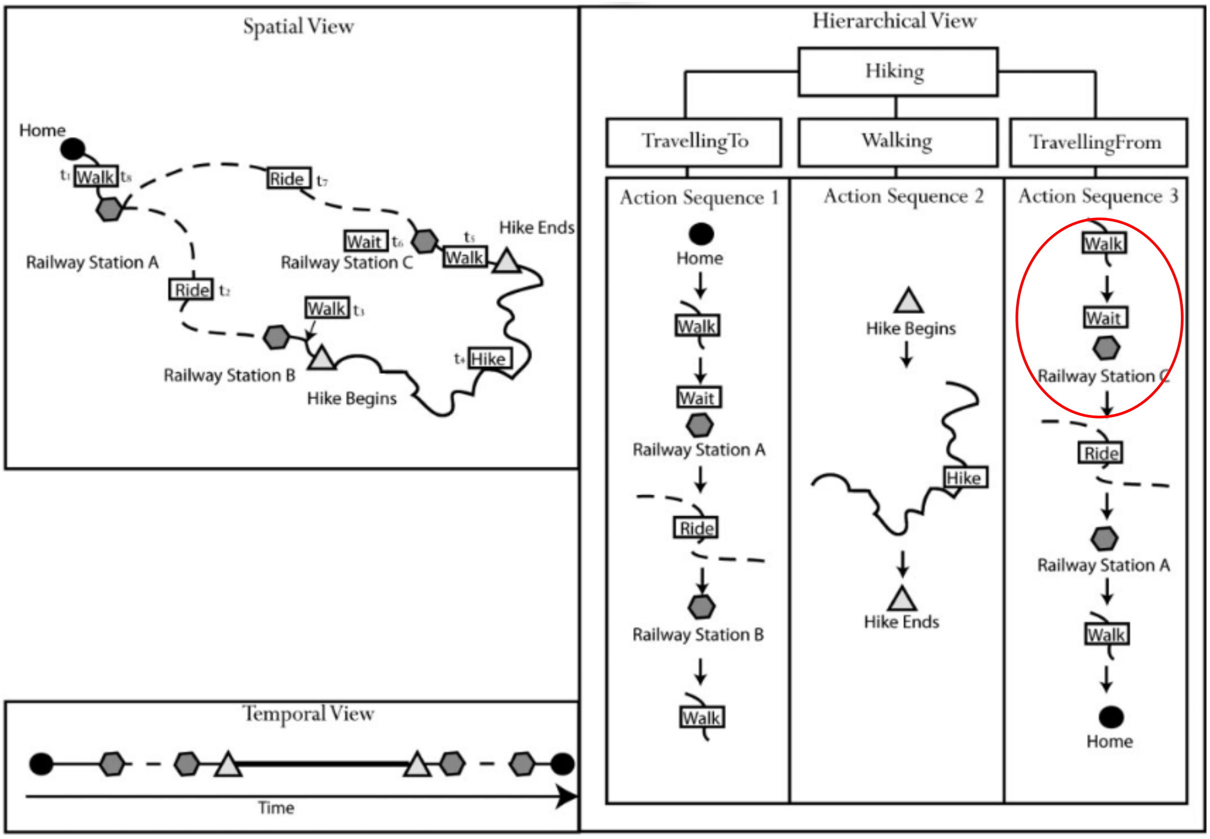

Figure 8: Spatial, temporal, and hierarchical view of a hiking trip from Crease & Reichenbacher (2013) with the red circle highlighting the focused scenario in this thesis

4.1.2 Mobile Usage Context

The *Mobile Usage Context* was introduced by Reichenbacher (2008) and described in section 2.2.2. The concept addresses the challenge of tailoring the visualization of geographic information to the specific needs and conditions of the mobile user's environment. The *Mobile Usage Context* involves the interplay of four dimensions: *System space*, *user space*, *physical space*, and *information space*. These spaces are now used to describe the situation of a hiker trying to find a suitable PT stop.

4.1.2.1 System Space

The *system space* covers technological factors and visualization-related factors (Reichenbacher, 2008, p. 679). In the case of a hiking trip, it is assumed that a mobile phone with an internet connection is available. The phone can locate the hiker with the viewing direction, retrieve real-time information, and display it on the screen, which is in portrait format. There is not much space to display information. This is why a simple visualization is beneficial. The interaction with a map app is limited to zooming, panning, and clicking/selecting. Hovering over a POI is not possible with a touchscreen.

4.1.2.2 User Space

The *user space* accounts for various user-specific factors, including their characteristics, the type of geographic information they need, and their ongoing activities. It encompasses elements such as user attributes, preferences, and behaviors (Reichenbacher, 2008, p. 679). Regarding a hiking trip various factors within the *physical space*, such as the terrain, environmental conditions, and the hiker's mobility play vital roles in shaping the user's experience. Hikers follow a leisure activity. Therefore, it can for example be assumed that hikers probably have no urgency to reach a specific PT stop and have basic physical fitness. However, other personal preferences regarding the terrain, path difficulty, distance to the stop, travel speed, or mode of transport cannot be assessed solely through the performed activity.

4.1.2.3 Physical Space

The *physical space* covers factors, which are mobility-related, situational, or physical (Reichenbacher, 2008, p. 679). This concerns primarily the position of the user in space and time, but also the surrounding environment. On a hiking trip in Switzerland, landmarks like lakes, mountains, or forests can be expected. The environment probably contains changes in elevation and paths with different difficulty levels. A hiker normally travels along such paths, which are implemented in the map data. They walk at a designated speed, and they are near or at the end of their hiking trip. Temporally, the user is located at a specific point in time probably in the afternoon or evening. This is the moment the user requests information. It is likely that PT stops are at a reasonable distance from the user offering different mobility options.

4.1.2.4 Information Space

The *information space* is closely linked to all the other dimensions. It defines what information is both accessible and necessary for users to make decisions (Reichenbacher, 2008, p. 679). The context provided by the other dimensions determines these information needs, and the ability to fulfill them depends on the availability of the required data.

4.1.3 Criteria for Geographic Relevance

De Sabbata & Reichenbacher (2012) suggest multiple relevance criteria, which can be applied to a geographical context. The *Mobile Usage Context* allows for a selection of criteria, which should be considered for the use case of finding a PT stop at the end of a hiking trip. These criteria provide the basis to fulfill the information needs of the user. All criteria found by De Sabbata & Reichenbacher (2012), which might relate to geographic relevance, are listed in Figure 9. These criteria can be categorized as *fundamental*, *primary*, and *secondary criteria* as described in section 2.1.1.

This is done similarly in the context of a hiking trip. Criteria that relate to the previously defined *Mobile Usage Context* are selected and categorized. Criteria, of the presentation group, as seen in Figure 9 will not be considered since it is not known how the presentation of information should look like. This will be examined using the other criteria and by comparing current map apps, which is done in section 4.2. Several criteria which are listed in Figure 9 were found to be applicable to the hiking context and therefore highlighted:

Properties	Geography	Information	Presentation
Topicality	Spatial proximity	Specificity	Accessibility
Appropriateness	Temporal proximity	Availability	Clarity
Coverage	Spatio-temporal proximity	Accuracy	Tangibility
Novelty	Directionality	Currency	Dynamism
	Visibility	Reliability	Presentation quality
	Anchor-point proximity	Verification	
	Hierarchy	Affectiveness	
	Cluster	Curiosity	
	Co-location	Familiarity	
	Association rules	Variety	

Figure 9: Relevance criteria by De Sabbata & Reichenbacher (2012) with the chosen criteria highlighted in blue

4.1.3.1 Fundamental Criteria

Topicality

The user is interested in PT stops. All other possible POIs are irrelevant. One could argue that taxi stops could also be relevant but in the case of hiking, it is very unusual that such POIs exist. Therefore, these are not considered in this thesis. Furthermore, it is not directly the PT stop but the event of traveling with PT, which needs to be within reach. A bus stop where the last bus drove off is therefore not relevant to the user.

Spatio-temporal proximity

The *spatial* and *temporal proximity* must be considered together. The closer a PT stop is located to the user, the more relevant it is. How spatio-temporally close a PT stop to the user is considered a *fundamental* criterion. The question is, is the PT stop in reach of the maximum distance the user is ready to walk, and is the needed service provided as soon as one reaches the POI?

4.1.3.2 Primary Criteria

Coverage

This criterion describes to which extent the user needs are satisfied with the information provided by the respective POI. A PT stop, where the right bus drives as soon as the user arrives there, fulfills the needs of the user better than a stop where the user needs to wait a long time. The probability that a bus drives in the right direction is higher if more lines and transport modes with a high frequency are available at the stop.

Availability

Availability is the amount of information that can be accessed about the desired map element. If important information about a PT stop is not available, the stop is less relevant to the user. Missing timetable information would make a PT stop less relevant or even unusable to the user.

4.1.3.3 Secondary Criteria

Directionality

POIs that are in the direction of travel of the user can be considered more relevant than others. A stop where the user needs to walk back the same path would be considered less relevant than a stop in the direction of travel with a similar distance.

Currency

Currency describes how recently updated or new information is. A PT stop where RTI is accessible would be more relevant than a similar stop with static timetable information because RTI is up to date since the most recent state is communicated to the user.

4.1.4 Task Relevance

In the next step, the goal of finding the best PT stop in the context of a hiking trip is analyzed. This is done similarly to the approach of Crease & Reichenbacher (2011). For this matter, the mentioned goal is divided into specific tasks or steps. These are the steps a walker must take to reach the goal of finding a suitable PT stop. Each step can be related to the defined relevance criteria from the previous section 4.1.3. The order of the steps helps to identify which information needs to be provided more or less prominently in the used map app. The visualization of the relevant information depends on the order in which the individual steps must be completed. With these steps it can be concluded which information needs to be visible directly by looking at the map and which can be provided as additional information after interacting.

Table 5: User tasks and related relevance criteria

Task Nr.	**Analysis Task**	**Relevance Criteria**
1	Locating own position in space	-
2	Find locations of PT stops	Topicality
3	Estimate arrival time of user at PT stops based on walking speed	Spatio-Temporal Proximity
4	Define candidates for accessible PT stops	
5	Check if information is available on a PT stop	Availability
6	Check to which extent the user needs are satisfied by the information provided by the respective PT stop	Coverage
7	Define the hierarchy of relevance for the spatio-temporally accessible PT stops	
*8**	Check how up-to-date the information is or if RTI is included	Currency
*9**	See which stops are in the direction of a hiking route	Directionality
Select the final PT stop		

**Only necessary if there are still multiple similar options left after the first seven steps*

First, users need to establish their precise location along the hiking route, which serves as the starting point. Subsequently, they must identify the positions of nearby public transport stops. Estimating the time required to reach these stops based on walking speed aids in efficient planning. Once a list of accessible stops is found, users need to check if further information is available about them. If information is available, the suitability of this information to meet specific needs, such as departure times and accessibility, should be assessed. To make an informed decision, hikers can establish a hierarchy of preference for the stops based on their spatio-temporal alignment and the quality of information provided. If multiple options of PT stops remain similarly relevant, further information can be considered. Understanding how up-to-date the provided information is can enhance confidence in its accuracy and validity. Furthermore, aligning the selected stops with the hiking route ensures a smoother transition. Ultimately, users can confidently decide on the most suitable public transport stop, utilizing these steps as a basis. A map app can facilitate accomplishing this goal most efficiently if the visualization is adapted according to the order of the required relevant information.

4.2 App Comparison

The results of the app comparison provide a comprehensive evaluation of map applications, which is organized into three distinct categories for comparison. Firstly, general app features are assessed by exploring the functionalities and capabilities of each app. Secondly, the focus is set on the *visual attributes* of POIs, examining how PT stops are represented in current map apps. Lastly, additional information on PT stops, which is not directly visible to users, is investigated.

4.2.1 App Features

The compared apps have different features implemented to help the user. Table 6 provides an overview of the features found in the apps selected for comparison. The features are described in more detail in this section.

Table 6: Overview of app features

App Feature:	**Self-Location**	**Filter POIs**	**Back- vs. Foreground**	**Hierarchy of POIs**	**Route Planning Tool**	**Display after interaction**
Swisstopo	X	(X)	X	-	X	-
Google Maps	X	(X)	X	(X)	X	X
Outdooractive	X	X	(X)	-	X	(X)
SBB Mobile	X	-	X	(X)	(X)	X
Citymapper	X	X	X	X	X	X

4.2.1.1 Self-Locating Feature

Indicating the position of the user on the map is a common feature, which is implemented in all compared apps. Precise self-localization on the map allows users to estimate the distance to other objects on the map. All chosen apps do not only show the location but also the viewing direction, which is indicated by a cone or arrow-shaped icon.

4.2.1.2 Filtering of POIs

This feature refers to the relevance criteria of *topicality*. Except for *SBB Mobile*, all apps provide an option to filter POIs in some way. Filtering in general contributes to the design principle of *simplicity*. By filtering out irrelevant information, the visual complexity can be reduced.

With the *Swisstopo* app, there is the option to hide the PT layer. There are also other layers available in the hiking mode of the app, but these options are quite limited. These features are not other groups of POIs but rather path and area-related, covering for example geological information or the closure of passages.

Google Maps also offers different layers to display. One of them is the PT layer with different kinds of stops displayed as POIs. Other layers show for example the transit situation, cycling paths, or air quality. Besides those layers, there are also other POIs like restaurants, viewpoints, parks, etc. displayed on the map. However, it is not possible to filter them. The filtering of PT stops is also limited, since bigger stops are always displayed on the map as POIs. By selecting the PT layer, more stops are displayed with a higher degree of detail. One helpful example of additional transit information in this layer is the visualization of tram lines in Zurich, which show their route displayed by a line with the respective color of the service.

The most topical filter options are available with the *Outdooractive* app. Specific filters can be selected in the top bar or less specific ones in a side slider. PT stops are only available with the specific filter option. Although the default base map already contains PT stops, it is still possible to overlay POIs with this information. This results in two versions of PT stops displayed on top of each other.

With *Citymapper* it is a bit different. Here the user can filter which type of transport mode should appear. Only transit-related objects like bus stops and train stations can be filtered and shown on the map or in an additional sliding window. Thereby, only stops of the chosen transport modes are visible. Additionally, the PT stops shown in the additional sliding window are ordered by the minutes it takes the user to reach it.

4.2.1.3 Background and Foreground Distinction

The design objective of *visual hierarchy* refers to the organization of geographical objects on the map. This objective is accomplished if the visual elements form a clear hierarchy. This facilitates the visual scanning process (Swienty et al., 2008, p. 232). A POI, which is part of the foreground, should therefore have more salient features than the background. All compared apps more or less follow this design principle. One example of this is the self-locating feature, which looks almost identical in all apps. They all are set in the foreground, visualized with a white stroke around a blue circle to elevate the arrow-icon or cone-icon from the basic map layer.

The PT-related POIs in the *Swisstopo* app have a white stroke around the pictogram with a dark blue background. This makes them stand out from the map, even though the background map displays a lot of objects and place names. The other layers can also be easily identified in the foreground. Other available layers like hiking paths, scenic routes, and restricted hiking paths are highlighted on top of already existing features of the background map. Therefore, the app follows the principle of *visual hierarchy*.

SBB Mobile has a very clear distinction between the POIs and the background. The POIs look almost identical to those in the *Swisstopo* app, except for the *visual variable shape*. They attract the attention of the user, especially in comparison with the subtly colored background. There are also lines visible that represent the transit routes. They are placed in the foreground, although not as noticeable as the POIs. The background map is simplistic with only a few labels of streets or places. This facilitates the identification of the POIs. Especially in smaller scales, the PT stops are clearly placed in the foreground.

The *Outdooractive* map can be confusing. The default background map already highlights some POIs like PT stops. On top of that, another layer can be selected. This layer is more clearly visible due to the big size of the top layer POIs. This is even more confusing considering that train stops are displayed with a red color in the background map and with a blue color in the top layer. All other PT stops are colored in blue in both layers. Therefore, the distinction between fore- and background is most difficult compared to the other apps.

Citymapper has a clean and simple design with a base map from *Google Maps* with slight changes. The streets are visible and mostly labeled. Different areas are represented with a corresponding color. In the foreground are the user's location, the center of the screen, which is shown as a green point or cross, the POIs, and a circle around the user's location, which shows a 5-, 15-, or 60-minute walking radius. There are different categories of PT stops, which are all distinct and represented as POIs. Small dots with strong colors for scooters, bigger, rounded squares with a pictogram inside for buses or trams, and larger symbols with a big white stroke for train stops. At specific zoom levels and filter options, the funicular and train station symbols used by Google are still visible together with the layer from *Citymapper*.

Google Maps manages to follow the principle of *visual hierarchy* even though a lot of information is displayed. However, how it is identified which information is considered less relevant and therefore filtered is not known. Even if the PT layer is selected, other information like restaurants, shops, or viewpoints are still visible. Because of the plain background map, these POIs can serve as landmarks, which provide orientation to the user. PT stops can be separated from the other categories of POIs because of the blue *color hue* and the distinct square *shape*.

4.2.1.4 Hierarchy of POIs

PT stops can be differently relevant to the user depending on the context and individual preferences. To illustrate the different relevance of these PT stops, it is necessary to visualize the hierarchy between them for the user. This refers to the design objective of *conciseness.* The saliency of relevant information can be improved by using strong attention-guiding properties for important objects and reducing the degree of less relevant context information. Multiple relevance criteria were identified in a hiking context, which could contribute to the hierarchy of PT stops, for example, the *spatio-temporal proximity* and *coverage*. To which extent the affordance of the entity satisfies the user needs can be influenced by many factors. In the following, it should be recorded which apps provide a hierarchy of POIs.

None of the apps visualize a clear hierarchy of PT stops. The different pictograms used in the apps do indicate different transport vehicles but do not directly refer to a higher or lower relevance. Some sort of relevance indication is given in *Google Maps*, *Citymapper,* and *SBB Mobile*. *Google Maps* displays the pictogram for train stations slightly larger compared to the other transit stops of buses and trams. *SBB Mobile* does something similar. At the closest zoom level, there is no *visual hierarchy* between the POIs but if it is zoomed out, the only transit stops that remain are train stations. With *Citymapper*, three different types of transit options are covered and their *visual hierarchy* is mainly communicated by their *size*. The small dots represent scooters; larger squares are used for buses; and trams and train stops are shown with the biggest symbols. Zooming out leads to the omission of everything except for train and boat stops. All three apps therefore suggest that train stations are more relevant than other transit stops.

4.2.1.5 Route Planning Tool

Planning and following a route refers to the relevance criteria of *directionality*. This feature can be important for deciding between two or more similarly relevant PT stops because the user normally prefers a POI in the direction of travel instead of having to walk back the same way.

All apps include a route planning tool but for different use cases. *Google Maps* is also able to include different transit options in the planning process; can be used for the hiking trip itself; and for getting to a PT stop. The route planning tools of *Swisstopo* and *Outdooractive* are specifically designed for hiking including for example height information. Therefore, they are best suited to guide the user on a hiking trip, but they are in comparison to other apps not equally useful to guide the user from the hiking path to the preferred transit stop. *Citymapper* has two route functions. By tapping on a POI, the walking route is visualized on the map with its location as the starting point. The second route planning option is to select a point on the map, which results in multiple route suggestions to get there. *SBB Mobile* does have a route planning tool. However, this can only be used for transfers or to reach the PT stop.

4.2.1.6 Display after Interaction

Modifying the visualized information after interacting with a POI, allows for the provision of supplementary information to the user. The POI on the map can be highlighted through various methods, accompanied by additional information either directly on the map or within a pop-up window. This newly presented data offers more detailed insights, by displaying relevant information, which can be related to the identified criterion of *coverage*.

The *Swisstopo* app does not provide further information after interacting with the POI. By tapping on the icon, the user is automatically redirected to the scheduling tool of *SBB Mobile* with the selected PT stop as the origin point.

Tapping on the POI on the map of *SBB Mobile* itself results in a change in the POI display and a pop-up window appears. The selected POI increases in size and changes from the color blue to red, which distinguishes it from the other, not selected, transit stops. The pop-up window only contains information about the distance in meters and the option to choose the selected point as the origin or destination point of the aforementioned scheduling function.

In *Google Maps,* the map display and the representation of the PT stop changes after interacting with it. The POI changes in *shape* and *color hue* and all transit routes, which can be used from the selected transit stop, are shown as an additional layer on the map. In addition, a pop-up window appears displaying the next departures in real-time with the regarding line information and direction.

With the *Outdooractive* app, there is almost no additional information provided. The POI and map display do not change after tapping on it. A small pop-up window appears with the name of the PT stop and the category of the POI. By clicking on it, the user has the option to be redirected to the website of the SBB.

Tapping on a POI in *Citymapper* opens a pop-up window displaying the next three departing lines at this stop. It depicts which lines stop at this POI and in how many minutes the next vehicles drive in the respective direction. Additionally, it is also indicated how many minutes it takes to get there by foot. A similar window appears if one selects a filter first and hovers over the map with the center curser. The only difference is that more than three lines are displayed for each POI. Additionally, other stops are shown right below the first one. The walking route is also visualized on the map itself after tapping. To highlight the selected POI, it increases in size after tapping on it.

4.2.2 Visual Attributes of Transit-Related POIs

Previously in section 2.3.1 *visual variables* were introduced. To include other ways of displaying POIs, the term *visual attributes* was introduced. *Visual attributes* enable the guidance of the user's attention. Depending on the app, the attributes of the PT-related POI can vary. Table 7 shows an overview of *visual attributes* applied in the compared apps.

Table 7: Overview of visual attributes

Visual Attribute:	**Pictogram/ Symbol**	**Color hue**	**Color Value/ saturation**	**Trans-parency**	**Size**	**Orien-tation**	**Text**	**Motion**
Swisstopo	X	-	-	-	-	-	-	-
Google Maps	X	(X)	-	-	X	-	X	(X)
Outdooractive	X	(X)	-	-	-	-	-	-
SBB Mobile	X	-	-	-	-	-	(X)	-
Citymapper	X	X	-	-	X	-	X	-

4.2.2.1 Pictogram & Symbols

All compared apps use pictograms or symbols to indicate different types of transport modes. For *Google Maps* and *Citymapper,* these can also change slightly depending on the region. In Germany for example, *Google Maps* provides a special symbol for the S-Bahn. Another similar variant can be seen with *Citymapper*, where the logo of the national railway company for train stations is used. *Outdooractive* has the least differentiation since they only use pictograms to differentiate between bus and rail.

4.2.2.2 Color (Hue)

Swisstopo and the *SBB* app use the *color hue* blue for all transit-related POIs. No other *color hues* are used to distinguish between different kinds of POIs in those two apps. *Outdooractive* and *Google Maps* do use multiple *color hues* for all sorts of POI categories. An example would be the already mentioned S-Bahn in Germany, which is colored green, or the London tube, which is displayed with the classic tube logo. However, apart from those exceptions, a different *color hue* is not used within the category of PT-related POIs, but only to distinguish them from other POIs such as restaurants. The only app that uses multiple *color hues* to distinguish different sorts of PT stops displayed as POIs is the *Citymapper* app. Every transit stop, that offers train connections, is displayed mainly in red because of the SBB logo, whereas yellow is used for stops of post bus services, and blue for the other stops.

4.2.2.3 Color (Value/Saturation) & Transparency

None of the apps uses different *color values* or *saturation* to indicate a *visual hierarchy* between PT stops. The same also applies to *transparency*.

4.2.2.4 Size

Size is just used in *SBB Mobile*, *Google Maps*, and *Citymapper*. Transit stops, which offer train connections, are displayed bigger than others. Next to transit stops, *Citymapper* also includes the location of scooters and bikes on the map, which are displayed the smallest compared to the other POIs.

4.2.2.5 Text

Outdooractive as well as *Swisstopo* do not use text information for displaying PT stops. Both apps have some text included on the background map itself, but this information is not attached or directly related to the POIs.

SBB Mobile does not use text directly attached to their POIs either. The names of some stops appear if the user zooms out quite far. Additionally, the names of transport stops that are not train stations are displayed when zoomed in more closely. They are depicted with another small point, showing the exact position of the stop. It is not possible to interact with them, but those more exact points are used for the route planning feature, which can help the user find the way when switching the transit vehicle. Text is also shown at a closer zoom level to indicate the exact platform location at train stations. This information is visualized with another set of rectangular POIs. They appear smaller than the PT stops and contain the number of the platform.

Citymapper uses text for all of their PT stops. For train stations, the respective name is displayed even on a smaller scale. Zooming closer to the POIs, the line service information of the chosen stop is also written in text underneath. This is applied to every kind of POI, including bus and even boat stops.

Google Maps also displays text underneath certain POIs. For train and tram stops the respective name is displayed underneath the POI. For train stations and certain major tram stops there is also text information about how busy a place currently is. However, this kind of text information is not available for bus stops.

4.2.2.6 Motion

The only app, that has moving features implemented, is *Google Maps*. The POIs of the transport stops themselves have no moving component. Some buses are indicated as an additional moving POI on the map.

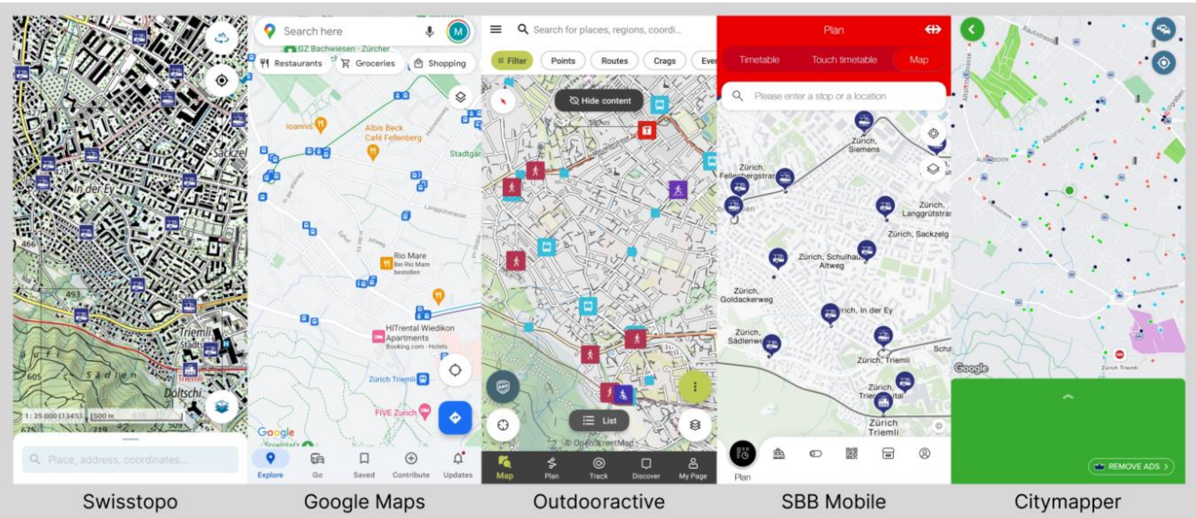

Figure 10: Overview of apps which represent POIs differently

4.2.3 POI Related Information

Another aspect to compare is the information, which is available after interacting with a POI. In most cases, after tapping on a POI, additional information appears in different ways on the screen.

Table 8: Overview of POI-related information

PT stop related info:	**Vehicle Location**	**Distance**	**Absence of info**	**Route/Service (Pop-Up)**	**Route/Service (Map)**	**Arrival/ Departure**	**Vehicle info**
Swisstopo	-	-	-	-	-	-	-
Google Maps	(X)	(X)	X	X	X	X	X
Outdooractive	-	(X)	(X)	-	-	-	-
SBB Mobile	-	X	-	(X)	-	(X)	(X)
Citymapper	-	X	X	X	(X)	X	-

4.2.3.1 Vehicle Location

Google Maps is the only app that has the feature of vehicle location implemented. This feature occurs rarely, since there are very few transit vehicles with a built-in GPS tracker, which enables this additional information to be displayed.

4.2.3.2 Distance

All apps except for *Swisstopo* include some type of distance information after interacting with a POI. This information can be depicted using the distance in meters or the required time to reach the selected POI. Since *Swisstopo* also includes a route function, it would be possible to use it to receive information about the distance to a POI. However, since there is no option to select a PT stop as a destination point by clicking on it, this function was not considered as available distance information.

Google Maps and *Outdooractive* offer a less cumbersome option to acquire distance information. Nevertheless, this information is not automatically displayed just by interacting with a POI, because the route planning tool always needs to be selected in a second step.

In *Google Maps*, it is necessary to tap on the POI first. A second interaction with the “Directions”-button directly shows the time and distance needed for one of the available transport modes, which are driving, PT, walking, and cycling. Furthermore, travel time for the other transport modes is also visible. The distance and more detailed route information for them is available after selecting the respective mode of transport.

With *Outdooractiv*e the case is similar. Tapping on the POI results in two fields, which let the user decide if it should be the origin or destination point. With selecting the POI as destination there are again two options to choose from: The “Route Planner” and the “Getting there” option. Selecting the “Route Planner” results in a suggested path to reach the POI with the distance, time, and height information given with the assumption that the user is walking. Selecting "Getting there" opens a window, where the user can select other apps to suggest the route.

SBB Mobile directly displays the distance information to the current location of the user after selecting a POI. However, more detailed route information is only shown in further steps. The PT stop can be chosen as the point of departure or destination, which leads the user to the route planning tool. There, different travel options are available and displayed above each other showing the start and end points connected by a line. It should also be noted that distance information is also included in this route planning tool. It shows the available route with the respective distance for switching between vehicles and between a transport stop and a specific location.

With *Citymapper*, there are two options to select a PT stop. The first one would be to tap on a POI. This directly results in a suggested walking route, which is displayed on the map. In a sliding window, which appears from below, the required time to reach the PT stop is shown next to its name. The second option is to filter the PT stops before selecting one. By applying a filter, all PT stops, that match the filter criteria, are shown in a sliding window. The displayed PT stops are ordered by the required walking distance. This information is depicted next to the name of the PT stop. The exact route on the map appears when the user taps on one of the PT stops in the sliding window. Like *SBB Mobile* or *Google Maps*, there is also more complex route information available, which also displays the different transportation modes and walking sections before, in between, or after. This feature can be selected by choosing a specific location on the map or with the search bar.

4.2.3.3 Absence of Information

Information is called absent, if it is implemented in a map app, but not available in the moment the user makes the query. The difference in the amount of displayed information between the compared apps, in general, is not considered an absence. An absence of information is most often observed for RTI and departure and arrival times. The assumption is, that the user has access to the internet and with that to the information sources connected to the apps. If there is a loss of internet connection, every app has their way of informing the user about it.

Swisstopo and *SBB Mobile* refrain from communicating that information is missing. *Swisstopo* displays no additional information to PT stops at all, which makes it obsolete to indicate the absence it. *SBB Mobile* provides some additional information, especially with the route planning tool, after choosing a POI as the starting or destination point. It depicts if a train is delayed. However, it is not possible to notice if RTI is used in the case of a punctual train. The app communicates general information about service disruptions. It for example provides a message that it is unclear how long it takes until the service can be provided again.

Nevertheless, there is not any absence of information indicated, which is directly related to a POI.

Outdooractive does not disclose specifically that information is missing either. It is indicated if no one contributed information to a POI, which can be considered as absent information. However, such information is user-generated and therefore not from the beginning implemented in the app.

Google Maps does indicate if the departure time related to a PT stop is RTI or just the scheduled time. The *color hue* green is used to indicate if the vehicle is on time and the *color hue* red is used to show if it is delayed. Like this, it is evident to the user, that RTI is used. If this is not the case, the word “scheduled” is written in the same spot in a grey *color hue*. For some PT stops, there is also information about how busy it is. However, if this information is not available, it is not specifically indicated and just omitted.

Citymapper visualizes the use of RTI in a similar way. For the departures of a selected POI, in addition to the line and direction of the coming vehicle, the departure time is also displayed. If RTI is available, it is indicated by two small quarter circles above the departure time. However, it is not apparent to the user whether a connection is late, as only the departure time is shown.

4.2.3.4 Route/Service (Pop-Up)

The only apps, that contain some sort of route or service information, are *SBB Mobile*, *Google Maps,* and *Citymapper*.

SBB Mobile is a special case because the route and service information is only visible once the POI is selected for departure or destination. The possible connections between the origin and destination points are listed below each other. Above the temporal representation of the connection, a pictogram with the type of traffic, the line information, and the direction in the form of the terminus of the first line segment are displayed side by side. Route information of the other possible segments is shown after tapping on the route. Even though this is included in the app, it is not directly available in the map feature.

Google Maps displays route information right after tapping on a POI on the map. Like *SBB Mobile*, there is a pictogram, the line number, and the direction written next to each other. A temporal view is obsolete since no specific connection is selected at this state. All departures are listed below each other. In addition, each line available at the selected stop is displayed above the departures. They provide an overview and serve as a filter. By default, all lines are selected. Tapping on one or more line icons, the user can filter to only see the departures of the selected lines.

Citymapper displays the line services similar to *SBB Mobile* and *Google Maps*. The sliding window shows one or more PT stops and their available services below each other. Further information in the sliding window is the display of a pictogram, the line number, and the direction next to each other. Except at train stations, all available lines are listed below the name of the PT stops as in *Google Maps*. As already mentioned, PT stops cannot only be selected by tapping on their respective POI, but also by applying a filter first. Using this filter option provides an overview of close stops displayed below each other in a sliding window. If buses or trams were chosen as filtering options, the user can use a search function to find a specific line. By selecting this function, all available lines can be searched and selected from a list. This results in the service information displayed on the map, which is described in the next section in more detail.

4.2.3.5 Route/Service (Map)

Google Maps and *Citymapper* are the only apps, which show route or service information on the map itself.

Specifically, *Google Maps* adds a layer on the map after interacting with a POI. This layer shows the line routing of the available PT options at the POI. It uses thick lines, which have one *color hue* per route, and small dots to indicate the other stops. If a PT stop with many available routes is selected, all of them are stacked on each other. It is possible to select one specific connection inside the pop-up window. Like this, only the specific route of the selected connection is visible on the map with an even thicker line and points.

Citymapper displays similar information on the map about the lines. However, it does need more steps to get there. After selecting a PT stop (via the map or a filter), the user needs to tap on one of the connections first, to see the route as a line on the map. The *color hue* only varies depending on the mode of transport. The routes of trains are depicted with a black line, whereas other modes of transport are displayed with a dark blue line. A difference to *Google Maps* is that the part of the line, that covers upcoming PT stops, has a higher *color value* than the other part and the display of small arrows indicating the direction of travel. The line design is also simpler compared to *Google Maps* since the stops are just connected with straight lines instead of following the exact route. Additionally, the selected stop is highlighted with the basic POI design displayed a little bit above the location. Above this is a text box containing the departure time of the selected connection.

4.2.3.6 Arrival/Departure

Similar to the route and service information, *Swisstopo* and *Outdooractive* do not include arrival or departure information by themselves, since they just link to other apps or websites.

SBB Mobile includes this kind of information, but it does not directly connect it to the POIs. This information is again only visible after selecting the origin and destination point. It is possible to select a POI on the map. Then, the current location is automatically chosen as the corresponding departure or destination point. In the same window, connections are displayed between the two selected points. All possible connections are visualized above each other, with the respective departure and the arrival time. The whole travel time is also displayed below. There, not only the time spent in the vehicle is presented, but also the time needed to walk before, between, and after it. The departure and arrival information for every vehicle is also available after tapping on one of the connections.

After tapping on a POI, *Google Maps* displays all departures from it. As already mentioned in section 4.2, RTI information is included if it is available. The scheduled departure time is always visible. However, it is crossed out if there is a delay. The delay next to the original departure time using text and the amount of delay in minutes. On the right side of the screen, the number of minutes until departure is also displayed. It changes to the scheduled departure time if it is more than one hour in the future. *Google Maps* also has the option to plan a route including PT. Like this, the display looks similar to the one from *SBB Mobile* but requires setting a route first. With this feature, the arrival time at the chosen destination is additionally displayed.

Citymapper also includes the departure time after selecting a POI. Compared to *Google Maps* it only displays the number of minutes until departure and not the exact time. Furthermore, the departures of the same line and direction are combined instead of listing every single service separately. Thus, up to three departures are displayed next to each other. Like in *Google Maps*, departures, that are in more than one hour, are displayed with the time of day instead of minutes. The content of sliding windows of train stations is displayed in a slightly different way compared to *Google Maps*. In *Citymapper*, the departure time is always shown in addition to the number of minutes. It also has a route planning tool, which offers different possible connections with their departure and travel time.

4.2.3.7 Vehicle Information

Overall, only *SBB Mobile* and *Google Maps* contain some variant of vehicle-specific information.

SBB Mobile contains a lot of information about the vehicles, but to get this information, a route has to be planned first. In the basic view where the connections are visible without any map information, the platform and the occupancy are displayed if they are available. The platform information is provided if there are multiple platforms for trains and in some cases for bigger bus or tram stops. The occupancy is only available for interregional trains and is represented with three different types of pictograms. Even more information for each vehicle is available after selecting a connection. It is depicted by small symbols, which are explained in a legend. This includes the availability of things like Wi-Fi, bicycle transportation, restaurants, seat reservations, and more.

Only *Google Maps* offers vehicle-related information after interacting with a POI directly. It automatically depicts this kind of information for the next departures. This includes the platform and occupancy of the vehicle. Like with *SBB Mobile*, the platform information is available if there are multiple platforms. However, the occupancy is shown for each type of vehicle and not only for interregional trains. It is represented with very similar pictograms, including a fourth one, which indicates that a vehicle is almost empty.

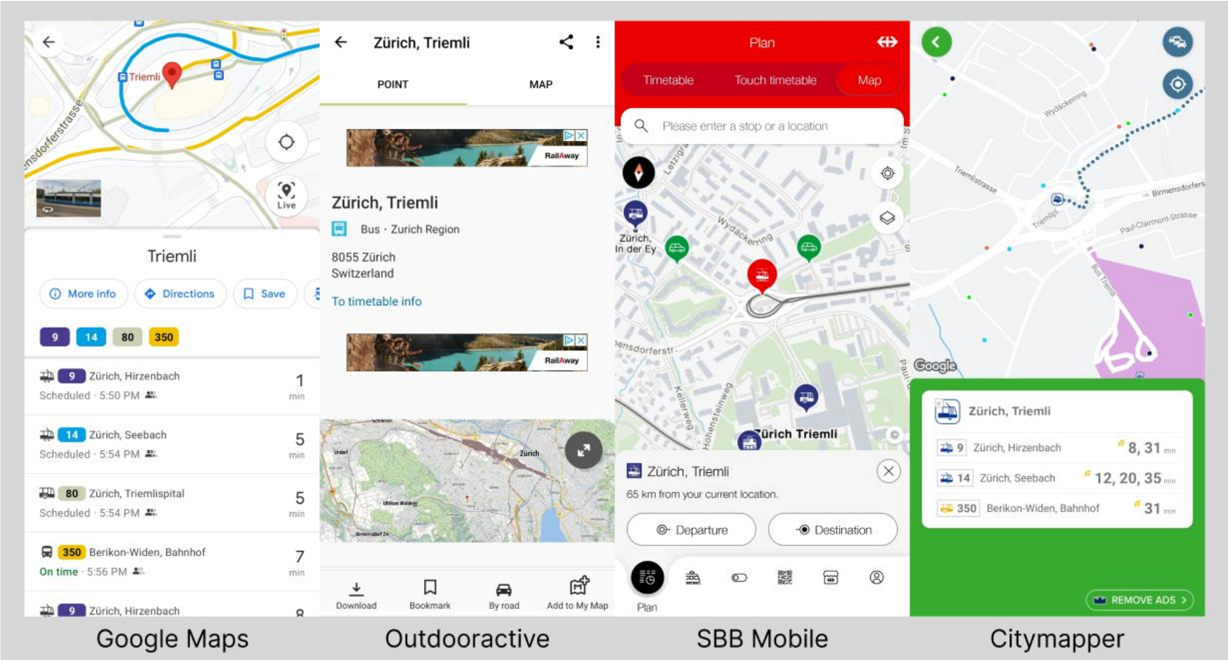

Figure 11: Overview of apps that represent additional information differently

4.3 Survey

The results of the survey are presented in the same order as the conducted survey. Therefore, Section 4.3.1 covers how participants hike and what equipment they use. Section 4.3.2 is the main part of the survey and includes the testing of the prototype. Section 4.3.3 contains the answers to the general questions about the prototype and demographic data. In total ten people filled out the survey.

4.3.1 Hiking Behavior

The first question after writing down the participant number was about the number of hiking days per year. 21-50 days was the most frequently selected category right after 1-5 days. Two participants reported that they hike 6-10 days a year and one of them 11-20 days. None of the participants selected an option above 50 hiking days per year. PT usage as part of a hiking trip proved important to all participants, although the frequency of use varied. While one participant reported rarely using PT on hiking trips, most of the others indicated using PT occasionally or most of the time. One participant even reported that PT is used every time. Regarding the app usage during hiking trips, all participants reported that they use multiple apps each serving a specific purpose like navigation, trail information, or PT.

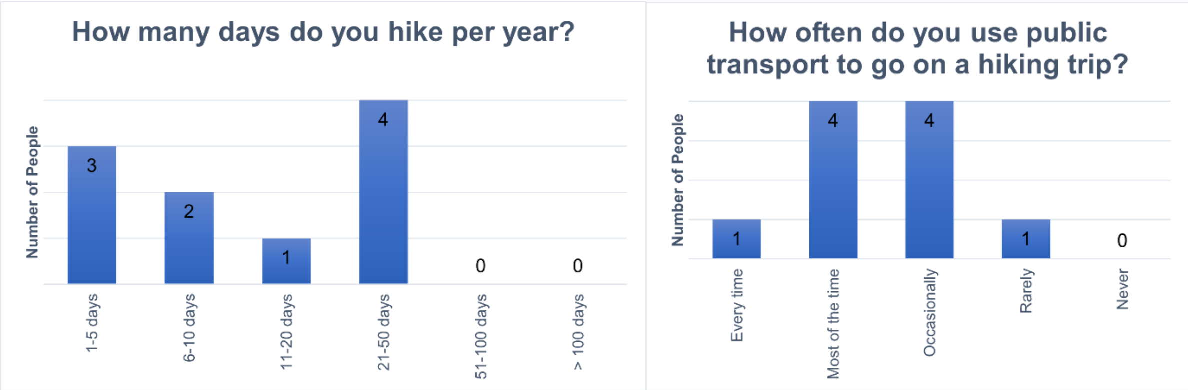

Figure 12: Hiking days and PT usage of participants

The participants' knowledge and usage of the in this thesis compared apps shows a large variation between them. *SBB Mobile* and *Google Maps* are the best-known apps, followed closely by *Swisstopo*. *Outdooractive* is not known well overall but multiple participants have some knowledge of this app. There is only one person who reported to know the app *Citymapper*. With the usage in a hiking context, the results seem quite similar on a first look but there are some differences. For all apps, the knowledge was rated higher than the usage. However, *Swisstopo* seems to be less known than Google Maps but nearly used as much for hiking trips by the participants. *Outdooractive* and *Citymapper* are rarely used. For *SBB Mobile* the usage is still rated rather high.

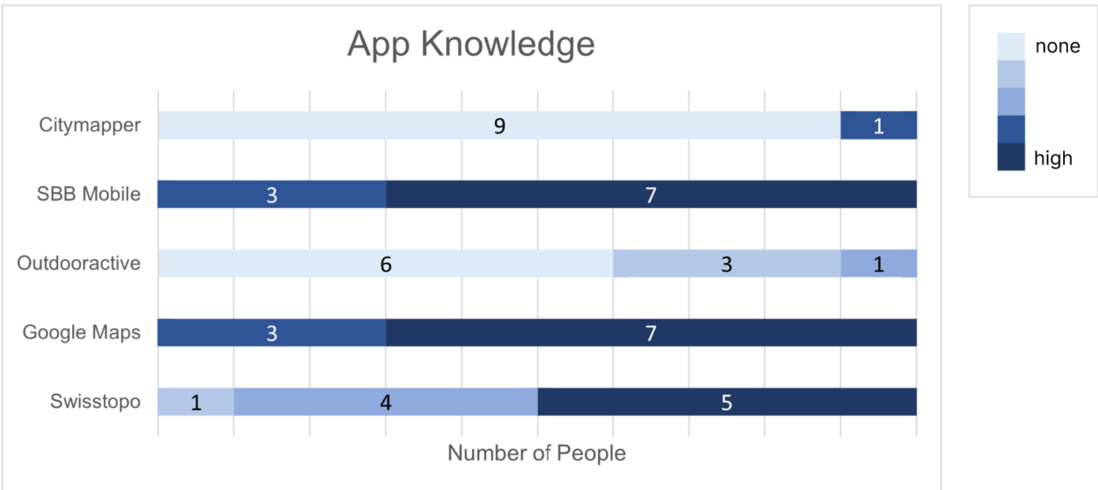

Figure 13: Participants' knowledge of the compared apps

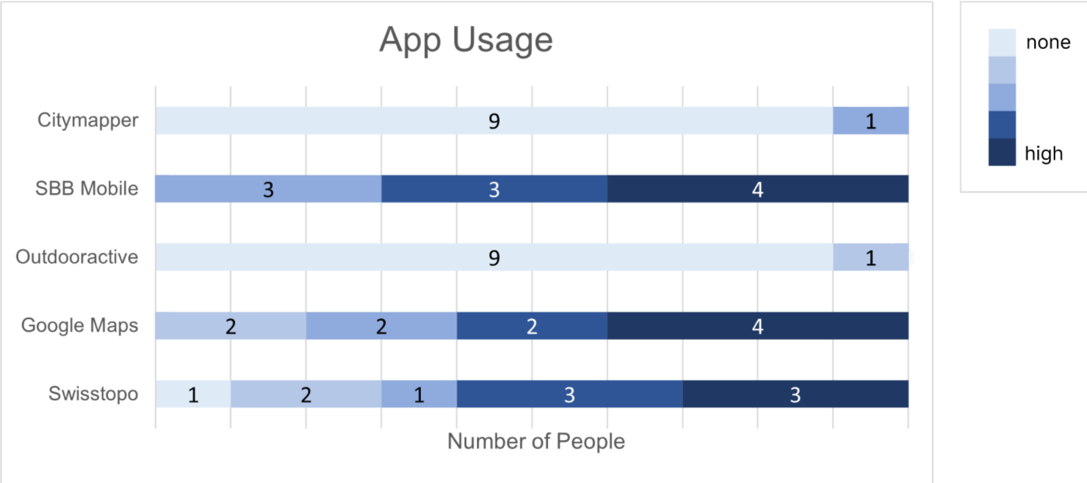

Figure 14: Participants' usage of the compared apps

Afterward, participants selected apps that are used regularly in a hiking context and commented on which specific tasks they are used for. Nine out of ten participants regularly use *Swisstopo*. The app is mainly used for navigation during the hiking trip. This includes route information for orientation and an overview of the area including topographic, trail, and distance information. The planning, comparing, and tracking of hikes was also mentioned as a use case.

All participants stated that they regularly use *Google Maps* on their hiking trips. The app is used for various purposes, which also include non-hiking-related activities. The participants mentioned most often the need for information about certain POIs like train stops, restaurants, or hotels. This includes routes, further stops of available connections, and opening hours of businesses. Planning and navigating were also mentioned, often being the reason to use *Google Maps* as an alternative to other apps like the *Swisstopo* or *SBB Mobile* app. More specifically, different connections, trails, or map elements were mentioned. Some participants use *Google Maps* also for the initial and broader planning process before going into more detail.

Another app used by all participants is *SBB Mobile*. Participants most frequently cited connection verification as a reason for using the app. One participant pointed out it is necessary to know the transport stop names before being able to use *SBB Mobile* and therefore needs to use other apps to find the stops and their names. Another participant mentioned using the app to purchase the tickets.

Only one participant reported using *Citymapper* regularly. Checking the connections in the city and also the state of E-Scooters was given as a reason to use the app. None of the participants use *Outdooractive* regularly.

In addition to the five compared apps, the participants named several others that they use in connection with hiking. *Komoot*, *SAC Tourenplaner*, *Switzerland Mobility*, *All Trails,* and *Maps*

Me were mentioned. These apps provide various features and information, such as planning, tracking, suggestions of hiking routes, and more specific information on hiking trails and surroundings. Gathering inspiration and finding new routes stands out as a feature, which is not mentioned in the five apps initially compared. Other apps mentioned are *MeteoSwiss* and *Peakfinder*, which provide additional information such as identification of surrounding mountain ranges and weather forecasts.

4.3.2 Prototype Testing

In this section of the survey, participants solved tasks using different variants of the prototype and answered questions regarding the tasks and how the prototype helped in the decision-making process. The test of the prototype is divided into three sections, in which different variants of features were evaluated.

4.3.2.1 Display of POIs

For the first task, the focus was set on how the transit stops are displayed on the map. Lally and Bains-de-l'Alliaz were both selected five times as the PT stop the participant would go to in the given scenario. Lally is a train station, which provides more connections. This results in a shorter waiting time. However, Bains-de-l'Alliaz is much closer to the participants' location but the waiting time for the next connection is longer. Les Motalles does not offer any connections and was not chosen by any of the participants.

Table 9: Properties of the available PT stops from the first task

PT Stop Name:	**Les Motalles**	**Bains-de-l'Alliaz**	**Lally**
Walking Time [min]	35	27	53
Shortest Waiting Time [min]	-	71	-1* / 18
Connections in the next hour	0	1	2
Mode of Transport	Ski Lift	Bus	Train
Distance [km]	1.9	1.7	3.4
Altitude up [m]	99	25	134
Altitude down [m]	19	118	32

*Connection that is possible to catch by increasing walking speed

From the three different variants, variant 2 with walking time displayed as text above the POIs performed best compared to the others. Six participants chose it as the best-suited variant to solve the task. However, four participants favored variant 1. In variant 1, one of the three POIs was displayed in gray with the written information that no departures were scheduled. Ranked most often as the least preferred version was the third one. This variant showed how many departures are scheduled in the next hour as text above the POIs.

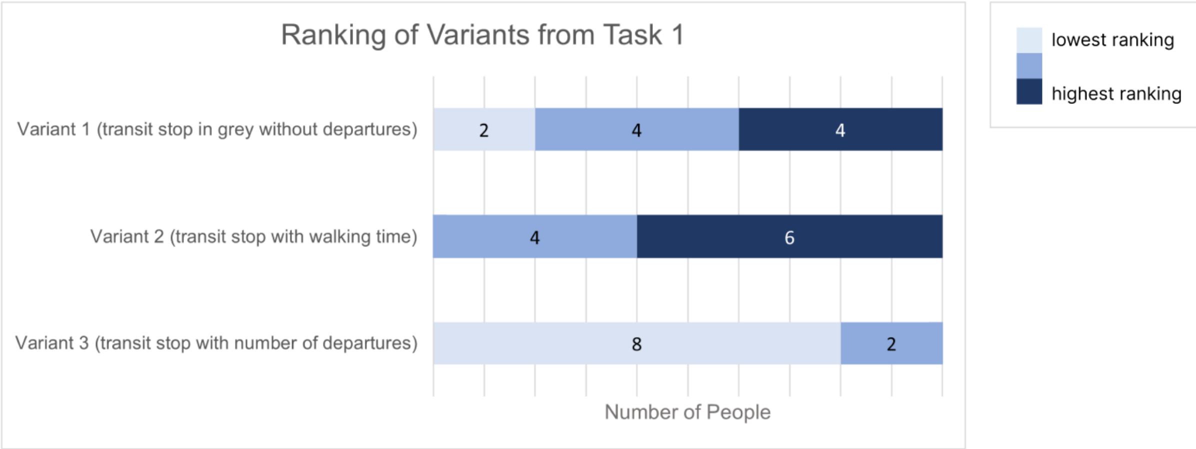

Figure 15: Participants' ranking of the different variants from task 1

The fact that two stops were chosen equally often suggests that there are different preferences among participants. Different preferences are also stated in the open questions regarding this scenario. Some described that it is helpful to see the walking time to estimate how long it will take to get to the PT stop since the departure information is visible after selecting a transit stop anyway. Others consider the information of importance that there are no departures at Les Motalles since they immediately know that this transit stop is not a viable option. In general, most of the participants thought both types of information were important and the preference, which should be visible, first varied. One participant even suggested to somehow mix the first two variants. Another participant described that the reachable PT stop with the least waiting time should be highlighted using the *visual variables color hue* or *size*. Another participant stated that it is confusing that the transit stop, for which there were no options, is even listed. Clearly, the variant with the number of departures in the next hour was described as the least helpful. The design and the kind of information of this version were frequently cited as a reason for the low rating. In particular, it was stated that this visualization contains too much text and that the information itself is too vague to decide where to go.

4.3.2.2 Connection Information

In the second task, the participants were asked to focus on the information regarding the different connections inside the sliding window. In this scenario, most of the participants chose Steg as the option they would walk to. Steg is a train station that offers the highest frequency of connections and short waiting times. However, it must be noted that the hiking trail to this PT stop is more challenging than the ones to the other stops. Sternenberg, Gfell, as well as Mühlrüti, and Hulftegg, are bus stops that were both chosen by one participant. Sternenberg, Gfell is closest to the participant location compared to the other two stops, which both have similar walking distances. Both bus stops do not have many departures but the waiting time for the next connection is shorter at Mühlrüti, Hulftegg.

Table 10: Properties of the available PT stops from the second task

PT Stop Name:	**Sternenberg, Gfell**	**Steg**	**Mühlrüti, Hulftegg**
Walking Time [min]	36	55	60
Shortest Waiting Time [min]	158	-2* / 5	15
Connections in the next hour	1	3	1
Mode of Transport	Bus	Train	Bus
Distance [km]	1.8	2.9	3.7
Altitude up [m]	32	7	54
Altitude down [m]	255	437	225

*Connection that is possible to catch by increasing walking speed

The fact that most participants chose Steg as their desired destination shows a clearer situation than in the first task. As with the selection of the POI, the evaluation of the different variants was also more evident. Variant 3, which includes both waiting and departure time, was rated highest by nine out of ten participants. Variant 1, which only depicts how long a user needs to wait or whether the connection can be reached at all, was ranked second by more than half of the participants. Variant 2 most often received the worst rating. It displays the departure time and not only the number of minutes in which the next connection leaves. Additionally, the information if a connection is delayed, on time, or scheduled was also shown in this variant.

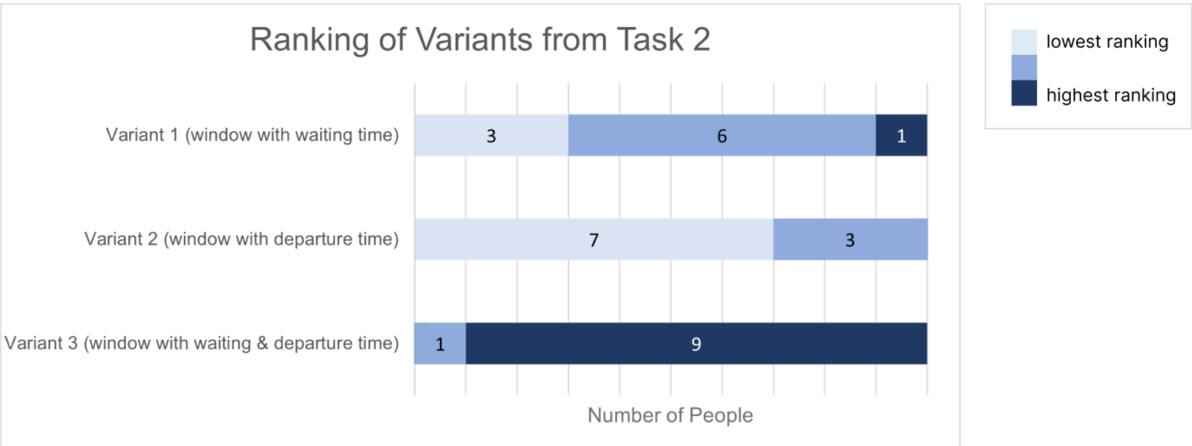

Figure 16: Participants' ranking of the different variants from task 2

The amount of information in variant 3 was not a problem for most participants although the waiting and departure times were displayed simultaneously. Even if it was not immediately clear to everyone, the time a user must wait at a stop was found to be very useful, especially in combination with the departure time. One participant mentioned that not having to calculate how long one needs to wait at a transit stop is beneficial to quickly decide where to go. The indication that a connection is not reachable in time or may not be caught raises the question of how the threshold responsible for this distinction is determined. One participant decided that the connection at Sternenberg, described as “not reachable”, is still accessible at a higher walking speed and decided to head to that PT stop. Another participant takes this idea one step further by suggesting to display the negative waiting time instead of text for reachable connections. This leaves the decision as to whether a connection is accessible to the user.

4.3.2.3 Background Map

The last task involved three different background maps that were to be compared in terms of their usefulness in solving the task. Here, the participants again chose different destinations. Three chose Brè, Paese which is the closest PT stop but with a longer waiting time for the next connection. Most of the participants chose Monte Brè as their destination. This stop provides the highest frequency of connections is farther away and has more elevation gain along the way. None of the participants selected Curregia, Paese. This bus stop was equally far away as the other stop, Monte Brè, but had a longer waiting time in comparison.

Table 11: Properties of the available PT stops from the third task

PT Stop Name:	**Cureggia, Paese**	**Monte Brè**	**Brè, Paese**
Walking Time [min]	29	34	10
Shortest Waiting Time [min]	92	12	51
Connections in the next hour	0	2	1
Mode of Transport	Bus	Funicular	Bus
Distance [km]	1.9	1.4	0.6
Altitude up [m]	4	153	13
Altitude down [m]	137	31	17

Eight of the ten participants rated variant 3 with the standard Swisstopo map as the background highest. However, one participant ranked this background map lowest. With the highest rating from two and the second highest ranking from eight participants, variant 2 still seems to be a useful background map. It depicted fewer features than the Swisstopo map background but still provided altitude lines and quite detailed information. Variant 1 is a much simpler background map including fewer features. Nine out of ten participants rated it the worst.

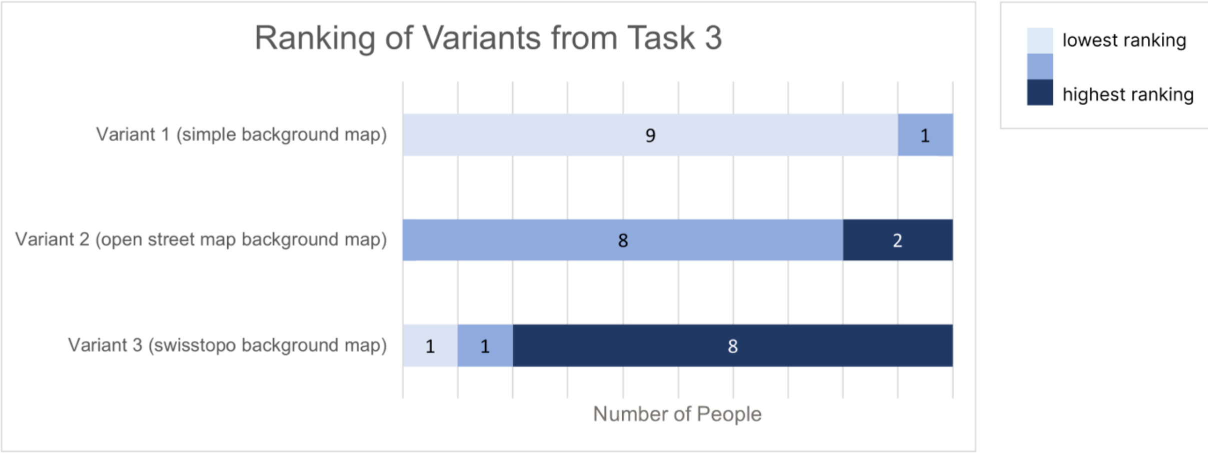

Figure 17: Participants' ranking of the different variants from task 3

As the ranking shows, most participants prefer the Swisstopo background map. They explained this with the amount of information and their familiarity with this map. Some participants responded that they liked to have a lot of information and that it was not distracting to them. Contour lines were mentioned by most participants as important information related to hiking. Displaying them on the map enables one to estimate the course of the trail and better understand the topography. Therefore, the simple background map, which does not include them, was described as less helpful for decision-making. One participant even mentioned that a map without altitude lines is not usable at all. Another property that stood out negatively in the simple background map, but also in the open road map version, was the thickness of the displayed roads. One participant mentioned the proportions of map elements and their relationship to each other on the Swisstopo map as being particularly helpful compared to the other versions. However, another participant considered the Swisstopo background map to be too cluttered to be useful and also doubted that the background map itself helped in decision-making. However, this stands in contrast to the majority of eight participants considering the Swisstopo background map of variant 3 as their favorite.

4.3.3 Overall Prototype and Demographics

In the last part of the survey, participants indicated how useful which feature or information of the overall prototype was. In addition, they were asked to provide feedback on which features were particularly useful, on what was missing, and on additional things that were not covered by the other questions.

For the first question participants rated the usefulness of features and information implemented in the different variants of the prototype on a scale from 1 (not useful) to 5 (very useful). Concerning Figure 18, overall, the participants considered all information as important to some extent. Overall, the walking time to a stop was rated as most important. Nine out of ten participants chose the highest ranking for this information. A majority with a minimum of eight participants rate the departure time of the connections; the waiting time at a stop; and path and altitude information with 4 or 5 and therefore as overall useful. No one rated those negatively. The provision of real-time and route and transport information was rated very differently by the participants. Their preferences range from not useful to very useful. The number of connections in the next hour is rated as the least important information among the given options. No participant rated this category as very useful.

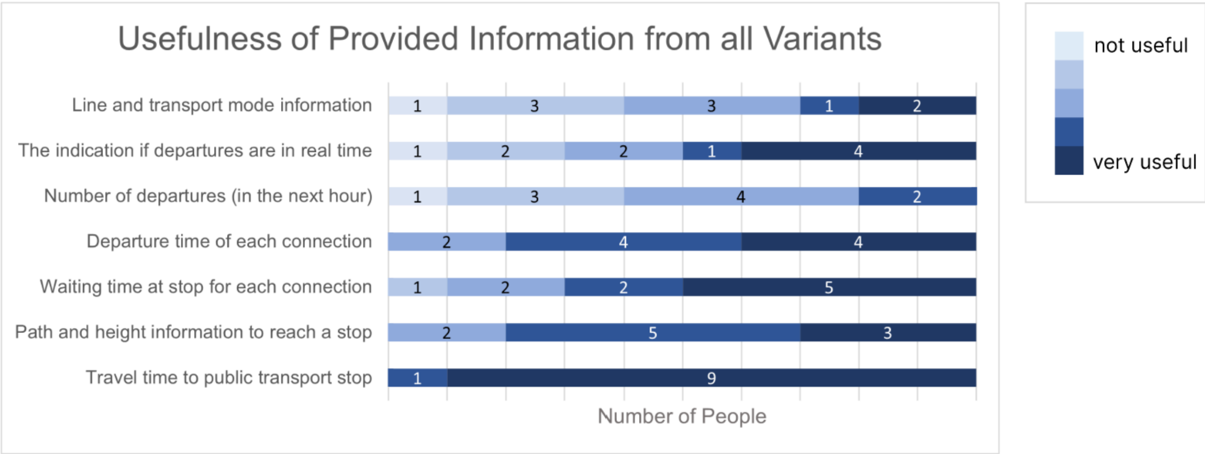

Figure 18: Participants' rating of the usefulness of the provided information

The participants were then asked to name a feature or displayed information, which they found particularly useful. Most participants responded that information about the waiting time for each connection at a stop and whether the connection is accessible or not is useful. One participant described that the calculation based on departure time and walking time takes time. Therefore, such a feature is particularly useful for a quick decision. Another participant pointed out that the reachability of a connection varies depending on the user. The participants also often brought up additional path information. In this regard, they mainly mentioned the walking time to a PT stop and also the height and length information of the path, because they could more easily compare different stops, knowing how long it takes them to get to the desired destination. Height information was described as helpful not only in the sliding window but also on the map itself. Additionally, one person wrote that the combination of the reachability of a connection, walking time, and path description allows for a quick decision. Furthermore, the participants who used the connection overview, which shows multiple stops at once, are useful. Displaying all upcoming departures at the various PT stops can contribute to a faster decision-making process. However, as the recording of their interaction with the prototype shows, eight of the participants did not use this feature to solve the tasks. Live information was said to promote trust in departure times and avoid switching the app to verification by one participant. Furthermore, another participant likes that stops with no connections were visualized in gray in one of the variants. However, the question remains whether this POI should have been displayed at all.

Next, the participants had the opportunity to mention aspects that they felt were missing. They most often stated additional information about departures as a feature, which could improve the decision-making process. One suggestion was to display the direction of each connection on the map itself. Others went a step further and proposed a feature that depicts the entire connection from the current location to the destination, not just to the next transit stop. Within this feature, the travel time of each section or the total time can be displayed and different route suggestions proposed. In this context, improved visualization of live information was also mentioned. Apart from route information, weather forecasts, and the location and other information of businesses were noted. A bad weather warning could help decide whether a shorter route to the PT stop or a longer route to a stop with better connections is more appropriate. Similarly, the occurrence of a restaurant, café, or supermarket can be decisive to with transit stop one prefers to go to.

Finally, participants answered the remaining questions about the personal data. Eight of the ten participants selected the age category of 25-34 and the others stated to be between 18 and 24 years old. Everyone decided to indicate their gender. The distribution of selected gender was relatively balanced with four female participants and six male participants.

5 Discussion

In this section, the initial research questions are addressed. All those questions are set in the context of the chosen use case of this thesis. The scenario which provides the frame of this discussion is a user who is on a hiking trip. More specifically, the final part of the trip, where a potential user would like to get home using PT. There are many existing apps, which can be used in such situations. The question is, how these can be enhanced to more effectively assist the user in planning the final stage of the trip. Especially the visualization of relevant information on map apps is a key element. To suggest improvements for apps, different aspects are discussed. These aspects are covered by the three stated research questions. The first part of this section covers the issue of which information even is relevant in a hiking scenario. The second part is about how this information can be visualized. Finally, a deeper understanding of the user's decision-making and sense-making process should be gained. Therefore, it is discussed how certain visualizations of relevant information influence users in their decision to select a PT stop.

5.1 Relevant Information

The first research question is about the kind of relevant information:

1. **What information contributes to the geographic relevance of PT stops?**

Depending on the context, the question of which information is relevant for map apps can be answered differently. The context of a hiking trip requires the inclusion of information that would not be needed in other scenarios like a more urban context. The research question is addressed by discussing the results of the context analysis from the previous section. The results from the app comparison and the survey are also taken into account for this purpose. These help to validate, which information can be considered relevant in the scenario of hiking.

Different relevance criteria, which are important in this context, were identified in the results section 4.1. Furthermore, the task of selecting a PT stop was divided into multiple steps. Each of these steps requires specific relevant information to be accomplished. Therefore, the discussion follows the order of these steps from section 4.1.4.

5.1.1 User Location

The first step is to locate the own position in space. Here, no relevance criteria can be assigned since the focus lies on the POIs and their relevance criteria. However, their relevance depends on the relation to their location in space. This is not specific to the hiking context but to any task involving space and time, as can be seen in the compared apps. No matter which purposes the apps serve, the location of the user is always displayed on the map.

Another basic requirement to be able to know the location on the map is the map itself. This can be described as the abstraction of the real-world environment. The coding and simplification of the real-world elements to a map enable the user to orient oneself. This basic informational need is closely related to the *physical space* of the user. This is also visible by looking at the difference between apps with a focus on an urban and an outdoor scenario. For urban settings, large streets, buildings, and landmarks like squares and statues are highlighted features. In an outdoor setting, particularly altitude lines, mountain tops, and lakes are displayed more saliently. However, landmarks like buildings and roads are also considered important by participants of the conducted user study, even though not being that common on a hiking trip. The assumption that elevation information is a key element for outdoor activities can be supported by the findings of the survey. No participant rated the map without altitude lines as their favorite option. Overall, most elements of *physical space* described in section 2.2.2 also enable a better orientation and therefore contribute to the task of locating the own position.

5.1.2 Selection of Stops

In the next step, the right group of POIs needs to be selected. A relevance criterion for the first filtering between different categories of POIs is *topicality* (De Sabbata & Reichenbacher, 2012, p. 1497). All elements that do not meet the specifications of a PT stop are not directly relevant to the scenario the user is situated. Of course, other contextual information can contribute to the relevance of a PT stop. However, such information is not a *fundamental criterion* and therefore discussed in the next section 5.1.3. The data set of PT stops, and their locations should match with the relevance criteria of *topicality*. However, the word “PT stop” implies that some mode of PT stops at its location, and after comparing and investigating different apps it was found, that this is not always given. There are PT stops in these apps which do not include any upcoming departures. Such a case was also tested in the user survey. It can be argued that such PT stops do not meet the *fundamental criterion* of *topicality* since it was suggested to omit them by a participant.

After identifying which of the POIs fit the category of PT stops, it needs to be estimated how far away they are. The *spatio-temporal proximity* is another criterion which was identified as *fundamental* in the results of the context analysis. To some degree, the compared apps support this statement. Centering the map view to the location of the user is a common approach by all the compared apps to point out nearby POIs. Furthermore, all of them show the distance information in relation to their location. An impressive example of this criterion is the app *Citymapper*. In an additional window, all stops are ordered in ascending order, according to the travel time needed to reach them. Such a window was also implemented in the tested prototype and specifically mentioned as a useful feature in the user study. Furthermore, explicitly showing the spatio-temporal constraints to see which connection is available or how long the waiting time at a stop is, was also considered tremendously helpful.

There is no strong evidence on which measure of proximity is best fitted for the hiking scenario. The distance as well as the travel time are considerable options. However, the travel time was considered most useful by participants to be displayed above a POI. Even though it was not compared with the distance information it underlines the importance of the criterion of *spatio-temporal proximity* in general. The travel time information might be more useful since more factors need to be included to calculate it. This would otherwise need to be done by the users themselves.

Multiple kinds of information are required to calculate how long it takes to reach a PT stop. Knowing the available paths helps to calculate how far a user must walk and how much time is needed. This relates to the *physical space* of the user. Depending on the terrain, the spatial distance information can lead to quite different travel times. The same distance downhill requires much less time than uphill. Therefore, the altitude information is also necessary to identify the walking time. Additionally, it is necessary to know how fast a potential user is walking. The results of the survey show that this is different depending on the user. Some prefer to walk faster and would also be willing to hurry if a connection can be reached. Modifying the walking speed, as it is already possible in the *Swisstopo* app, might be a good solution for this issue.

5.1.3 Hierarchy of Stops

The hierarchy between POIs can be specified with more information. One further criterion in this regard is the *availability* of information about the PT stop. Especially RTI has major benefits and is also expected by users (Lopez-Carreiro et al., 2020, p. 8). It should therefore be communicated to users if just regular timetable information instead of RTI is available. Compared apps that provide RTI have different methods to display its usage. After testing different variations in the prototype, a distinction between RTI and regular timetable information was considered helpful but not crucial by participants. However, the display of RTI overall was appreciated.

A further relevance criterion identified to establish a hierarchy between POIs is *coverage*. This criterion describes the extent to which the entity offers all the required services a user needs (De Sabbata & Reichenbacher, 2012, p. 1499). Different factors can contribute to the *coverage* of a POI. Departure and arrival time were found to be the most important information to know in a transit-related context in general (Harmony & Gayah, 2017, p. 96; Macedo et al., 2021, p.

735). When additional information about a PT-related POI is displayed, the arrival and departure times are most prominently featured in the compared apps. The departure time was also rated as one of the most useful kinds of information by participants and therefore confirms the findings from the mentioned research. The exact departure time can also include RTI. Knowing the exact state of the connection can have a positive effect on the waiting time (Berggren et al., 2021, p. 527; Brakewood & Watkins, 2018, p. 350). Having clarity about the departures is crucial to trust the displayed information (Macedo et al., 2021, p. 733). A. participant in the user study mentioned that omitting RTI would require the usage of additional apps to verify departure times. Therefore, the departure and arrival times of connections are relevant and necessary to be included, preferably with RTI. However, such information is not included directly in any of the compared outdoor-related apps. This underlines that current outdoor apps have significant potential to increase the attractiveness of PT for such activities.

In the scenario of hiking, PT stops tend to be further away and rather few connections are normally available at such stops. This was demonstrated in the scenarios visualized in the prototype. Waiting times in this scenario can therefore be much longer than in an urban context. It was therefore assumed, that whether individual connections are still reachable or not is something that determines whether a POI is relevant to users. This could be strongly confirmed by the results of the survey. Even though such information was not included in any of the compared apps, participants highly valued this new kind of information. Showing the waiting time was explicitly mentioned many times as an outstanding feature. Furthermore, a higher frequency and more services increase the probability that a user has a shorter waiting time. Therefore, it was assumed that the number of departures can also be of importance. However, this could not be confirmed by the user study since this information was perceived as too vague to create a hierarchy between POIs. The accessibility to vehicles, seating availability, and transport mode are further transit-related types of information mentioned in the literature (Harmony & Gayah, 2017; Macedo et al., 2021). A minimum fitness is required to be able to walk on hiking trails. Similarly, the seating availability can be considered less relevant than in an urban setting because of the target user group of hikers. This might be one explanation why features like ramps or barrier-free access to vehicles were not mentioned as important features by users. However, all participants stated to be under the age of 35, which can also affect the subjective relevance of such features. Furthermore, *Google Maps* and *SBB Mobile* do include information about seating availability or accessibility. The assumption that such information is less relevant in a hiking context is reasonable but cannot be fully substantiated with the used methods. The mode of transport might be of relevance too. Some of the compared apps use larger sizes for train stations. In most cases, train service is preferred over bus service because of its perceived reliability (Scherer & Dziekan, 2012, p.

90). However, in a hiking context, users tend to be more patient, which might mitigate such a preference. Overall, the user study does not reveal powerful results in that matter.

If two options are equally relevant, *secondary criteria* can provide the necessary information to decide between these options (De Sabbata & Reichenbacher, 2012, p. 1517). One identified criterion from section 4.1.3 is *directionality.* If a PT stop is in the direction of the ongoing hiking trip it might be considered as more relevant since it is not necessary to go back on the same path. However, neither in the compared apps nor in the survey could this assumption be confirmed. The criterion of *currency* is implemented in many apps and the prototype as RTI of the departures. In the conducted user study, such information was rated less useful compared to others which matches with the classification as a *secondary criterion*. The high reliability of PT in Switzerland and other factors like the difficulty of the terrain were mentioned by participants that explain this assessment.

5.2 Visualization Techniques

The second research question covers the visualization and implementation of relevant information in map apps:

2. **How can identified relevant information help to improve the visualization of PT stops in map apps?**

After discussing which information can be considered relevant in a hiking context, the visualization of this information is addressed. The literature and the comparison of apps provide concepts and solutions on how to visualize relevant information on map apps. The different approaches are set in the context of the hiking trip. It is discussed how the task of finding a transit stop can be simplified with intuitive visualizations. The single steps to find a PT stop were discussed in detail in the last section 5.1. The discussion of the second research question is structured similarly. In the first part, the focus lies on the task of locating oneself on the map. Here, the visualization of the surroundings using the background map is particularly important. The second part addresses the first layer of additional information, which is on top of the background map. After that, the information displayed in additional windows is discussed. With this form of display, the focus lies more on the hierarchy between the stops.

5.2.1 Location and Background

As discussed in section 5.1, the initial step in the process of navigating to a PT stop during a hiking trip involves determining the spatial location. Comparing various map applications reveals several standard features shared across them. Among these features is the inclusion of the user's precise location on the map using a blue marker. This is ideally accompanied by the indication of their viewing direction, which enables the user to adjust the map orientation to match the current direction. Marking the location transfers the cognitive task of the user onto the cartographic representation (Crease & Reichenbacher, 2011, p. 12). The dot on the map then works as external memory and does not need to be remembered by the user. Users seem to be very familiar with this feature. In the conducted survey of this thesis, no one specifically mentioned the location marker, but the recordings reveal that the feature to set the own location to the center of the screen was used multiple times.

Next to the marker, the map itself needs to provide the context information. A universal principle is a clear demarcation between the map's background and foreground (Swienty et al., 2008, p. 232). This is seen in the compared apps. The background map does not stand out but offers an overview of the surroundings. The location marker is distinct and prominently visible. It therefore quickly draws attention to the user's location. There is some variety between different apps but all of them follow the general principle of *visual hierarchy*. From the comparison, it is apparent that apps that are designed for hiking include more information in their background maps than the others. Balancing the provision of information with visual clarity is crucial. An overload of information or excessive saliency in the background can divert attention from the most relevant information in the foreground (Swienty et al., 2008, p. 232). This balance ensures that the background enhances rather than distracts from the user's navigation experience. Especially with maps serving an outdoor activity, it is more difficult not to overload the user with information, since more information is required. However, outdoor-related apps that were compared managed to include more information on their maps. In addition, participants of the survey also advocated for the map with more information, despite being more cluttered.

Given the user's need for orientation, landmarks play a pivotal role within the background map, which was discussed in detail in the last section 5.1. Mountain tops are specifically important and relate to altitude information. They are not distinctive for the hiking context but are visualized in different ways depending on the focus of the app as seen in the app comparison. It seems that on a hiking trip, the tops of mountains serve for orientation and understanding the terrain. Map apps that are not solely for hiking, often do not include all mountains. If they include mountain tops, additional information like user ratings seems to be more important. *Google Maps* for example visualizes the most iconic mountains using markers that provide such information.

One distinct feature of outdoor maps is altitude information displayed with lines. Since walking distances are normally longer and the terrain can be more complex while hiking, the altitude information was identified as a distinct part of the *physical space* in a hiking environment as seen in section 2.2.2. That maps without altitude lines are not usable in a hiking context is emphatically mentioned in the survey. Being able to detect how steep certain paths are or how many meters need to be climbed was considered necessary for a successful planning process by participants. The level of detail concerning small footpaths also differs. Since trail options are very important on a hiking trip, even small paths tend to be visible on the investigated outdoor map apps. Additionally, information on the condition of trails is often included in such apps, which is not featured in the compared apps with a focus on a more urban context. In Switzerland, the difficulty of hiking trails is color-coded (ASTRA, 2013). The quantitative *visual variable color hue* is used and shows easy trails in yellow, mountainous trails in red, and alpine trails in blue. The difficulty of a path can be visualized by displaying the path of the corresponding *color hue*. This visualization was also used in multiple variations of the app prototype and none of the participants had trouble understanding the color coding of hiking paths. Other contextual information like vegetation zones is more saliently visualized as well in the compared outdoor-related apps. This is not surprising, since there are fewer buildings or other features which would help with the orientation in an urban context. Furthermore, a user can draw more information from such distinctions. Knowing if there is a forest, glacier, or wildlife zone is crucial to plan the walk through such environments. Forest for example could provide shade, passing a glacier or a wildlife zone requires special attention and is no reasonable place to rest. This is apparent when considering comments from the conducted survey which refer to the background map.

5.2.2 Displaying Relevance of POIs

The available transit stops are the locations a user wants to go to since they enable the usage of PT. They are added as a layer onto the background map. Again, the *visual hierarchy* is a key concept that supports the user's visual scanning process (Swienty et al., 2008, p. 232). Therefore, POIs need to be easily noticeable. Placing them in the foreground by using distinct *visual variables* highlights the relevant information and is implemented in all of the compared map apps. A classic and well-known design for POIs is a point or bubble-shaped object, which highlights them from the background (Yu et al., 2013, p. 174). This design and the general concept are not exclusive to the hiking context. However, how POIs are highlighted from the background differs depending on the scenario. To avoid clutter on the map, which is even more important on mobile displays (Setlur et al., 2010, p. 2), irrelevant features need to be filtered out. Following the criterion of *topicality,* a layer with transit stops as a filtering option could be implemented. However, a very similar option which is more popular in the compared apps is to provide activity-related layers with combined topical information from multiple sources. One example would be the hiking layer in the *Swisstopo* app. With this adaptable map element, users can take control of the displayed information. If apps have a rather narrow focus solely on PT like the *SBB Mobile* app filtering might not be necessary since it already fits the design principle of *simplicity*.

However, for broader use cases multiple types of POIs must be visualized at the same time. The *visual variable color hue* is suitable for distinguishing POIs depending on their category (Slocum et al., 2022, p. 69). This technique is used in the compared map apps that have a broader focus. In the case of hiking, there are different types of potentially interesting POIs like businesses, water fountains, or transit stops as mentioned in the survey. Blue is a commonly known *color hue* to be associated with PT stops as it is used by all compared apps. Particularly in Switzerland, since the SBB always displays PT stops in this *color hue*, which is also evident in their app.

A special way of filtering implemented in *Google Maps* is to show features of the same category in grey if they do not match the needs of the user. In a hiking context, this could be an officially marked PT stop that has no upcoming departures. The POI does not fulfill the need of the user at the moment of the query, but it still can be identified as a PT stop. Using a grey *color hue* for such POIs clearly communicates a lower relevancy level. Since there are only two possible display options POIs of the same group can be divided into the two categories of relevant and not relevant ones. If there are more categories, a quantitative *visual variable* like *size* or *transparency* is better fitted since a *visual hierarchy* could be communicated like this (Garlandini & Fabrikant, 2009, p. 209; Oliveri & Reichenbacher, 2021, p. 2). The grey *color hue* of PT-related POIs with no departures was tested and correctly read by most participants of the conducted study. However, as discussed in section 5.1 it can be argued if such POIs should be included at all.

The type of transit mode available at a stop can also be visualized using a pictogram and is used across all compared apps inside their markers of PT stops. This practice facilitates quick recognition and categorization of PT-related POIs, supporting users in identifying their preferred modes of travel. *Size* is also a *visual variable* that was shown to communicate relevance very efficiently in general (Slocum et al., 2022, p. 69). However, it is particularly difficult to use on mobile devices because of the small screen (Setlur et al., 2010, p. 2). Even though the *visual variable size* was used in most compared apps to highlight train stations, this might not be a sufficient criterion to create a *visual hierarchy* between POIs. No matter the mode of transport, a POI could be equally relevant to get to the desired location. In the conducted user study, the preference for which PT stop was chosen was never justified by the mode of transport. One explanation might be, that since there are normally not many options available, every PT stop which offers connections can be of relevance. Furthermore, a large icon covers more of the background. Larger amounts covered in the background could be even more severe with a higher density of elements, which is common in a hiking context.

Relevant to the user is the *spatio-temporal proximity* of a POI, which can be read to some extent from the background map according to statements of participants. However, since this information is considered a *fundamental criterion* (De Sabbata & Reichenbacher, 2012, p. 1517), a text above the POI could be of use to display that kind of information. Text can be useful for communicating specific information that cannot be easily read from quantitative *visual variables*. This is also implemented in compared apps that use text to show which lines depart there or how busy it is. However, the outdoor-related apps did not communicate any information using text apart from the name of the PT stop. In general, POIs that represent PT stops are displayed very statically in those apps and none of them directly include timetable data. PT in general does not seem to be acknowledged as relevant information from those apps. One reason could be that the availability of PT is not as large in other countries compared to Switzerland or that the implementation is technically demanding. Nevertheless, it is evident from the conducted survey that PT-related information using text is helpful while hiking. However, using text for specific information is only used in higher zoom levels in the compared apps. A reason might be that text has the disadvantage of needing much space on a small screen. This can be confirmed by participants who did not like this visualization technique when the text was rather long.

The travel time as well as the number of departures can imply a hierarchy between POIs. By just using text, the different relevance levels only become clear, when the information above all POIs is read. A solution to make this hierarchy more saliently visible is the use of quantitative *visual variables*. Since *transparency* was identified as the most effective qualitative *visual variable* it was assumed to be effective for visualizing a hierarchy between POIs (Oliveri & Reichenbacher, 2021, p. 2). However, *transparency* was not considered a useful display method by participants and was not implemented in any of the compared apps. One explanation could be that combining a long text above a POI with a transparent marker requires much space and is visually overloaded. Participants stated that it is hard to even see the transparent POIs on top of the cluttered background. Therefore, transparent POIs tend to disappear which makes the quantitative variable of *transparency* rather unsuitable in the chosen scenario.

5.2.3 Visualizing Additional Relevant Information

Since there is a lot of relevant information that helps the user to make decisions, tapping on a POI should reveal more than what is initially shown on the map. Additional windows and map elements are possible solutions, which are commonly seen in map apps. This section delves into the design principles that should govern the visualization of additional information associated with PT stops in a hiking context. If additional information is displayed on the map and in an additional window, the window does normally not cover the whole screen. The map is still visible but takes up less space to fit the additional window. A more advanced design is if the size of the window is adjustable to different sizes and seen in most of the compared apps.

Being rated as the most important information in several papers (Cláudio et al., 2011, p. 14; Garlandini & Fabrikant, 2009, p. 209), the departure times of the upcoming connections are commonly implemented in PT-related apps. Since these departures are also relevant in a hiking context as seen in section 5.1, this should be added to such apps as well. The departure time together with the line information and destination of the vehicle is frequently visualized in an additional window of the compared apps. More specifically, each information of a single connection is allocated to its own box. These boxes are displayed on top of each other and sorted according to the closest departure times. Furthermore, RTI was found to be a key component of the departure information (Harmony & Gayah, 2017, p. 96). The *visual variable color hue* is again well fitted to symbolize this by showing a delay in red and a punctual connection in green as stated by participants of the survey. The red *color hue* is frequently used in transit apps displaying delays as seen in *Google Maps.* Service disruptions seem to be more frequently shown in transit-related apps that do not focus on maps such as *SBB Mobile*. This can be explained because of the higher amount of available space in these apps since no background map needs to be visible at the same time.

The *availability* of information was seen in the compared apps, which did not focus on outdoor activities. The design varies but if no data is available, it is normally written in the space where otherwise the connections are displayed. Like this, it is clear to the user if there are just no upcoming departures or if there is no data. Furthermore, RTI is not always available either. A delay can normally only be stated if a vehicle is already in operation. Therefore, a distinction between connections with and without RTI is desirable. One indication can be an additional symbol like a pictogram symbolizing a signal or text information. Both proved to be successful in communicating if RTI is present in the user study. Nevertheless, using text caused less confusion among participants.

The already mentioned RTI is relevant for PT use in general. Therefore, apps with a focus on this topic already provide different implementations. However, apps that are commonly used for planning hiking trips do not seem to include this kind of information. Furthermore, information that is specifically relevant in a hiking scenario regarding PT like the waiting time is not visualized in any of the compared apps. The waiting time and which connection can be caught is a new kind of information users are not familiar with. To avoid confusion the visualization needs to be as clear as possible. Using text information is an unambiguous way for this matter. To further improve the clarity, the metaphor of the traffic light and the corresponding *color hues* was used in the prototype to show the state of the connection. This metaphor is widely known and recognized by potential users (Cila et al., 2014, p. 258). Red is associated with stopping and can be used for connections that are clearly not reachable anymore. Orange is associated with being in between red and green, which is why this *color hue* is suited to display connections that may not be caught. The green *color hue* indicates a state that approves moving and can be used to show the waiting time. The metaphor proved to work in the survey of this thesis and did not confuse participants. That multiple connections with different statuses are visible at the same time might contribute to its successful implementation.

As discussed in the previous section 5.1 more specific path information is relevant while hiking. This can be accomplished by visualizing such information on the map or in an additional window as seen in the compared apps. From existing route planning functions of apps, a visualization of the path to a transport stop was adopted in the prototype. Due to the difficulty of a trail, it is possible, that a user wants to take an alternative route apart from the suggested one. Therefore, a dotted path is likely to be a good solution because the underlying path is still visible. This is particularly important if the difficulty of the trail is indicated by its *color hue*, which should not be covered with the suggested route. However, the survey cannot support this assumption since participants did not mention it. Many apps also display some kind of distance information. The background already provides information about the *spatial proximity* of POIs. However, the travel duration is commonly visualized by showing the walking time in a small bubble next to the visualized path like it is done for example in *Google Maps*. Furthermore, a height profile visualized in an additional window is used in the compared outdoor apps. Meters up and down, distance, and travel time information are visualized in these apps and were also implemented in the prototype. Participants described such additional information as intuitively understandable and had no issues understanding it.

As elaborated before, there are a lot of different kinds of information that must be considered to find the optimal PT stop. Making a quick decision is therefore not always possible by looking at the POIs visualized on a map, which only display a limited amount of information. Comparing all the different options in their entirety therefore requires the selection of every available POI. This can potentially cost a lot of time. One way to overcome this issue is to add an additional overview window. An example can be seen in the app *Citymapper*. Such a window contains all the departures and travel time information from each PT stop in one window. This feature enables the user to compare all the available connections from different PT stops at once. Therefore, it was implemented in the prototype. It covered the background map completely. However, the departure time, which is considered as most valuable information (Harmony & Gayah, 2017, p. 96), is visible at first. The path information is visible in a second step by selecting one specific PT stop from the overview window. Like this, the user navigates to the window of a single POI, which is more detailed but only contains information from one POI. Thus, the specific information about the trails is visible after the departure time.

5.3 Support of the Decision-Making Process

The last of the three research questions focuses on how decisions are made by users:

3. **How can an improved visualization of PT stops support users in their planning, decision-making, and sense-making processes?**

With the first two research questions it was discussed, which information is relevant and how it can be visualized for the scenario of hiking. Understanding how improvements in map apps enable more effective communication of information is addressed in this final section of the discussion. With the prototype, suggestions from the context analysis and the comparison of apps were implemented and tested in a survey with a focus group of ten people. The results of section 4.3 provide information about the extent to which different presentation methods helped participants in making decisions. Like the discussion sections before, this section is structured according to different elements of the app. More precisely, the information about the surroundings in the form of the background map, the information displayed using POIs on a map, and the visualization of additional information inside sliding windows.

5.3.1 Type of Background

Participants liked background maps with rather more elements, which is not surprising. The hiking context requires more information on the terrain and certain landmarks, which is better covered by maps with more information on it. More information in general enables better predictions of the path to come, which is crucial in alpine areas and was mentioned by most participants. The orientation is supported as well with such background maps. If features like mountain tops, land surfaces, path types, and most importantly altitude lines are missing, the map itself does not contribute enough to the decision-making process. However, the usability of specific landmarks was never mentioned explicitly by users. One reason could be that these are essential to the extent that they are no longer consciously perceived.

What was mentioned explicitly by almost all participants was the altitude information. Path and height information was overall considered as very important information too. Looking at the recording, participants seem to estimate the route to the stops from the beginning using the map information before selecting their first PT stop. How strenuous and long the way to the PT stops is, was considered when POIs were selected in the task. This is visible in situations where participants picked POIs that are easier to reach, although the waiting time was longer. One participant mentioned that even though the most basic map seems to enable a quicker overview of the whole area, the altitude lines are needed to read the topography from the map. The steepness of areas and how possible paths look are understandable with the displayed height information. Participants with less hiking experience did not describe the use of altitude lines as specifically as more frequent hikers. This indicates that some experience with complex maps is required to use them effectively. The experience also transfers to the popularity of the background map from Swisstopo. Most participants are familiar with the style of this map, which makes it easier to extract and use the visualized information. For less familiar users, the map was considered too cluttered and therefore not as useful as the map of OSM with slightly fewer elements.

A distinct visualization of roads and paths with their difficulty through using a specific *color hue* is considered crucial as well. A realistic size ratio compared to the real world was specifically mentioned as useful to decide between different PT stops. A possible explanation could be, that real distances and sizes matter more in a hiking context. Estimating if a shortcut over unmarked paths or the crossing of the street is possible, does not work with a higher level of abstraction.

5.3.2 Informational Content of POIs

Communicating relevant information directly with a proper visualization of POIs enables users to quickly make decisions. Being placed in the foreground as an additional layer on the map, they attract the user's attention. Since there is not much space, not every kind of information can be visualized at the same time. When participants spotted POIs on the map, they selected them to get additional information because the displayed information on the map was not sufficient to make the final decision about where to walk. Which PT-related information is displayed initially on the map, influences which POI is selected first. This can be seen in the answers of the participants in which they state what information is needed in the first or second place. The answers to the survey show, that there are different preferences among participants. Some prefer the least strenuous route possible, and others want the fastest possible connection. These preferences were also taken into account when determining the type of information, which should be visible directly on the map.

Among the participants, the number of departures emerged as the least favored option. This can be attributed to the higher perceived importance of the other tested choices. Furthermore, some participants found the concept of "number of departures in the next hour" too vague. They noted that since precise departure times, waiting durations, or directions were unknown, this information alone was insufficient to assess the relevance of the POI. Displaying the walking time or that no departures are available directly on the map was regarded as more helpful. In addition to the perceived lack of clarity in the information provided, participants also criticized the visualization, which was previously discussed in section 5.2.2. However, the nature of the information was most prominently mentioned as a problem. Therefore, the *visual variable transparency* might be better suitable to communicate more objective relevance criteria in other contexts.

Regarding the POI which does not provide any departures, the combination of grey *color hue* and text was effective in communicating a lower relevance. The grey *color hue* attracts attention and symbolizes a lower relevance. The text above the POI explains the reason for the lower relevance: The missing available departures. As expected in section 5.2.2, participants understood the use of the grey *color hue* immediately. However, one participant was confused as to why the POI with no departures was displayed at all. Removing POIs from the map that lack connections could resolve the dilemma of what information to display due to space constraints. However, it is essential to reflect on why there are no departures available for display. Sometimes there is no timetable data available for cable cars or ski lifts since they run continuously. Furthermore, the PT stop could be relevant on another day of the week or another time of the day. Knowing that the PT stop itself exists, can therefore still be of importance to obtain a full picture of the surroundings. However, a POI not showing any departures happens rather rarely.

Utilizing both textual information and pictograms to convey walking time proved to be highly effective and did not lead to any misunderstandings. A short walking time was mentioned as important to know since the users are at the end of a hiking trip and potentially tired. Furthermore, participants stated that there is no hurry on a hiking trip. Therefore, longer waiting times are accepted in favor of a shorter walk. All these factors contribute to the relevance of the time needed to get to a PT stop. It appears that the number of minutes serves as a satisfactory measure for describing the proximity of POIs to the user. Notably, none of the participants suggested that distance and altitude differences would be a better option, as it was previously established that this information can be estimated by examining the map and its altitude lines. Therefore, displaying the walking time first is probably useful in more scenarios.

5.3.3 Sliding Window Information

Information in the sliding windows is an addition to the already displayed information on the map and is more specific. Users can compare the different properties of PT stops in more depth and make their final decision. Looking at the favored version it becomes clear, that multiple kinds of information are considered by participants to help in their decision-making process. The new feature of displaying the waiting time as well as the departure information in real-time was positively mentioned in the text answers. Participants described that all the important information is visible at once and it is therefore most useful instead of just showing one of them. One concern was that this could cause a conflict since displaying both kinds of information would result in a lack of clarity. It was pointed out that displaying less information may be an optical improvement. However, participants explicitly stated that not seeing both kinds of information at the same time would result in a lack of information. Similarly to a detailed background map, a large amount of displayed information does not seem to be an issue for users who are familiar with the usage of outdoor-related apps. The explanation could again be the familiarity with more complex information like the Swisstopo background map. Furthermore, all participants stated to be under the age of 35 which is associated with a higher app usage in general compared to older age groups (Berggren et al., 2021, p. 525).

Surprisingly, some participants found the version that only includes real-time information on the departures most confusing, even though less information is visible overall. The description that a connection is delayed with the crossed-out original departure time was not clear to everyone. With the minutes until the next connection departs additionally displayed on the right, this seemed a bit redundant for some participants. The version including the waiting time and the delay was more clear because of a slightly different display of delayed connections. Here, a plus sign with the number of minutes the connection is delayed was used. The less descriptive display just using the plus sign was more intuitive to participants. The plus indicates that an addition to the originally scheduled time is necessary. This is not the case with the description that a connection is delayed. It is not communicated, if the delay needs to be added to the originally scheduled time or not. Furthermore, the *SBB Mobile* app also uses the plus sign to communicate delays. Since all participants are very familiar with this app, this could be another factor that explains why participants like the version with the plus sign. If a connection is on time was also displayed slightly differently in both versions. However, there were no issues with the clarity regarding both versions. This is not surprising, since an on-time connection always arrives at the scheduled time and there can be no confusion if the delay needs to be added or not.

The variant that only shows the waiting time does indicate if the information is in real-time using small yellow arcs, which look similar to the Wi-Fi symbol. These were less specific as it was not possible to tell whether a connection would be on time or late. This was also mentioned to be less clear compared to explicitly showing if a connection is on time or delayed. It was only clear that the connection should depart in the specified number of minutes. *Citymapper* uses a similar visualization of RTI. Since most users are not familiar with this app, this symbol of RTI does not seem to be known but is still intuitive to some extent. RTI in general was considered less important than the waiting time as most experiences in Switzerland have been positive with reliable connections. However, RTI was also described to positively influence the trust in the reliability of departure times by a participant. Therefore, double-checking the departures in another app would not be necessary anymore. This aligns with the literature, where increased trust was stated to be a positive aspect of RTI (Macedo et al., 2021, p. 733). This variant which does not show the exact delay was not rated worst by participants. One reason for this is, that the departure time is still indicated on the right in minutes or with a clock.

Most importantly, the feature showing if a connection is reachable or how long the waiting time is was acknowledged as very useful by all participants. This was most often mentioned when asked which features stood out positively across all different prototype variants. Since the waiting time can be calculated using the departure and walking times, participants considered the departure time still as slightly more important. This is in line with previous research, where the departure time is considered as most important in a transit context (Harmony & Gayah, 2017, p. 96; Macedo et al., 2021, p. 735). Nevertheless, knowing if a connection is reachable and how long the waiting time is reduces the cognitive load of a user. In the answers, it was clearly stated that not needing to calculate it saves time and therefore helps to decide quickly. The traffic light metaphor was generally accepted and enabled a quick recognition of the different categories. What was questioned is, how it is calculated if a connection is not reachable in time or may not be caught. In one case, a participant even decided that even though a connection was displayed as not reachable, it would nevertheless be possible to reach it. In the compared apps, there is no need to handle this issue since the reachability of a connection is not indicated in any of them. Users always decide for themselves, whether they can still reach this connection or not. Even though such a feature is appreciated in a hiking context, users like to have control over the assessment of the reachability of POIs. This is in favor of an adaptable system, where users can change this parameter in the settings. With such a setting one could argue that connections which are not reachable in time are not relevant. Therefore, the display of these unreachable connections might not be necessary anymore or just by scrolling upwards. This is similar to the compared apps which show the departures at the PT stop. Only the connections that are in the future are displayed. Scrolling upwards reveals earlier connections.

Another feature that stood out positively was the overview window where all PT stops and their connections are visible at the same time. Although this window was described as decisive in selecting a POI, the recordings show that it was rarely used overall. Again, the lack of familiarity with such a feature is a likely explanation. This feature is only implemented in the *Citymapper* app. If this feature of the overview window was used, it was selected before selecting any specific POIs. Seeing all connections at once enables the user to directly identify the most relevant option. Afterward, the specific information of the path on the map and the height profile can be used to identify the best suitable option by selecting specific PT stops. Another observable use case of this feature from the recordings is that after selecting every PT stop, the connections do not need to be remembered since they are simultaneously listed in the overview window. Through this, it is possible to verify whether the selected stop is the best option without needing to switch between multiple information windows of POIs. Therefore, this overview window is a promising feature that might be very useful if users get more familiar with it.

5.4 Limitations

This section is divided into three parts where the different limitations of each method are described. The first part is about the limitations of the context analysis. The second part deals with issues regarding the comparison of different apps. The last part addresses the limits of the informative value from the conducted focus group survey.

5.4.1 Context Analysis

The analysis of the context using multiple concepts from literature provided insight into which informational needs a user has. The user is situated at the end of a hiking trip somewhere in Switzerland. The start and end points should be accessible by PT and a smartphone with map apps is available as an information source. A major limitation is the scope of the analysis. The focus lies on one specific part of the action sequence of getting home. More specifically, the process of deciding which available PT stop to go to. Other informational needs from different sections of the hiking trip are not considered, even though map apps normally serve a larger purpose. An app that targets a broader user group results in a classic problem in information retrieval, which is a usability tradeoff (Bartling et al., 2022, p. 237). This means, that the design is not always satisfactory for all users and situations. To be able to make clear statements, the use case was intentionally set to a specific situation. All possible use cases might not be considered like this, but this allows for a deeper analysis with more meaningful results.

The context can result in different information needs depending on the user and their different backgrounds and preferences. The preferences can also vary depending on socio-demographic factors like the age of the user (Berggren et al., 2021, p. 525), which were not specifically considered in the identification of geographical needs. One example of different preferences can also be seen in the result section 4.3.2, where different PT stops were preferred even though the setting was the same. To avoid major cultural and social biases, the scenario was set in Switzerland and the participants were only selected if they had some experience with using PT and map apps for a hiking trip.

The resulting informational need and possible display options are always dependent on the technological factors described in the *system space* of the *Mobile Usage Context* in section 2.2.2. These are based on assumptions that may not be true depending on the situation. An internet connection or necessary computing capacity may not always be available. Additionally, the weather conditions and their influence were not explicitly considered even though they could influence the preferences of users and also the smartphone usage. The screen might not be visible with a high solar irradiation or not navigable if it is raining. Such factors were not included since these would be hard to evaluate with a user study.

Furthermore, the focus was set on potential new features, which rely on these digital possibilities.

Context analysis involves interpretation and judgment to describe information needs from contextual factors. The perspective and biases of the study organizer can therefore influence the interpretation of the situation and potentially lead to subjective conclusions. This is particularly true for the identification of relevance criteria from section 4.1.3 and the detailed description of steps from the user task in section 4.1.4. However, to allow for a more objective assessment, these criteria and the resulting design elements were tested in a user study, where additional views were included.

5.4.2 App Comparison

With the comparison of different mapping apps, the visualization of information identified as relevant information can be observed. The design of such apps can provide valuable information about which information is highlighted depending on the intended purpose. With five compared apps in total, the selection only offers a limited insight into which features are commonly used. A broad variety of different apps was chosen to overcome the issue of too similar features. Using a smaller number of apps, they could be compared in more detail.

Since all apps should be available in Switzerland, popular apps from other regions were not compared. Different features or data based on the region that are not available in Switzerland can therefore not be considered. Furthermore, regional differences also occur inside the same app if it covers multiple areas. *Google Maps* and *Citymapper* show different kinds of visualizations and informational contexts depending on the region. Examples would be another icon for the metro system of the city or the availability of movement information for buses in other countries. However, only apps that work in Switzerland were chosen to increase the comparability between them.

The compared apps target multiple user groups. The preferences and expectations of users can therefore vary depending on the app. These differences can lead to features that are not available in all apps, which makes a comparison harder. Furthermore, similar features with different variations or data sources might not work the same but are still listed in the same category. These apps are designed for different purposes which results in specific design challenges. *Google Maps* for example provides multiple categories of POIs and to filter them requires a rather complex relevance assessment of POIs. *SBB Mobile* does not need to deal with this problem since only transit-related POIs are shown on the map. Like this, the purpose influences which features are implemented and how they look like. Accepting the difficulty of comparing the chosen apps was a deliberate choice to ensure an overview of a broader range of features.

The focus was set on which app features are implemented, how POIs are visualized, and which additional information is shown after interacting with a POI. This enabled an exploration of the full potential of new features. Therefore, performance and reliability are factors that were not considered. Nevertheless, how often apps crash or which information is available offline can be an important factor for the user experience in a hiking context. The assumption is, that all the requirements are given that let the user enjoy the full width of app functionalities. Therefore, the results of this thesis do not indicate how design choices affect performance or which information can be provided without optimal conditions like having internet access.

Apps change over time. This thesis provides a snapshot of the most recent design of those apps. However, planned updates or new features might change their design and functionality. A comparison might therefore be outdated if new versions are released shortly after this analysis.

5.4.3 Prototype Evaluation

The design of the prototype is based on the findings of the app comparison and context analysis. Therefore, the limitations described for those methods also impact the prototype. Design choices and features relate to the compared apps. The window which shows multiple PT stops and their departures as in the app *Citymapper*, is also implemented in the prototype since it was considered as potentially useful in a hiking context. Similarly, the assessment of *transparency* as the most effective quantitative *visual variable* found its way into one version of the prototype. Therefore, a different assessment of the relevant information in a hiking context or another selection of apps could lead to a different design of the prototype. A large variety of nine different variations with a diverse focus was implemented to counteract this issue.

Next to design choices, there were also technical challenges. Some features that are common in map apps could not be implemented due to the limitations of *Figma*. Zooming using two fingers was not possible and required the use of an additional button. Like this, only two zoom levels were available. Furthermore, the background map always showed the same amount of information. A generalization depending on the zoom level could not be achieved. During the survey, it was clear that participants tried to zoom in using two fingers to see more detailed information. With the availability of this function and a different amount of information available depending on the map scale, the behavior of participants might be different. However, overall *Figma* served as software with powerful tools to create a realistic-looking prototype and participants had no trouble interacting with it.

This thesis specifically focused on the situation where potential users select a PT stop to get home. The route planning tool is a feature that was not provided in the prototype since this does not directly relate to the task of finding a PT stop. However, these are commonly found in transit-related apps and were also mentioned by participants as beneficial features. Knowing exactly where the bus goes or getting specific route suggestions for the whole path home, could influence the user's assessment of relevance. Testing the usefulness of these features and how they contribute to the decision-making process might therefore be interesting for future research.

Three scenarios in different locations were set up for the tasks which were solved. The surroundings and available options might also influence the decision-making process of the user. A more alpine setting for example could lead to a different perceived relevance of specific trail information. Some participants might also be familiar with a region and include information like nice viewing points in their decision-making. However, such information is not available to every participant since it is not displayed in the prototype.

The user study conducted with ten participants to solve tasks and answer questions also has certain limitations that should be considered. The study's small sample size of ten participants, who are recruited from the extended environment of the study organizer, might impact the generalizability of the findings. This small size was chosen in favor of more qualitative feedback from the participants.

Another limitation is that all participants chose an age category below 35 years. Potential users of a higher age group were found to have different preferences but were not considered in this survey (Berggren et al., 2021, p. 525). However, a younger user group might give more detailed qualitative feedback due to their experience with modern technologies like map apps.

Familiarity with certain apps influences the results. Participants frequently use map material provided by the federal office for topography used in the *Swisstopo* app. Similarly, *SBB Mobile* is known and used by all participants frequently. The familiarity with those apps was explicitly mentioned by most users and affects preferences that are in favor of the mentioned apps. However, knowing which features people in Switzerland are familiar with can help to design better features for this user group. Nevertheless, people who are less familiar with the activity of hiking or are not used to these apps might give different valuable insights. A larger-scale study with a more diverse and randomly selected participant pool could potentially enhance the quality and breadth of the results.

The design of the survey is meant to provide insight into the decision-making process of the participants. Because of the rather low number of ten people contributing to the survey, the focus was set on qualitative feedback. Quantitative measurements must be treated with caution and must always be set into the context of the qualitative answers of participants. Therefore, which features are the most popular ones among participants do not accurately represent the entire target population. Furthermore, the questions are set in a fictional scenario in a silent room. Participants might struggle to accurately recall past experiences, leading to answers that might be different in a real-world setting.

By changing the scenario between the tasks, it was tried to keep the survey interesting. Nevertheless, answers might be more rushed in a later stage of the survey because participants get used to solving the task. For a user to be able to answer the questions about the overall prototype, they are placed at the end of the survey. Things that come to mind during the solving of tasks but are not covered with the posed questions might be forgotten until the participant reaches the more general questions. Therefore, the ordering of questions might affect the responses.

6 Conclusion

The objective of this thesis is to give insight into how current mapping apps can be improved. Three major issues were identified and addressed with a mixed-method approach. The first issue was about which information is relevant to a user. The second issue covers the optimal visualization of relevant information. Finally, how visualizations contribute to the decision-making and sense-making process of users was addressed as the third issue.

6.1 Insights and Key Findings

By specifying and analyzing the *Mobile Usage Context*, criteria for geographic relevance were identified. The scenario of the user who wants to end the hiking trip generates a different informational need compared to an urban context. *Fundamental criteria* identified were the *topicality* and the *spatio-temporal proximity*. POIs which are PT stops and in reach of the user are most relevant and therefore indispensable. Other POIs which do not contribute to the user's task are to be excluded. Next to those *fundamental criteria*, the *coverage* of a POI and *availability* of information are *primary criteria* of relevance. Whether a POI satisfies the user's needs depends on multiple factors. Most importantly, a PT stop must provide suitable connections to transport users to their desired location. Furthermore, the accessibility of the PT stop contributes to its relevance. More specifically, path information like trail difficulty, distance, and altitude. The resulting travel time in combination with the upcoming departures needs to be considered to calculate if a connection at the PT stop is reachable. The resulting waiting time is very relevant to users of such apps. Finally, *secondary criteria* were identified. If PT stops are in the direction of travel and if the provided information is current were identified as *secondary criteria* of relevance. The provision of RTI makes one of two similar POIs more trustworthy and therefore more relevant. However, no statement can be made if a POI is more relevant if it lies in the direction of travel.

The comparison of map apps that are related to transit usage or hiking gave insight into which features are commonly used. Furthermore, it was assessed how relevant information is visualized in current apps and if they follow design principles from the literature. It was revealed that all apps have a self-location feature that shows the user's location including the viewing direction on the map, which enables users to transfer this task onto the representation. Almost every app provides some kind of filtering option, but this depends on the purpose of the app. If the focus is more specific, less filtering is needed since most displayed POIs should be relevant to the user. The purpose of the app also influences how the background map looks like. All apps established a *visual hierarchy* between the foreground and the background. However, outdoor-related apps include more map elements than apps with a more urban or multi-use focus. Landmarks like mountain tops, land surface cover, or water bodies are more highlighted in apps with an outdoor focus. Furthermore, altitude lines and specific additional path information are common and useful in outdoor-related apps. Apps used in urban settings provided more information on PT stops in the form of different *color hues*, *sizes*, and text above the respective POI. This divide between outdoor and urban-focused apps becomes more evident in the additionally displayed information. A schedule with RTI and route suggestions including PT is only implemented in apps with a transit focus. Apps that can be used for hiking do not include such detailed transit information and only refer to other apps. Innovative features and dynamic visualizations are not commonly used in outdoor apps. Especially by adapting features to fit the context of hiking, outdoor apps could benefit from more implemented information.

Finally, insight into how users benefit from the displayed information to effectively make a decision was investigated. A prototype was designed based on the previous findings and tested by a focus group of ten people, which provided valuable qualitative feedback. It was revealed that a higher complexity is generally accepted in the scenario of hiking. Users of outdoor-related apps appreciate a large amount of information and are used to a more cluttered visualization. Altitude lines and the already mentioned landmarks in outdoor apps are crucial to assess the difficulty of paths to PT stops. In general, a more dynamic visualization including specific contextual information was highly appreciated. POIs were visualized with different kinds of information and designs. The travel time displayed as text above the POI proved to be most relevant as the first information to be provided to the user. Greying POIs that do not provide departures seems to be more controversial. However, the number of departures with different *transparency* levels is not suitable as the first visible information because it was too vague for a relevance assessment. Particularly important for the final decision was the additional information after interacting with a POI. Indicating if a connection is reachable by displaying the waiting time was very effective in a hiking context. Furthermore, RTI of departures and delays was well known and appreciated. Showing all at once for each available connection provided the best overview and enabled effective decision-making. The feature displaying connections from all relevant POIs was appreciated. However, since participants were not familiar with this feature it was barely used.

In conclusion, the observation that outdoor-related apps only provide very static information could be confirmed. Users would benefit from a dynamic display of specifically customized information depending on the context. A more advanced display of PT-related POIs, as well as additional information after interacting with them, offer the highest potential for improvement in outdoor-related apps. The results of the survey indicate that even more additional information than tested could potentially benefit users in their decision-making process.

6.2 Future Research

Improving mapping apps is a complex matter and requires interdisciplinary research efforts. The mixed method approach applied in this thesis is suited to cover such a broad topic. However, considering the specific focus and limitations, several possible improvements and future research topics can be addressed.

The focus of this thesis was set on the task of finding a PT stop at the end of a hiking trip. Most apps are meant to cover a broader range of tasks. Therefore, future research also needs to address other information needs resulting from different scenarios. In this thesis, the needs were identified using a context analysis, which relied on previous research. To gather more reliable and specific information, other approaches can be beneficial. Measuring eye movement and other interactions in a larger user study could provide a deeper insight into the behavior of potential users.

The comparison of the five apps presented is a snapshot of the existing app landscape. Future research could expand this approach to include a broader array of apps, encompassing a larger spectrum of user demographics, geographical regions, and use cases. This expansion would yield a comprehensive overview of trends, gaps, and opportunities within the current landscape of apps.

The qualitative user study underscored the importance of user feedback in assessing the prototype's effectiveness. Participants indicated that additional information about the waiting situation and connections would be beneficial. An improved version of the prototype would be needed to test such implementations. Future research could therefore incorporate iterative prototyping, engaging participants in successive rounds of testing and refinement. This iterative approach allows for the identification and rectification of usability challenges and design limitations, leading to a prototype that optimally aligns with user needs. Furthermore, participants were required to recall past experiences while solving the tasks. Letting users solve tasks in real-world scenarios could therefore avoid inaccuracies in responses.

This thesis provided suggestions on how to improve current mapping apps. One single app cannot be perfect for everything or everyone. The usefulness of an app changes depending on the experiences, scenarios, and preferences of its users. Nevertheless, some principles should be followed to provide adequate and usable map apps. Analyzing the context of the hiking scenario, comparing apps, and evaluating a prototype provided a comprehensive understanding of user needs and app design dynamics. Further research will give more insight into how to identify and visualize relevant information. Accomplishing this task can only be achieved with a collaborative effort from different fields of research.

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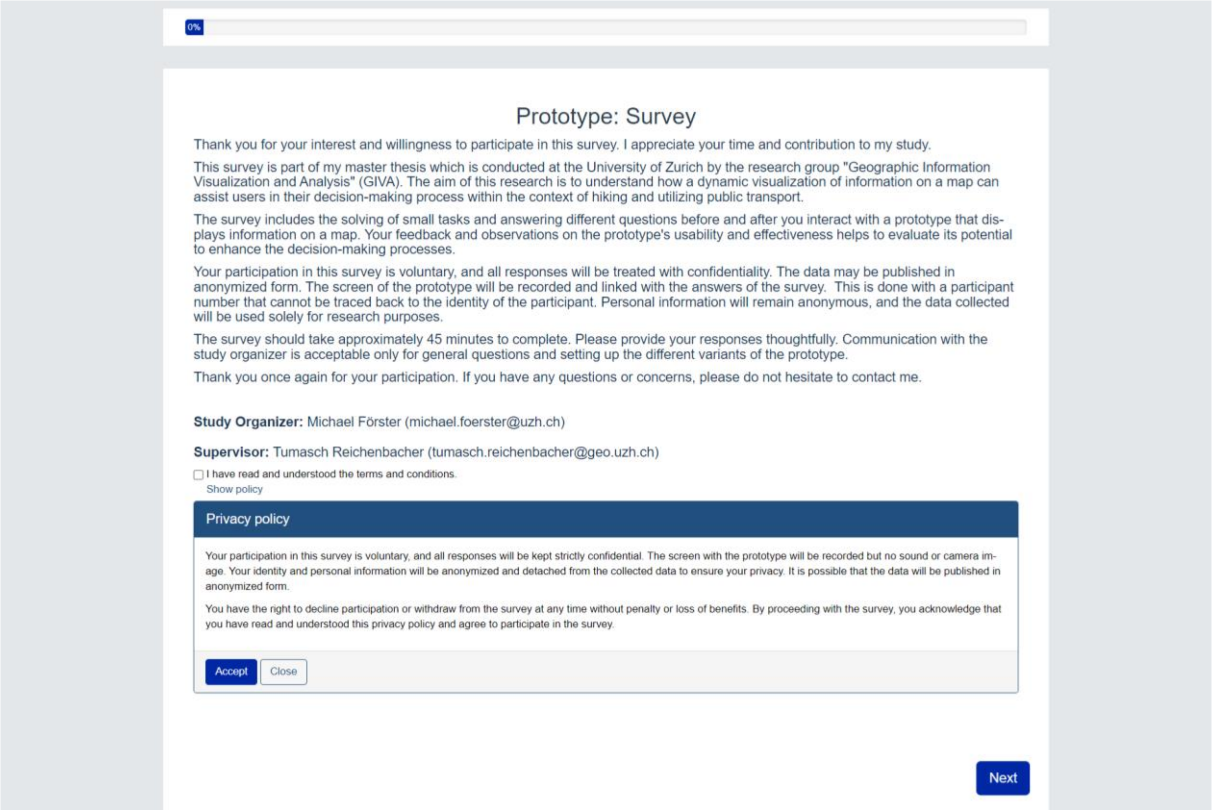
Appendix

A. App Comparison

App Name	App Category	Development Studio	App Version (from 22.09.23)	Description	Reason for Inclusion in Study
Swisstopo	Outdoor	Ubique Innovation AG (on behalf of Swisstopo)	1.12.0	Official Swiss mapping app with detailed topographic maps, and hiking trails.	Switzerland specific Outdoor related
Google Maps	Navigation	Google LLC	11.98.0300	Popular navigation app with turn-by-turn directions, and real-time traffic information.	Popularity Multi-use mapping app
Outdooractive	Outdoor	Outdooractive GmbH	3.13.12	Hiking and outdoor activities app with detailed maps, hiking trails, and information about outdoor activities.	Popularity Outdoor related
SBB Mobile	Public Transport	Ubique Innovation AG (on behalf of SBB)	12.17.2.55.master	Official Swiss Federal Railways app with real-time arrival information, route planning, and ticket purchasing.	Switzerland specific Popularity
Citymapper	Navigation/ Public Transport	Citymapper Limited	11.5.1	Navigation app for public transportation, with real-time arrival information, route planning, and live maps for major cities.	Focus on the map and PT

B. Survey



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Prototype: Survey

Thank you for your interest and willingness to participate in this survey. I appreciate your time and contribution to my study.

This survey is part of my master thesis which is conducted at the University of Zurich by the research group "Geographic Information Visualization and Analysis" (GIVA). The aim of this research is to understand how a dynamic visualization of information on a map can assist users in their decision-making process within the context of hiking and utilizing public transport.

The survey includes the solving of small tasks and answering different questions before and after you interact with a prototype that displays information on a map. Your feedback and observations on the prototype's usability and effectiveness helps to evaluate its potential to enhance the decision-making processes.

Your participation in this survey is voluntary, and all responses will be treated with confidentiality. The data may be published in anonymized form. The screen of the prototype will be recorded and linked with the answers of the survey. This is done with a participant number that cannot be traced back to the identity of the participant. Personal information will remain anonymous, and the data collected will be used solely for research purposes.

The survey should take approximately 45 minutes to complete. Please provide your responses thoughtfully. Communication with the study organizer is acceptable only for general questions and setting up the different variants of the prototype.

Thank you once again for your participation. If you have any questions or concerns, please do not hesitate to contact me.

Study Organizer: Michael Förster (michael.foerster@uzh.ch)

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

- [ ] I have read and understood the terms and conditions.

Show policy

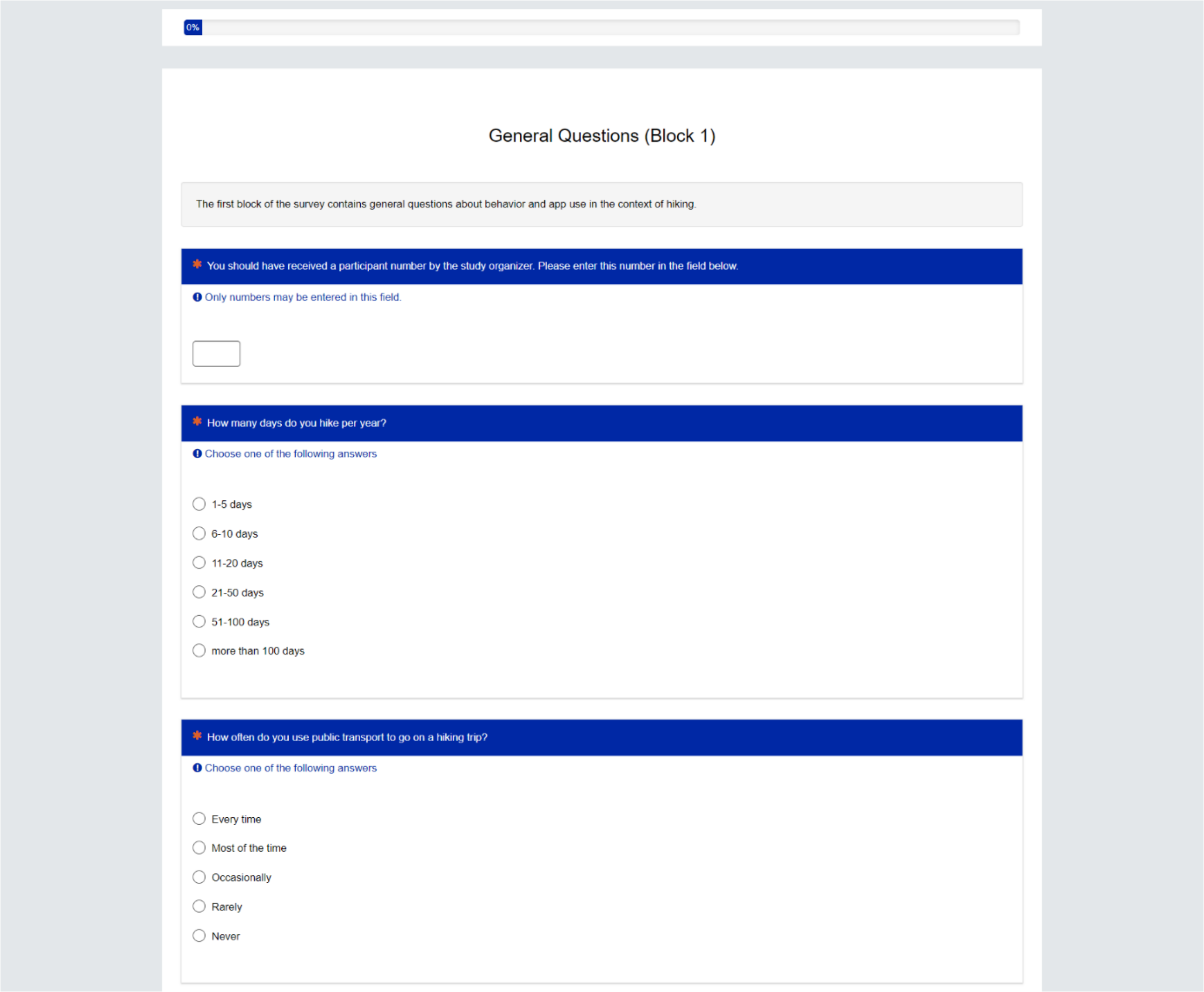
Privacy policy

Your participation in this survey is voluntary, and all responses will be kept strictly confidential. The screen with the prototype will be recorded but no sound or camera image. Your identity and personal information will be anonymized and detached from the collected data to ensure your privacy. It is possible that the data will be published in anonymized form.

You have the right to decline participation or withdraw from the survey at any time without penalty or loss of benefits. By proceeding with the survey, you acknowledge that you have read and understood this privacy policy and agree to participate in the survey.

Accept Close

Next



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General Questions (Block 1)

The first block of the survey contains general questions about behavior and app use in the context of hiking.

* You should have received a participant number by the study organizer. Please enter this number in the field below.

Only numbers may be entered in this field.

* How many days do you hike per year?

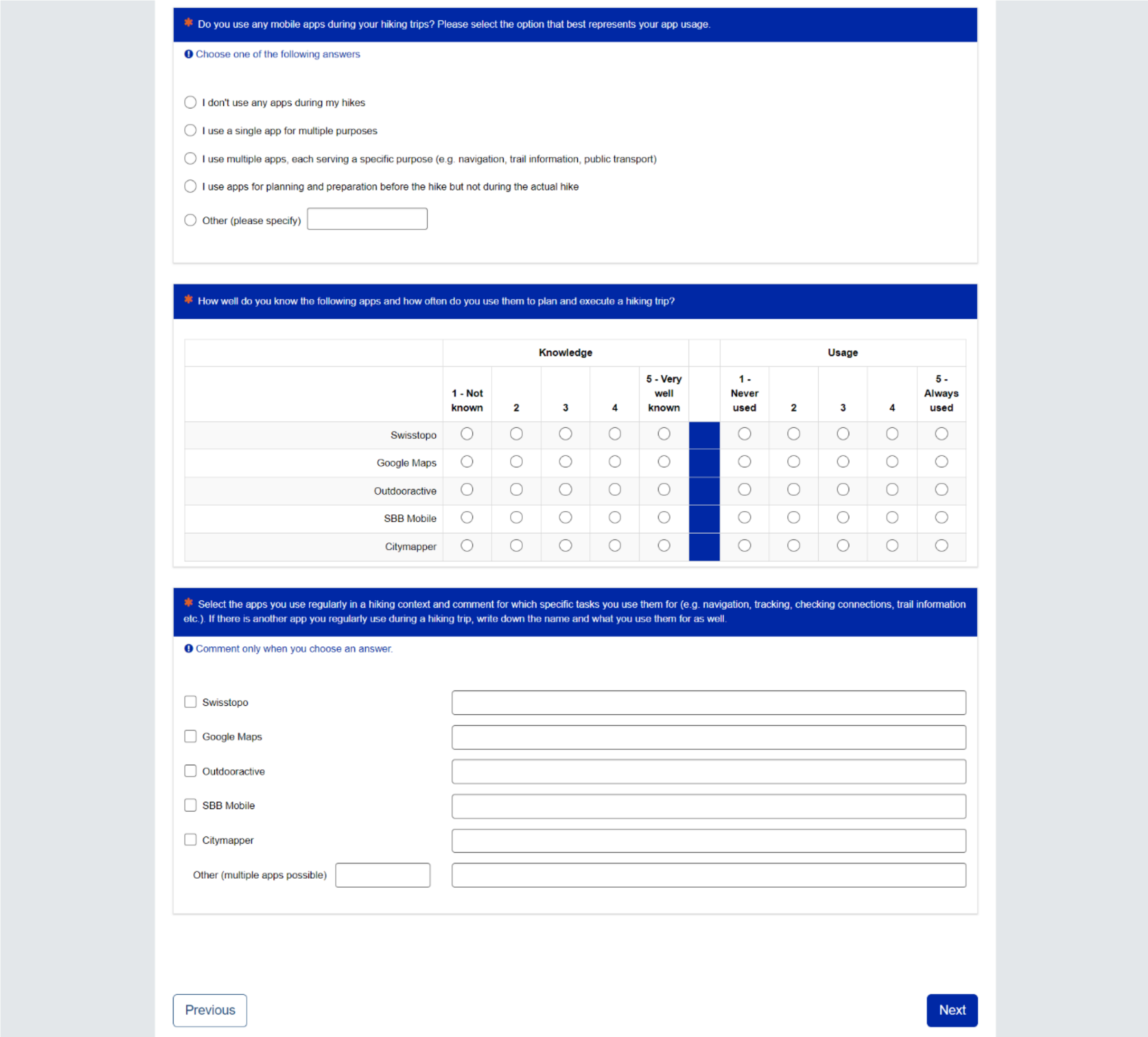
Choose one of the following answers

- 1-5 days
- 6-10 days
- 11-20 days
- 21-50 days
- 51-100 days
- more than 100 days

* How often do you use public transport to go on a hiking trip?

Choose one of the following answers

- Every time
- Most of the time
- Occasionally
- Rarely
- Never



* Do you use any mobile apps during your hiking trips? Please select the option that best represents your app usage.

Choose one of the following answers

- I don't use any apps during my hikes
- I use a single app for multiple purposes
- I use multiple apps, each serving a specific purpose (e.g. navigation, trail information, public transport)
- I use apps for planning and preparation before the hike but not during the actual hike
- Other (please specify)

* How well do you know the following apps and how often do you use them to plan and execute a hiking trip?

	Knowledge						Usage				
	1 - Not known	2	3	4	5 - Very well known		1 - Never used	2	3	4	5 - Always used
Swisstopo	○	○	○	○	○		○	○	○	○	○
Google Maps	○	○	○	○	○		○	○	○	○	○
Outdooractive	○	○	○	○	○		○	○	○	○	○
SBB Mobile	○	○	○	○	○		○	○	○	○	○
Citymapper	○	○	○	○	○		○	○	○	○	○

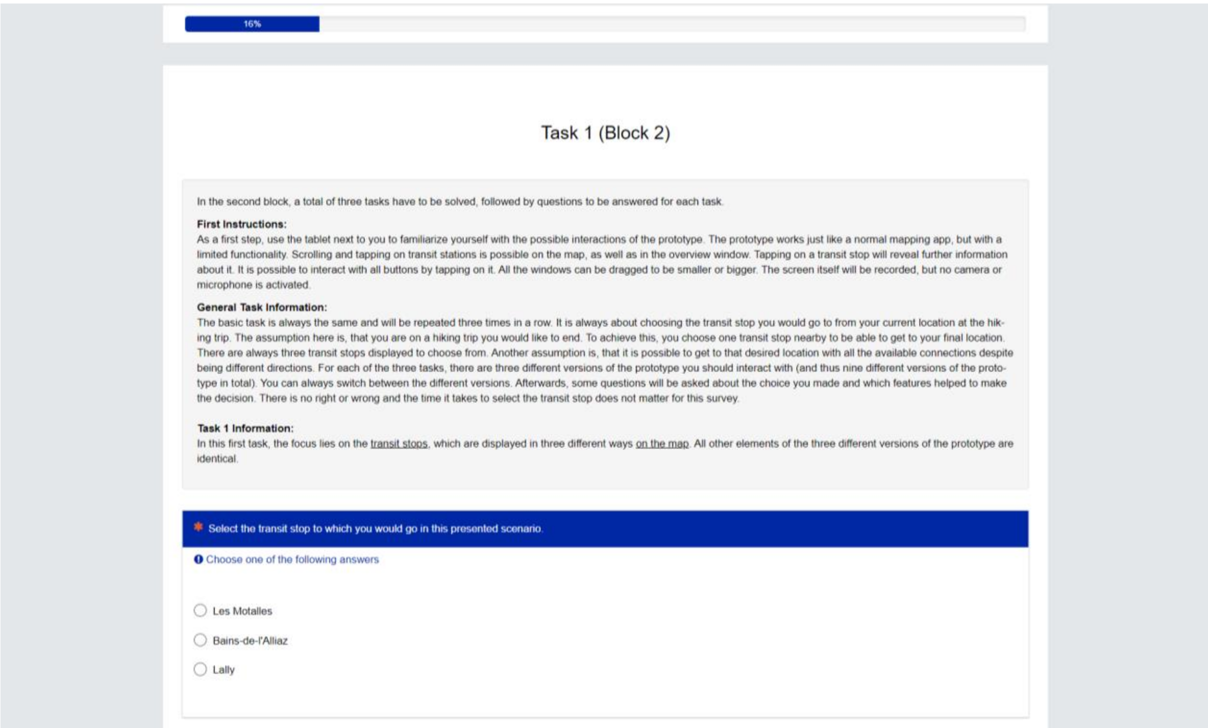
* Select the apps you use regularly in a hiking context and comment for which specific tasks you use them for (e.g. navigation, tracking, checking connections, trail information etc.). If there is another app you regularly use during a hiking trip, write down the name and what you use them for as well.

Comment only when you choose an answer.

- Swisstopo
- Google Maps
- Outdooractive
- SBB Mobile
- Citymapper

Other (multiple apps possible)

Previous Next



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Task 1 (Block 2)

In the second block, a total of three tasks have to be solved, followed by questions to be answered for each task.

First Instructions:
As a first step, use the tablet next to you to familiarize yourself with the possible interactions of the prototype. The prototype works just like a normal mapping app, but with a limited functionality. Scrolling and tapping on transit stations is possible on the map, as well as in the overview window. Tapping on a transit stop will reveal further information about it. It is possible to interact with all buttons by tapping on it. All the windows can be dragged to be smaller or bigger. The screen itself will be recorded, but no camera or microphone is activated.

General Task Information:
The basic task is always the same and will be repeated three times in a row. It is always about choosing the transit stop you would go to from your current location at the hiking trip. The assumption here is, that you are on a hiking trip you would like to end. To achieve this, you choose one transit stop nearby to be able to get to your final location. There are always three transit stops displayed to choose from. Another assumption is, that it is possible to get to that desired location with all the available connections despite being different directions. For each of the three tasks, there are three different versions of the prototype you should interact with (and thus nine different versions of the prototype in total). You can always switch between the different versions. Afterwards, some questions will be asked about the choice you made and which features helped to make the decision. There is no right or wrong and the time it takes to select the transit stop does not matter for this survey.

Task 1 Information:
In this first task, the focus lies on the transit stops, which are displayed in three different ways on the map. All other elements of the three different versions of the prototype are identical.

* Select the transit stop to which you would go in this presented scenario.

Choose one of the following answers

- Les Motalles
- Bains-de-l'Alliaz
- Lally

* Rank the three tested variants according to their helpfulness in solving the task.

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 3 answers

Your choices	Your ranking
Variant 1 (transit stop in grey without departures)	
Variant 2 (transit stop with walking time)	
Variant 3 (transit stop with number of departures)	

* Briefly explain what was more or less helpful to solve the task when comparing the three different variants. Please only consider the differences between the variants and not the overall prototype.

Write down if there was something you want to mention or which did not seem clear to you in any of the three variants.

Previous Next

33%

Task 2 (Block 2)

Task 2 Information:
In this second task, the focus lies on the different type of information, which is displayed in three different ways inside the sliding window. All other elements of the three different versions of the prototype are identical.

* Select the transit stop to which you would go in this presented scenario.

Choose one of the following answers

- Sternenberg, Gfell
- Steg
- Mühlrüti, Hulftegg

* Rank the three tested variants according to their helpfulness in solving the task.

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 3 answers

Your choices	Your ranking
Variant 1 (window with waiting time)	
Variant 2 (window with departure time)	
Variant 3 (window with waiting & departure time)	

* Briefly explain what was more or less helpful to solve the task when comparing the three different variants. Please only consider the differences between the variants and not the overall prototype.

Write down if there was something you want to mention or which did not seem clear to you in any of the three variants.

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Task 3 (Block 2)

Task 3 Information:
In this last task, the focus lies on the three different background maps that are used to represent the user's environment. All other elements of the three different versions of the prototype are identical.

* Select the transit stop to which you would go in this presented scenario.

Choose one of the following answers

- Cureggia, Paese
- Monte Brè
- Brè, Paese

* Rank the three tested variants according to their helpfulness in solving the task.

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 3 answers

Your choices

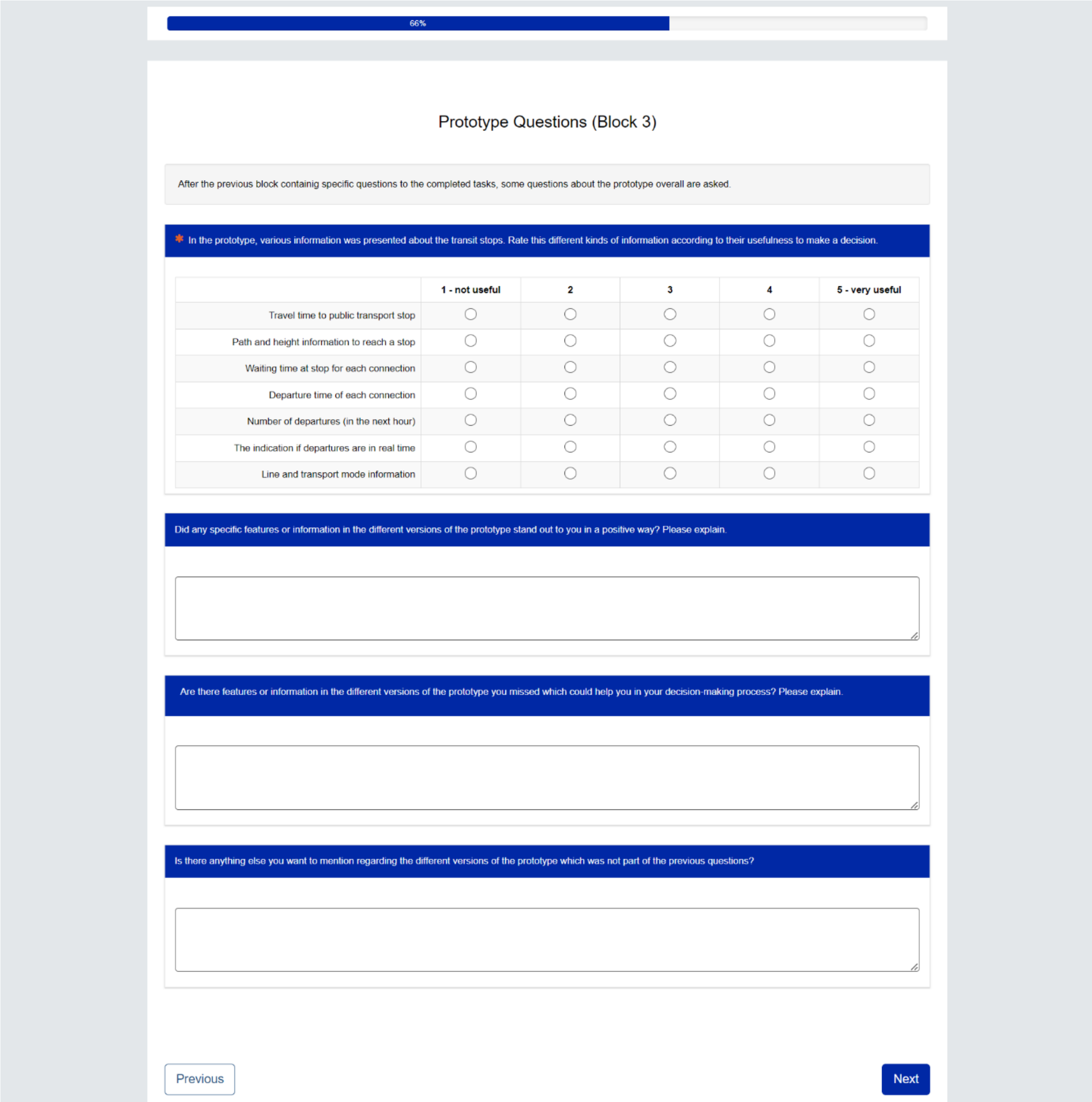
- Variant 1 (simple background map)
- Variant 2 (open street map background map)
- Variant 3 (swisstopo background map)

Your ranking

* Briefly explain what was more or less helpful to solve the task when comparing the three different variants. Please only consider the differences between the variants and not the overall prototype.

Write down if there was something you want to mention or which did not seem clear to you in any of the three variants.

Previous Next



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Prototype Questions (Block 3)

After the previous block containig specific questions to the completed tasks, some questions about the prototype overall are asked.

* In the prototype, various information was presented about the transit stops. Rate this different kinds of information according to their usefulness to make a decision.

	1 - not useful	2	3	4	5 - very useful
Travel time to public transport stop	○	○	○	○	○
Path and height information to reach a stop	○	○	○	○	○
Waiting time at stop for each connection	○	○	○	○	○
Departure time of each connection	○	○	○	○	○
Number of departures (in the next hour)	○	○	○	○	○
The indication if departures are in real time	○	○	○	○	○
Line and transport mode information	○	○	○	○	○

Did any specific features or information in the different versions of the prototype stand out to you in a positive way? Please explain.

Are there features or information in the different versions of the prototype you missed which could help you in your decision-making process? Please explain.

Is there anything else you want to mention regarding the different versions of the prototype which was not part of the previous questions?

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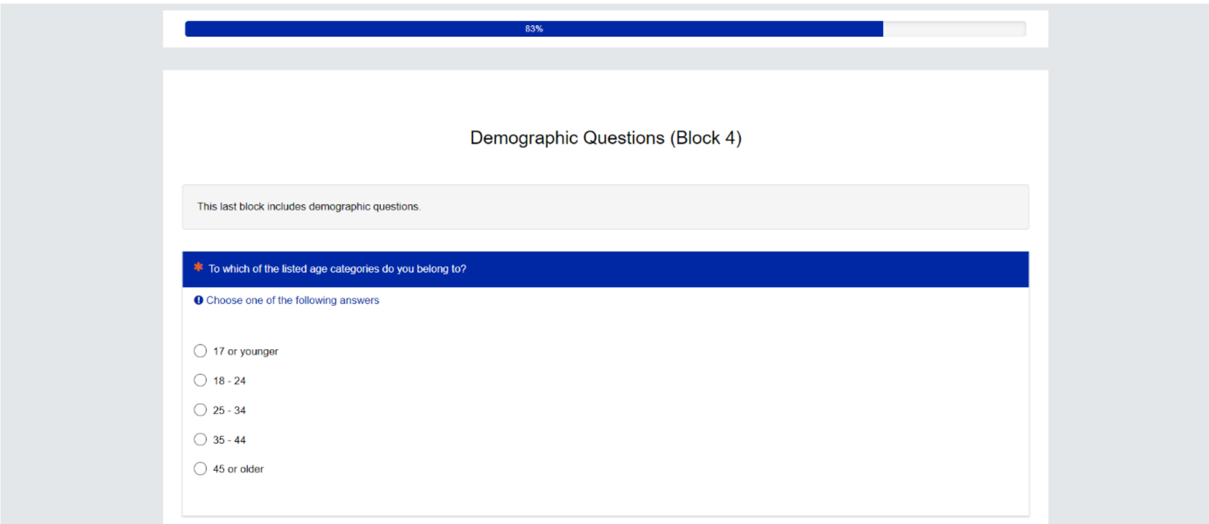

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Demographic Questions (Block 4)

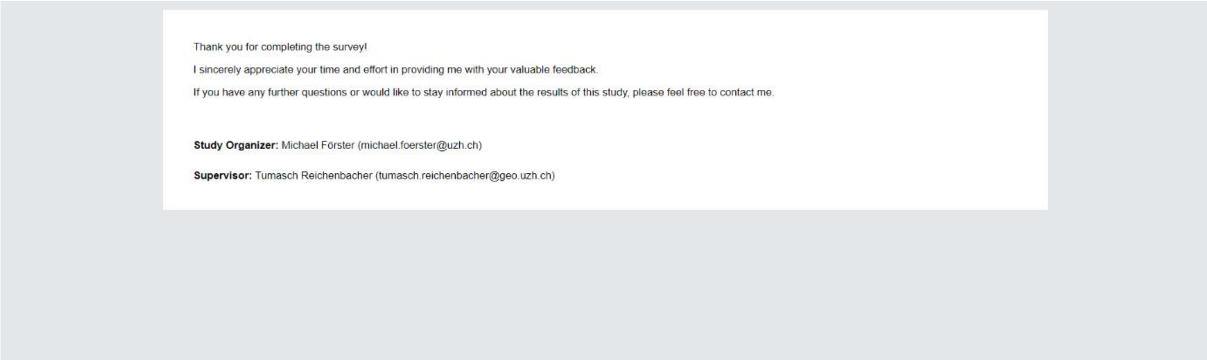
This last block includes demographic questions.

* To which of the listed age categories do you belong to?

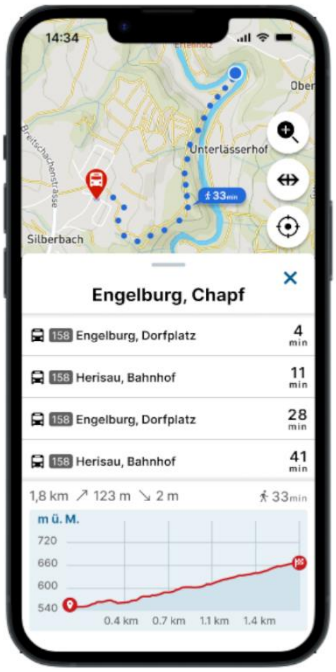
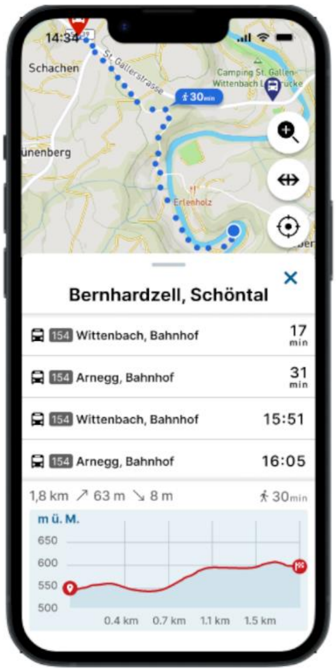
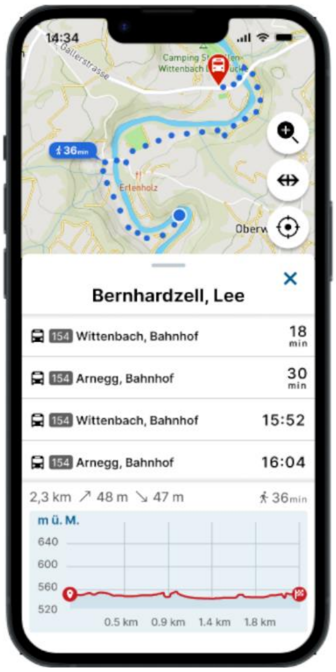
Choose one of the following answers

- ○ 17 or younger
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 or older


What is your gender?
Choose one of the following answers
Please choose...
Previous
Submit


Thank you for completing the survey!
I sincerely appreciate your time and effort in providing me with your valuable feedback.
If you have any further questions or would like to stay informed about the results of this study, please feel free to contact me.
Study Organizer: Michael Förster (michael.foerster@uzh.ch)
Supervisor: Tumasch Reichenbacher (tumasch.reichenbacher@geo.uzh.ch)

C. Prototype

Test Version for Practice			
Departures			
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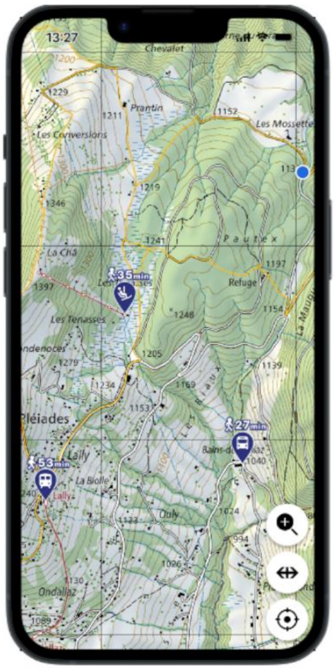
<td>
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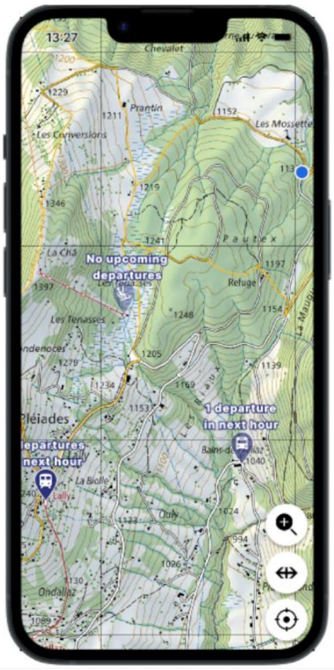
<td>
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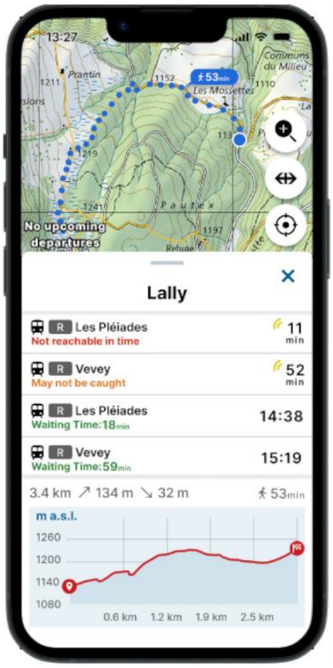
<td>
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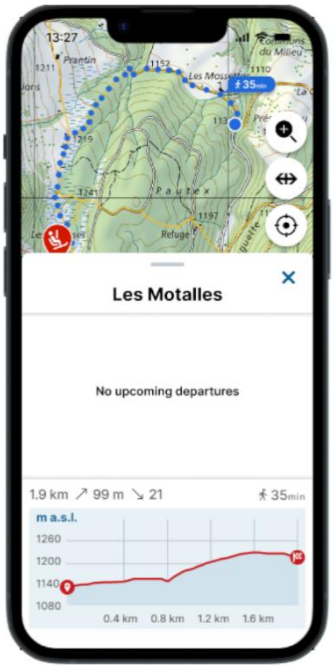
<td>
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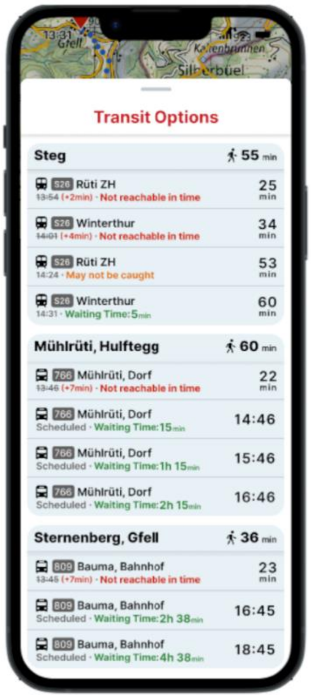
</td><td>
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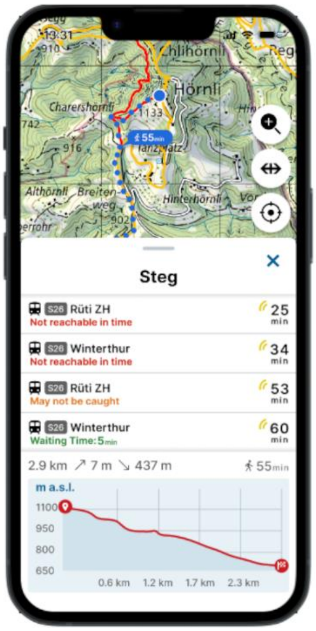
</td><td>
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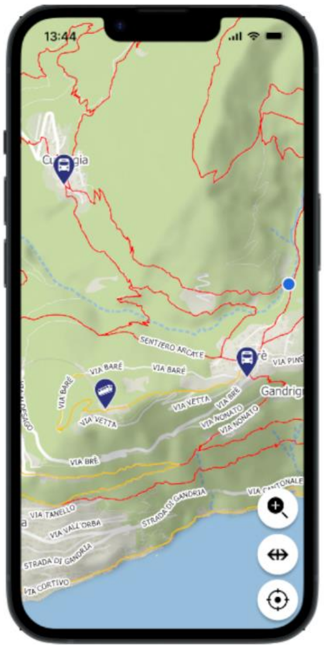
<tr><td>Variations</td><td>
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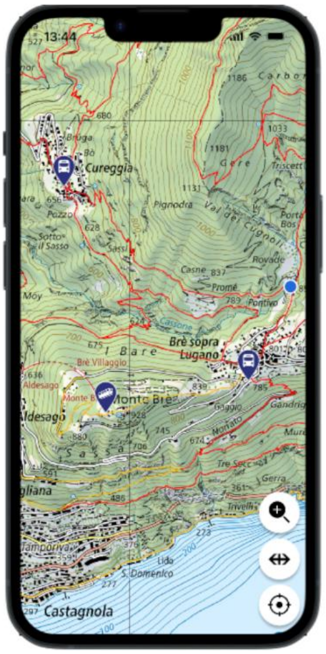
</td><td>
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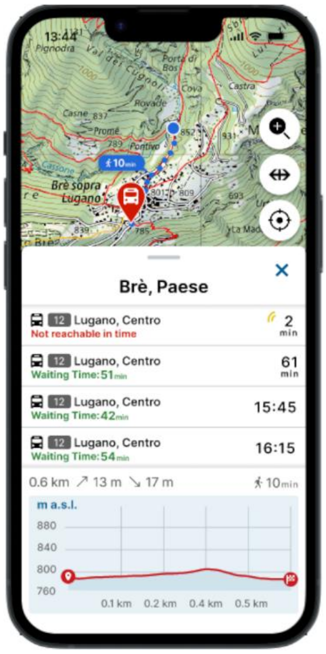
<tr><td>Departures</td><td>
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Personal Declaration

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

St. Gallen, September 27th, 2023

Michael Förster