Analysis, Conception and Prototyping of a User Preference Service for Mobility Planning Assistant

Bachelor Thesis

by

Kihun Kim

Industrial Engineering and Management B.Sc.

Matriculation Number: 2098888

Institute of Applied Informatics and Formal Description Methods (AIFB)

KIT Department of Economics and Management

Advisor:	Prof. Dr. Andreas Oberweis
Second Advisor:	Prof. Dr.-Ing. J. Marius Zöllner
Supervisor:	M.Sc. Alexandra Wins
Submitted:	September 8, 2021

Contents

1 Introduction

1.1 Motivation

Since private transportation have popularized, individual mobility has become an indispensable presence in mobility planning. Because of that, the number of private transportation seen on the road gradually increased. From the standpoint of this phenomenon, it is not surprising that private transportation accounts for the largest share of total traffic volume [CAR17]. As a result, the rapid increase in using private transportation causes environmental concerns such as air pollution, noise, and related adverse effects. At the same time, the consequences of increased traffic volumes by private transportation, there are also social problems such as enormous traffic congestion, lack of parking spaces, and environment pollution. Thus, the importance of independence from using private transportation is constantly on the rise.

In attempts to reduce the adverse effect of excessive usage of private transportation, several solutions have been studied and applied in practice with different outcomes [HAR13]. As a promising solution, a flexible combination between many different modes of transportation has emerged as an alternative. Using this solution, mobility users can plan their travel routes more flexible than before. However, showing all possible combinations of transportation for travel routes can bring difficulty and confusion to mobility users. They might have a problem finding the mobility option that best suits their mobility preferences. For mobility users to reduce this problem, the mobility service needs to provide personalized travel routes to mobility users based on their mobility preferences.

In practice, however, there are not many existing mobility planning platforms that offer personalized travel routes based on the many different individual mobility preferences. Some of the mobility platforms provide a few mobility options for individual adaptation to specific situations e.g., by prioritizing modalities according to the different travel purposes. Many mobility users begin to demand for the user preference services that can manage their unique mobility preferences. If there is a user preference service that allows mobility users to set, modify and store their mobility preferences themselves, the mobility platform will be able to utilize this service to provide personalized travel routes to mobility users based on their mobility preferences.

1.2 Objective

The primary objective of this thesis is the conception and implementation of the user preference service. For this purpose, identifying different types and characteristics of relevant mobility profiles for individual mobility preference will be the first step. Subsequently, prototypical implementation of the user preference service will be executed. The biggest challenge in this thesis is to build and design a generic conception of mobility profile model for individual mobility preferences. To solve this challenge, this thesis will combine literature-based and existing application-based methodology to build a new mobility profile model.

1.3 Structure

After introducing the motivation and objective, this section shows how this thesis is structured. In section 2, this thesis will show the explanation of the theoretical knowledge, important terms and definitions needed to understand the user preference service and mobility profile. The technical background such as characteristics and features of software architecture will be introduced as well. At the end of section 2, the project MobiPlan will be introduced. This project aims to create an integrated mobility platform. Introducing this project is important for understanding of the user preference service. In section 3, this thesis will introduce different methodology for the mobility profile modeling. This modeling will be used as a fundamental of the mobility profile in the user preference service. After that, it will also introduce many different mobility profiles in different categories. Based on this mobility profile and modeling approach, this thesis will show how to build a prototype of the user preference service in section 4. In this section, the requirement elicitation and framework for different requirements will be also described. Afterwards, the server, database and the software architecture of this service will be conceptualized with example images and diagrams. In section 5, this thesis will introduce a fictitious persona which is related to mobility profile and user preference service. Based on this persona, the corresponding mobility profile will be derived, and functional and non-functional requirements will be evaluated. Finally, section 6 summarises the most important aspects of the thesis and discusses the extension of the user preference service in the future.

2 Basis

2.1 Mobility

Mobility is formally defined as the ability or tendency for the movement that someone gets from one place to another by using a number of different transpositions. For this purpose, the concept of mobility operates based on the movement requirements by mobility users. The movement requirements represent a large difference depending on whether the number of targets being asked is an individual or a group. If there are a large number of people requiring movement, the decision is made by putting together all opinions and they find a middle point. However, the individual's requirement of movement depends on the individual's propensity and preference for mobility. In other words, for individual movement requirements more sophisticated and personalized services will be more required than the group's movement requirements. The fulfillment of requirements for mobility is essential for social activities such as commuting to work, outdoor activities, and daily schedules.

Mobility is a term that encompasses mobility options and mobility behavior. Mobility option describes the possible alternative for mobility users to be able to carry out activities in changing locations. Mobility behavior includes actual movement of individuals or groups when location with their spatial and modal characteristics is changed. Mobility behavior is influenced by many different factors. For example, individual preference is one of the factors that have significant influence on mobility behavior. Depending on which mobility preferences, the mobility behavior of mobility users can be changed.

For example, the coronavirus, which began spreading around the world in December 2019, affected mobility behavior of many mobility users. Prior to COVID-19, many mobility users used public transportation such as buses and trains to go to work, but the process of Corona's progress reduced the amount of breastfeeding for public transportation. However, after the COVID-19 outbreak, the demand for public transportation has decreased, and many mobility users use walking or bicycles to and from work. This change in mobility behavior has also been proven by literature research. According to the research 'Impact of SARS-CoV-2 on the mobility behaviour in Germany', before COVID-19, using public transportation, e.g., bus/tram and train, accounted for 23 percent of the total mobility plan [PET21]. However, during COVID-19, the number of people using public transportation is dramatically diminished. The usage rate of public transportation has been reduced to 5 percent. Unlike public transportation, the individual preference of walking as alternative mobility has risen to 14 percent. The proportion of people using private vehicles has also increased slightly as well. What this literature research shows is that changes in mobility behavior have a significant impact on the overall mobility structure and characteristics.

2.2 Unimodal mobility

Unimodal mobility is classified as one of the mobility types. This type allows only a single mode of transport for the whole trip. Since unimodal mobility uses only single transportation , it is most efficient to travel to the destination by private vehicle if possible. It's because if travelers use private vehicles, they can drive to wherever they want. However, public transportation only travels on a fixed route. The advantage of using private vehicles is that they're relatively less influenced than public transportation by external factors, e.g., weather. In the case of public transportation, delays or cancellations can often occur due to the weather. Unlike public transportation, these situations might occur relatively less [JAK15]. If mobility users take unimodal mobility with single public transportation, then due to its low flexibility, they may not be able to reach their desired destination at once. In some cases, transit and waiting times may occur. As a promising solution, multimodal mobility and intermodal mobility are conceptualized as an alternative.

2.3 Multimodal mobility

Multimodal mobility is one of the promising solutions for the problems related to unimodal mobility. In comparison with unimodal mobility, multimodal mobility allows the selection of different modes of transport. Selected transportation will be implemented for different trips in a certain period. For instance, in the morning, travelers can drive a shared electric vehicle to commute to work. After work, they ride a bike to the grocery store. On the weekend, they use public transportation to visit their cousins. As seen from this example, different transportation is used for different trips and periods.

2.4 Intermodal mobility

2.4.1 Definition

Intermodal mobility is one of the other promising solutions of unimodal mobility. It allows using more than one mode of transport during one trip for a single route. The purpose of intermodal mobility is improving the efficiency of a single route with sequential combination of a single transportation. By sequential combination, intermodal mobility tries to offer travelers seamless trips. To do this, intermodal mobility should integrate the different transport services. Each transport service has its own conditions. Intermodal mobility must consider them and organize connections between different modes of transport. At the end, intermodal mobility needs to create an integrated mobility planning system.

2.4.2 Differences between intermodal- and multimodal mobility

The concept of intermodal- and multimodal mobility are sometimes used interchangeably. However, technically, they are concepts that have distinctly different characteristics and meaning. In short, the difference between them is that intermodal mobility uses more than one mode of transport for a single trip, whereas multimodal mobility uses different modes of transport for more than one trip in a certain period.

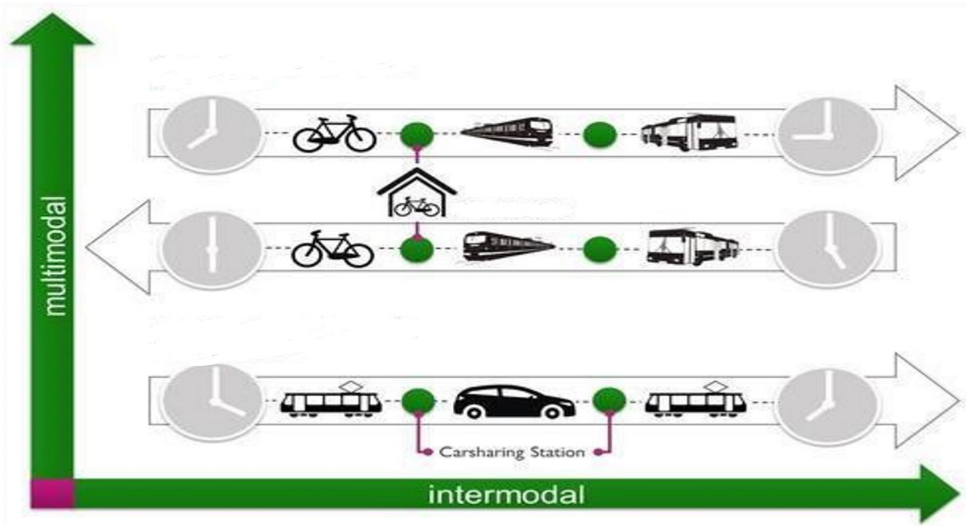

Figure 1: Difference between intermodal- and multimodal mobility[BER14]

Figure 1 describes the difference between intermodal-, and multimodal mobility. The x-axis shows the changes of transportation on a single trip. It represents intermodal mobility. The y-axis shows the changes of transportation on different trips in a certain period. It represents multimodal mobility. The first two trips in figure 1 describe an example of commuting from home to work. The bicycle, as a typical mode of transport for individual transport, brings the traveler to the train station which has a place for parking bicycles. After parking, the traveler transfers to the train and bus. It transports passengers to the workplace. After work, This process goes backwards.

This activity consists of two trips with three different modes of transport in a certain period (rush hour) [BER14]. Unlike that, the last trip shows the one way trip. The tram, as public transportation in cities, brings the traveler to the car-sharing station. After getting off the tram, the traveler goes to the car-sharing station and transfers to the sharing-car. After driving to the next car-sharing station, the traveler gets off the sharing-car and gets into the tram again. Finally, this tram will take passengers to the destination. Last example has only one trip with 2 different modes of transport. Through these examples, the two mobilties are clearly separated [BER14].

2.5 Software architecture

As the size of the software system is on the rise, a software system is getting more complex. Because of complexity, a collision within the software might happen. If these collisions are out of control by software, software will fall into a risk regarding the quality and performance. For instance, when the size of the software gets bigger, the communication between software components becomes more complicated. If this communication isn't considered during the development process, the outcome doesn't perform as expected. This problem tells us why it is important to build a software architecture correctly. Software architecture contributes to understanding the software logic [SHA93].

To create a good software architecture, we should look for the best pattern for our software. However, the best pattern doesn't mean that it should always be state of the art. It's important to find out which architecture pattern will be fit for our software system. The software architecture is formally defined as describing its gross structure and providing an explanation of the software system's operation principle. It gives a foundation on which software systems can be built. Because of that, it can have access to the structural overview of the software system. Accessing the structural overview makes the system visible at a glance. By ensuring access to the software structure, the quality of performance, wide scalability, and stability of the software architecture can be achieved. An advantage of its use is that it helps a third party to understand the software system. To maximize its advantage, building a reusable architecture is relevant. For this purpose, we will discuss the different design patterns of software architecture in the next section [GAR00].

2.5.1 Layered architecture pattern

The layered architecture pattern is known as the n-tier architecture pattern on which elements are organized together in horizontal layers. This pattern is a traditional design solution for object-oriented programming like Java. One of the important features of layered architecture pattern is that it is meant to be self-independent [RIC15]. All the elements within this pattern are interconnected, but they don't rely on one another. Because of that, the layers ensure their independence, and each layer has its own role.

Despite no limit of number and types of layers, this pattern consists of four different layers: presentation-, business-, persistence-, and database layer. At the beginning, a presentation layer will receive all the requests from the user interface. These requests are addressed within this layer and will be sent to the business layer. In the next layer, all the requests originating from the previous layer will be executed according to the specified business rules. It is notable that each layer doesn't consider what happens in other layers. Shortly, it's called separation of concerns among elements. This characteristic will constrain the layer's range of activities. Thereby, the layered architecture pattern can define the role and responsibility of each layer easily [RIC15].

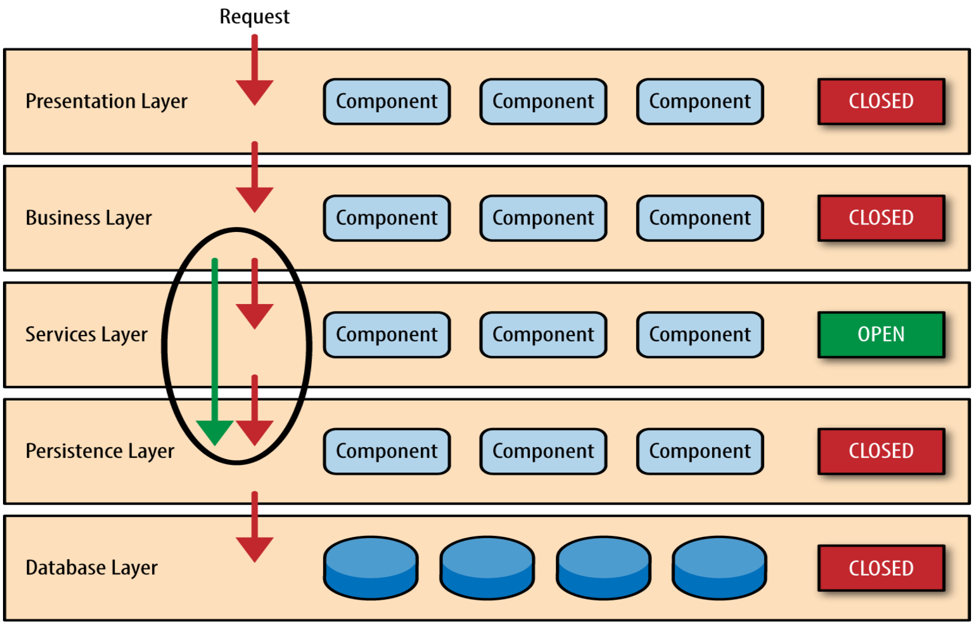

Figure 2: open/closed layers and request flow [RIC15]

The key concept of layered architecture pattern is 2 different statuses management. First, the closed status describes the transfer of the requests only to the next layer. In this status, skipping the next layer is not allowed. As seen in figure 2, the requests originating from the presentation layer pass the business layer. Then, it should pass the services-, persistence-, and database layer sequentially. Passing every layer takes a long time. However, by approaching the target layer at one, the software architecture can expect a much faster performance. Nevertheless, request should visit every layer one by one. The reason is that, this pattern ensures the independence of the layers. It indicates the isolation of each layer. Due to the isolation, the layer has no idea about the internal changes of other layers. This situation causes a problem that each layer has a difficulty understanding the entire architecture without investigating every module. This issue is called the separation of the layer on different levels. To avoid it, the requests must go through all the layers. By visiting all the layers, the requests know what happens in every layer. Consequently, the software architecture can keep the maintainability and testability of the layers. The open status gives options whether the requests skip the opened layers or go through it manually. This status is used for certain situations, e.g., a shared services layer. The shared services layer plays a role in sharing its services with other layers. However, it's not necessary in all cases. It doesn't make sense to be marked as closed every time. Therefore, this layer should be marked as open status so that the request can select whether to go directly to the layer below it or to pass the opened layer manually [RIC15].

2.5.2 Microkernel architecture pattern

The microkernel architecture pattern is known as a plug-in architecture for building product-based applications. It means that the this pattern allows adding new features as a plug-in into the core system. This pattern consists of the core system and plug-in components. First, the core system lies at the heart of the microkernel architecture pattern. The core system has minimal functionalities required to make the system running. When a plug-in approaches to settle into the core system, the core system will recognize the plug-ins' access requests and use them as additional functions. It can also attach the functionalities selectively. Because of selective attachment of new feature, the number of operating systems with microkernel architecture patterns increases. Second, the plug-in component is meant to be an independent object. The plug-in component can be attached to the core system without any internal and external restriction. Each component has its own specialized functionalities, features, and operating principle. These components will contribute to enhance the performance and extend the capabilities of the software systems. By using plug-in components, software architects can easily customize the core system.

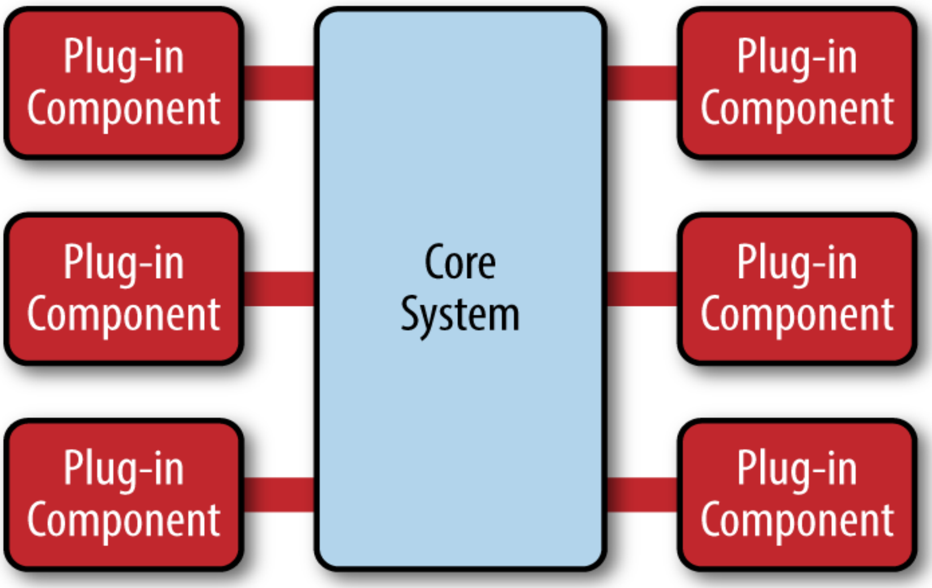

Figure 3: microkernel architecture pattern [RIC15]

The plug-in registry is a storage that saves information of plug-in components, including its features and access control. The core system can read each plug-in component information by using the plug-in registry. Using each plug-in component information, the core system learns how to connect to different plug-ins components. As seen in figure 3, in the center of software architecture, the core system is located. Many plug-in components connected through the plug-in registry are located around the core system.

Based on what we have discussed, the advantage of the microkernel architecture pattern is that it has high flexibility to respond quickly to a continuously changing environment. However, it has a low scalability. The scalability represents the capability to handle a number of computing processes. It's because this pattern is typically used for product-based application, and more generally, there are small scale systems [RIC15].

2.5.3 Microservices architecture pattern

A microservice is defined as an independent process that interacts via messages. These messages should be deployed in isolation, and each independent process has its distinct role and responsibility. When the microservices are completely used to build one software architecture, this architecture is called microservices architecture. The microservices architecture pattern is one of the architectural styles on which all its modules are microservices. This pattern seeks to generate many small programs and integrate them together. This pattern is also called a service-oriented architectural pattern because it refers to a technique that gives service providers how to design highly scalable, flexible applications.

The microservices architecture pattern provides a guideline for the design and implementation of distributed applications. By using this pattern, service providers can fully concentrate on development of the cohesive functionalities with other microservices. In recent times, this pattern is getting more popular. It's because its use can lead to reduced development effort. This pattern is used in practice as a substitute for monolithic applications and service-oriented architectures as well. This pattern helps service providers avoid letting their components evolve to be inflexible [SAF18].

The key concept of the microservices architecture pattern is separately deployment of units. As we have discussed at the beginning of this paragraph, this architecture pattern ensures the independence of microservice components. Like in figure 4, all modules in service components are stored separately. The separation of modules is an advantage for effective deployment and scalability. The service component is also the key concept of its pattern. It encompasses one or more modules so that it plays as an independent object. Each service component exist in an independent from with the software architecture. They are interconnected via the user interface layer. The user interface layer is also used to receive client requests. Through its layer, the service components are interconnected, and the server and client can communicate with each other. For this purpose, some sort of remote access protocol is necessary such as REST API (Representational State Transfer Application Programming Interface) [RIC15]. From the technical point of view, this pattern is proper for websites with small components or rapidly changing software systems. It can easily cope with a variation of each service component, which allows fast deployment and high scalability.

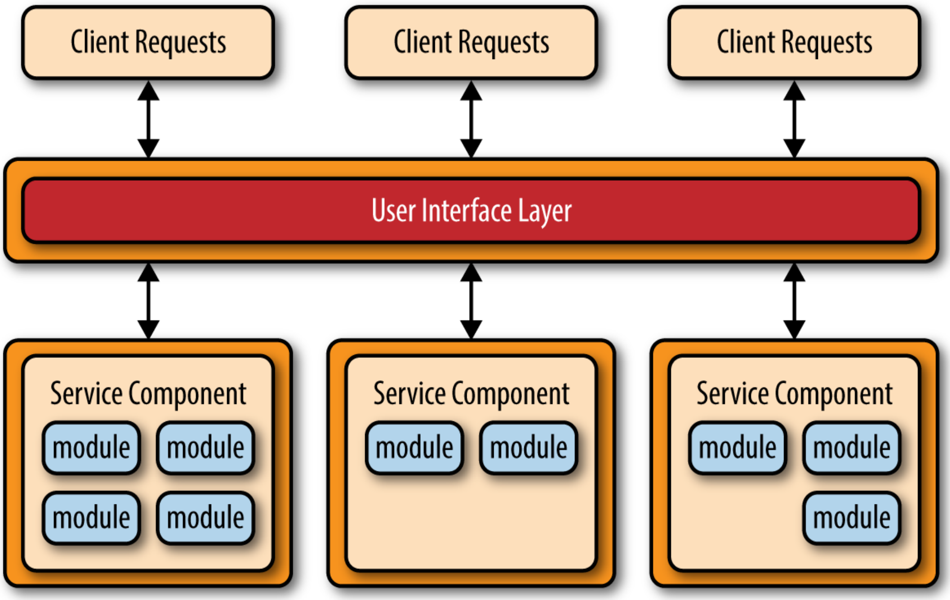

Figure 4: microservices architecture pattern [RIC15]

For software architecture of the user preference service, this thesis will use microservice architecture pattern. The reason for using this pattern is independent operation of microservice components and simple connection with clients by REST API.

REST API is a communication method between client and server. It gives HTTP URI, a unique ID to all resources and classifies them by name and exchanges the status of the resource. It applies CRUD (Create,Read,Update,Delete) operation on the resource through HTTP Method. This thesis will use the GET,POST, and PUT HTTP Method for the REST API. The GET method is used to request from data to the specified resource URL such as name or value pair. For the GET method to get specific data, the query string with name or value pairs is sent in the URL of the GET request. The POST Method supports the web server to accept the data from clients included in the body of the message. The PUT Method is used to modify or update a specific resource which is already stored in the server.

REST API will classify the client's request according to the http method. The classified data are worked differently according to the requested information and purpose. Sometimes, it needs to communicate with the database to get the required data by clients. If all REST API processes are finished, REST API responds to clients with the data in JSON or XML format. REST API consists of a total of four logical layers: API controller layer, service layer, repository layer, and entity layer.

First, the API controller layer classifies client requests according to API resources and HTTP methods. According to the classification API controller layer applies different internal logic to deliver client requests to the service layer. Second, the service layer receives client requests from the API controller layer. The service layer will check whether the data of the client request is valid. When all checks are passed, the data goes to the repository layer. The repository layer basically has a function to store data that has passed through the service layer. The repository layer basically has a function to store data that has passed through the service layer. When saving, specify the entity layer as the default type and save.

In the entity layer, data type, variable name, primary key, column name, etc. are designated. The repository layer uses the entity layer as a manual when storing data in the database. The repository layer will store it in the database according to the variable, type, and column names specified in the entity layer. In addition, since the repository layer is a part that directly connects to the database, it can also perform the function of retrieving data from the database according to specific conditions such as primary key.

2.6 Mobility- & Activity-based Planning assistant (MobiPlan)

MobiPlan is an integrated mobility platform project by Forschungszentrum Informatiks. The reason for mentioning this project is that the user preference service is a component that belongs to MobiPlan. Besides the user preference service, there are other components such as routing adapter and GATSP solver. These are also currently under development to launch an integrated mobility platform. The goal of MobiPlan is to develop an integrated mobility platform with a routing algorithm for finding an best possible order for daily activities and routes between them [FZI20]. This platform should cope with the personalized route planning based on mobility user's preferences. Through this project, mobility users can get personalized routes. Through this platform, reducing the uncertainty of daily mobility and maximizing productivity and efficiency of mobility planning are expected.

3 Mobility Profile

3.1 Methodology

Section 3.1 describes which methodologies this thesis uses to construct the mobility profile for the user preference service. This thesis put together the advantages of literature-based mobility profile modeling and existing application-based mobility profile modeling to build a new modeling called 'unique mobility profile modeling'. This modeling will be used directly in the theoretical background of the mobility profile when developing the user preference service.

3.1.1 Literature-based mobility profile modeling

There has been a growing body of research that explores how to build mobility profile for the user preference service. Modeling based on actual research cases and literature is the first modeling approach for the mobility profile.

Literature-based mobility profile	
Options	References
Demographic data	[ZIE14]
Transportation for the physically handicapped	[ZIE14] [KRA14]
Environmental friendliness	[ZIE14] [JAK15] [CAB15]
Giving different weight to preferences	[uM20]
Light rail travel	[CAB15]
Travel cost	[RIE06] [ZIE14] [JAK15]
Travel time	[RIE06] [ZIE14] [JAK15]
Transfers	[RIE06] [JAK15]
Private transportation	[ZIE17]
Waiting times	[RIE06] [ZIE14] [JAK15]
Capacity utilization of public transportation	[VOE19] [YAN15]
Travel purpose	[HEI16]
Weather	[KEN11]

Literature-based modelling focuses on several things. First, for literature-based modelling we need to investigate and collect mobility profiles based on the literature research. Mobility profiles obtained through literature research will be used for modeling. Second, for literature research-based modeling, this thesis will use a variety of keywords and recently published papers. The reason for using the recently published paper and various keywords is to create a model which considers the latest trends and situations as much as possible. For the literature research, this thesis uses Google Scholar, websites of topic-related journals, and Elsevier for the paper resources. Furthermore, mobility planning, preference, intermodal mobility, multimodal mobility, public transportation, travel chain, personalization, and sharing economy are used as main keywords.

3.1.2 Existing application-based mobility profile modeling

Existing application-based mobility profile refers to a modeling method based on the mobility profile used by an existing mobility application or API (Application Programming Interface). The advantage of using applications and APIs that are used in practice is that mobility users are using them directly, and feedback on them. Such feedback is a positive factor for user-oriented system development.

Existing application-based mobility profile	
Options	Application or API
Payment method	KVV.regiomove, DB Navigator
Subscription	DB Navigator
Favorite place	Google Maps API, Mapbox API
Living Street	Openrouteservice API, Valhalla API
Preferred transportation	DB Navigator
Road inclination	Openrouteservice API
Road surface	Openrouteservice API, Valhalla API
Sharing transportation	KVV.regiomove, StadtMobil
Current location	Apple Maps API, Google Maps API
Traffic condition	TomTom API, Google Maps API

3.1.3 Unique mobility profile modeling

Unique mobility profile is a profile that combines elements from literature-based modeling and existing application modeling. Figure 5 describes a unique mobility profile with tree-structured modelling. The tree-structured model classifies many different mobility profiles into three categories: static user profile, dynamic preference profile, and situational contexts.

First, static user profile is a preference for the mobility profile that is not dependent on travel purpose or context. However, since the user preferences are very heterogeneous, the only preparation of the static user profile by existing user preference services is no longer sufficient for modelling mobility profile. For sufficient preparation for modelling mobility profile, the user preference service should deal with dynamic user preferences as well.

Second, dynamic preference profile is a category of mobility profile that changes dynamically depending on the travel purpose and the context.

Third, situational context describes exogenous factors of specific situation or circumstances that influence the preferences of mobility users. Situational context also shows the appropriate action or behavior related to this situation. Typically used in regards to mobility profile are weather and traffic conditions.

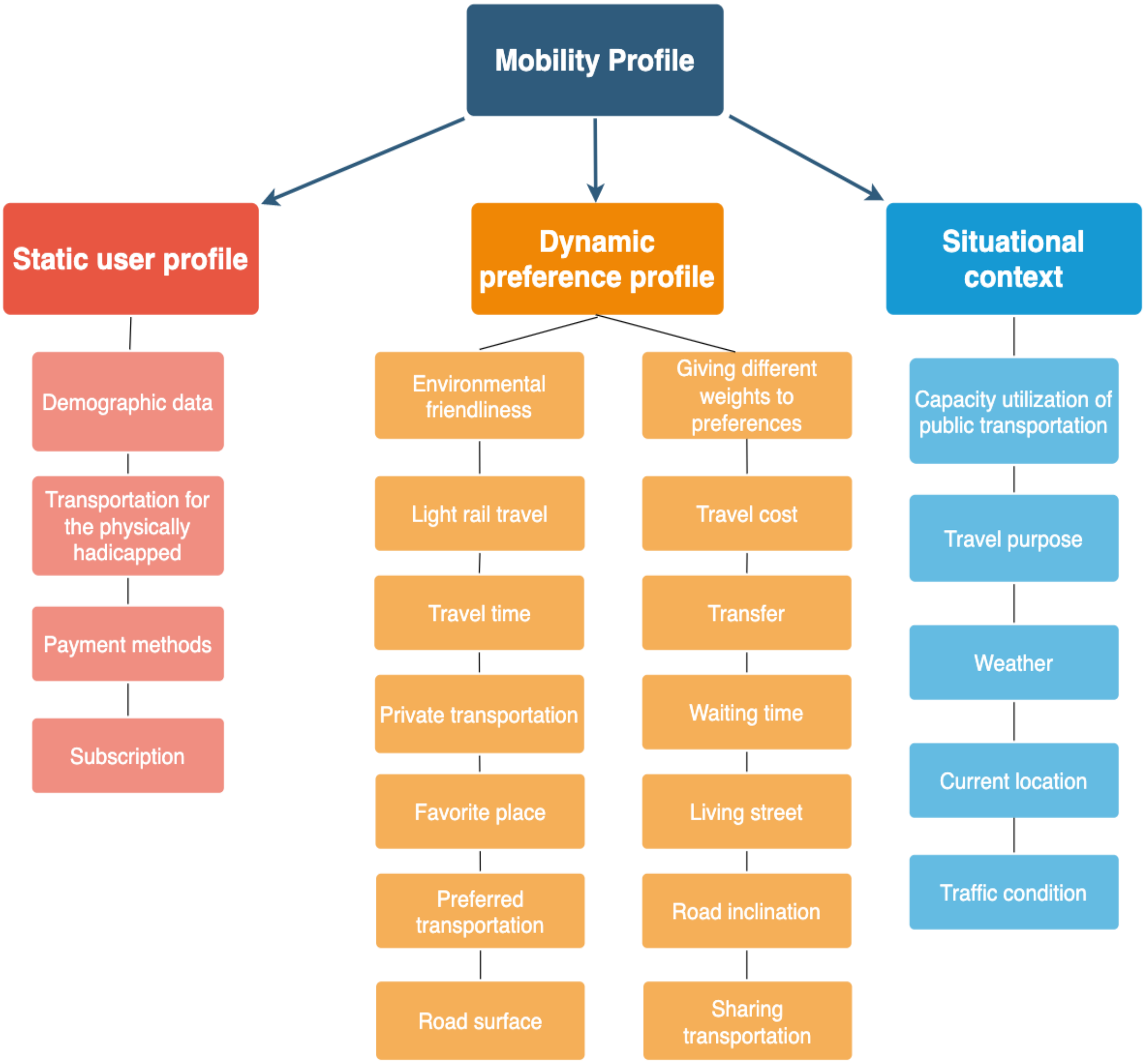

Figure 5: Tree-structured modelling of mobility profile

The reason for classifying the mobility profile into three categories is to configure a more subdivided mobility profile and provide a service method suitable for the characteristics of the category.

3.2 Relevant personalization option

Relevant personalization option refers to mobility profiles that must be considered to provide mobility users with the best possible personalized travel routes. Relevant personalization option is also used as an upper term of 3 different categories introduced in section 3.1.3. Each category includes many different types of mobility profiles structured through the tree model in section 3.1.3. In the next subsection, description of the mobility profile, reason and its logical fundamentals will be described in more detail. Also it describes how each mobility profile will be implemented in the user preference service.

Demographic data

Demographic data includes statistical information such as age, gender, race, and occupation, income level, homeownership, marital status, and religious affiliation. The user reference service will provide mobility users with input fields to enter or select their age and gender information when they sign up. The reason why this service requires demographic data such as gender and age is that it can be used for statistical analysis and incorporated into artificial intelligence for the future works [ZIE14]. For example, among artificial intelligence techniques, there is a method called classification. Classification is often used to create predictive models in machine learning. In the case of demographic data genders, it is clear to classify them as men and women. Age is also a good data to be used to create a predictive model by classifying it as teenagers and twenties. Thus, by using demographic data from the user preference service, mobility planning platform will be able to provide more personalized and best possible travel routes to mobility users.

Transportation for the physically handicapped

Most of the infrastructure and public facilities used in the community are designed that there are difficulties for people with physical discomfort to use. These people need to have a special infrastructure and therefore there is a need for a service that can reflect their opinions and requirements. Their particular profile must be considered when they plan to build travel routes. In public transportation, which is common in daily life, mobility users can find spaces or functions that consider the situation of the physically handicapped. For most mobility users, such spaces and functions may not be important, but for those such as the physically handicapped these spaces and functions are essential [KRA14]. However, when the physically handicapped want to use public transportation, they need to find whether there is any available transportation for the physically handicapped. For them, this kind of transportation is an essential user profile rather than a preference. If mobility users can directly enter and store information about transportation for the physically handicapped by using the user preference service, it can be useful when setting up a travel route. Therefore, the user preference service will provide an input field through which the physically handicapped can input information about transportation for the physically handicapped.

Payment method

With the rapid development of the financial technology sector, mobility users are now able to access many different kinds of payment services. As different mobility users use different payment services, the mobility platform also provides the ability to book and cancel transports using a number of payment services. The user preference service need to provide an option to mobility users so that they can select the payment service which they use. This service will classify selected payment services as user profile. This profile will be used when mobility users want to to schedule or cancel transportation for their travel routes.

Subscription

In mobility planning, subscription is a mobility service that mobility users use at regular cost. As an example, Deutsche Bahn provides a train discount subscription service called BahnCard. When passengers book a train ticket with BahnCard, they can receive a discount on the train ticket. In mobility planning, subscription is a paid service. Thus, the costs incurred here are included in the travel cost. Subscription is one of the important personalization options for individual mobility planning. The reason is that the service subscribed to mobility users means that it is their preferred service. Therefore, knowing which services mobility users have subscribed helps the user preference service provide the best possible travel routes to mobility users.

Environmental friendliness

Due to rapid industrialization and urban development, numerous natural landscapes are disappearing over a long period of time. From the perspective of mobility, natural destruction is closely related to transportation. Environmental friendliness in mobility means mobility that minimizes environmental destruction and coexists with nature and humans [JAK15]. In the past few years, many developed countries have put a lot of effort into announcing an eco-friendly policy such as the Paris climate agreement. In particular, interest in electric cars has increased recently and many companies that manufactured internal combustion engine cars have begun to release electric cars. If there is a service that can store eco-friendly mobility preferences, mobility users can easily create an eco-friendly travel route. This feature will be provided by the user preference service.

Giving different weights to preferences

Giving different weights to preferences is one of the ways to prioritize dynamic individual preferences. Assigning lighter or heavier importance to specific factors brings a significant impact on the outcome. The process of giving different weights to preferences emphasizes the facets and features of the weighted preferences over others. By emphasizing, these preferences can bring more contribution to the outcome than others.

Giving different weights to preferences is also relevant in mobility planning. There has been a growing body of research that explores which preference is most weighted in mobility planning. In November 2020, Allgemeine Deutsche Automobil-Club (ADAC), reported the study "Mobil in der Stadt" [uM20]. This study aims to describe the result of a satisfaction experiment based on individual mobility preference in 29 medium-sized German cities. The results of this study are divided into private transportation and public transportation.

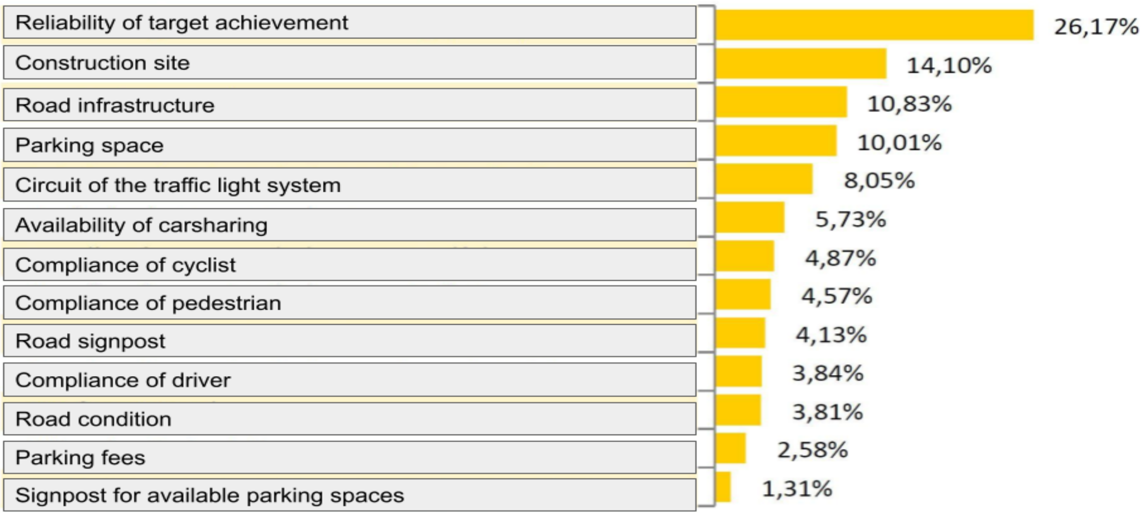

Figure 6: Different weights of preferences in private transportation [uM20]

First, figure 6 shows the different weight of preference in private transportation. The experiment participants gave the most weight on the reliability of target achievement in private transportation. Reliability of target achievement implies arriving at the desired destination in mobility planning. It is notable that the share of this preference exceeds a quarter of the total. Next, 14.1 percent of the experiment participants responded that site management is the second weighted individual preference in private transportation. Afterwards, road infrastructure follows. These two preferences have common characteristics. They are external factors that can make physical changes [uM20]. For example, because of the construction site, sometimes, the travelers need to take a long way, not going by the shortest route. The travelers must change the direction of driving. This situation could occur lower traveler's satisfaction. Also, their satisfaction can vary depending on how well the road infrastructure is built.

Second, figure 7 shows the different weight of preference in public transportation. The experiment participants gave the most weight on the price/performance in public transportation. The share of availability of direct connections is almost equal to the share of price/performance ratio. Besides that, the interviewers responded that compliance, security, and frequency of connections are important preferences for them as well.

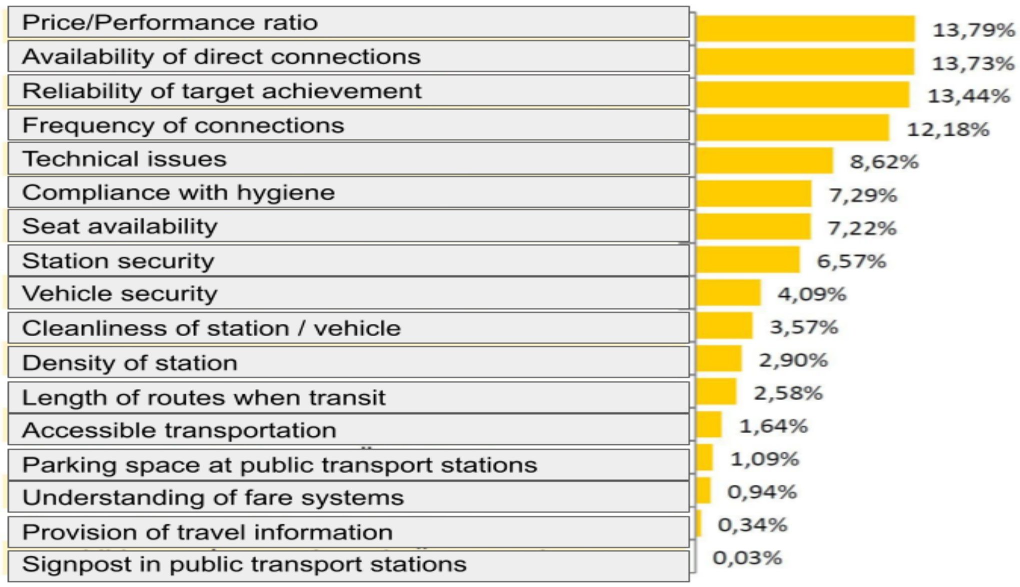

Figure 7: Different weights of preferences in public transportation [uM20]

This study found that mobility users tend to select different preferences depending on their mobility options. As we found in figure 6 and 7, the top 3 preferences by weight in public transportation and private transportation are different. In addition, even within the mobility options of the same category, the weight of the preferences is different. These results imply the implicit necessity of giving different weights to preferences for user preference services personalized route rather than suggesting all possible routes [LEO17]. Giving different weights to preferences allows user preference services to set priorities. This process contributes to providing a minimal, personalized route rather than suggesting all possible routes.

However, in reality, each individual has many different and detailed mobility preferences. ADAC's experimental results showed only about 10 different mobility preferences each for individual transportation and public transportation, but if this study considers all possible cases, there will be more detailed and diverse mobility preferences several dozen times more than the introduced mobility preferences in this study [uM20]. Therefore, it is almost impossible for a mobility platform to classify and to give different weights to all the different mobility preferences directly input by mobility users. Instead of manually inputting by them, the most commonly used method is that the user preference service will provide several choice experiments to mobility users [LEO17]. Mobility users can give a weight from 1 to 5 for each choice experiment.

Light rail travel

Light rail travel might be a rather unfamiliar mobility concept to many people. Light rail travel describes travel as a form of transportation passing on light rails. This transportation is characterized by a combination of urban rail transportation such as tram and metro. Light rail transportation is recognized as a more reliable, convenient and faster mobility option than traditional public transportation [CAB15]. Light rail transportation only passes on the designated rail. Also, it's less affected by road conditions or infrastructure.

Light rail can be a good mobility option for those who want to travel safer and more conveniently than bus. However, the light rail also has disadvantages. Building light rail requires a high initial cost. In addition, there are many restrictions in building light rail infrastructure where the terrain is not flat such as in suburban or rural areas. The user preference service will save whether mobility users prefer to travel on light rail transportation. Individual mobility preferences stored in relation to light rail travel will be used to provide personalized mobility routes in the integrated mobility platform.

Travel cost

Travel cost refers to all the costs that mobility users pay to move around. Travel cost depends on which transportation mobility users use and when they book transportation ticket. For example, train tickets price go up as the departure time approaches. In other words, if mobility users book a train ticket in advance, they can use it at a relatively low price. For example, if mobility users book a long-distance train ticket a week or two before departure, they can use it at a relatively lower price than they book the ticket on the day of departure.

In addition, depending on the travel cost, mobility users can use transportation that provides better service. For example, Deutsche Bahn provides many different types of trains for their clients. ICE is more expensive than other trains, but it runs faster to its destination than other trains. Unlike other trains, ICE also offers free Wi-Fi to passengers inside the train. As such, there are many hidden reasons why travel cost is different from transportation to transportation. The reason why travel cost is important to mobility is that their budgets are limited. They need to plan how much they can spend on transportation within a limited budget. If there is a service that stores mobility user's preferences for travel cost, they can easily proceed with mobility planning using the travel cost preferences they set. In the user preference service of this thesis, mobility users will be able to enter and save the maximum amount of travel cost for mobility planning.

Travel time

When planning travel, mobility users want to know how much time they need to arrive at their destination. Travel time is probably one of the first considerations for mobility users as much as travel cost. Travel time is affected by factors such as distance from starting point to destination, current location, and type of transportation. Mobility users have their preferred travel time. If their preferred travel time is a short period of time, they can choose a fast transportation and a travel route to their destination. If mobility users use public transportation such as bus, it takes a lot of travel time because it stops at many other stations. The user preference service will provide input fields where mobility users can enter preferences for travel time themselves. Mobility users can receive personalized routes closer to their preferences by storing their preferences for travel time in the user preference service.

Transfer

Transfer means changing from one mode of transportation to another. Transfer can happen to all types of transportation. However, in general, mobility users frequently transfer when using public transportation. The reason is that public transportation only travels on a fixed route. Passengers have difficulty getting to their desired destination at once. Also, transfers can affect waiting time and travel time. As the number of transfers increases, the waiting time and travel time increases as well. For instance, if the previous transportation is delayed and passengers arrive late to the next transfer point, they might miss the next connection. Passengers are also concerned about losing their luggage due to transferring many times. The advantage of transfers is that they are often cheaper than direct routes. If there is a mobility platform that makes travel routes reflecting mobility users' preferences for transfer, mobility users can use travel routes that are close to their preferences. The user preference service in this thesis will provide input fields to enter their preferences for the maximum number of transfers by mobility users.

Private transportation

Depending on the time and financial situation that each person has, the way how mobility users plan their travel route to destination is different. If the mobility user owns personal transportation such as a private car or bicycle, they can move relatively more comfortably than using public transportation such as bus or train. The reason is that private transportation can be used at any time the user wants, and it is possible to move to the desired destination at once without transferring. On the other hand, public transportation often does not get to the desired destination at once, so transferring is often almost essential. If there is a service or platform that allows mobility users to store their preferred transportation, mobility users will be able to create travel routes mainly through their preferred transportation. The user preference service will provide input fields for mobility users to select and store their preferred private transportation. Stored preferences will be used to create their personalized travel routes for mobility users.

Waiting time

Waiting time is the time mobility users wait while traveling. If mobility users use private transportation, waiting time does not occur because it is available immediately at the time they want. Waiting time usually occurs when using public transportation. Waiting time also frequently occurs when a mobility user travels to the destination by using intermodal routes. Depending on the waiting time, the mobility user has to adjusts the entire schedule. Also, the waiting time affects the decision of transportation. If there is a service and mobility platform that reflects the preference for waiting time, mobility users do not have to wait much time on the trip. The user preference service will provide input fields for mobility users to select and store their preferred maximum waiting time. Stored preferences will be used to create their personalized travel routes for mobility users.

Favorite place

When mobility users create a travel route through a mobility application, there are places that mobility users search relatively often. If it is a place that mobility users frequently visit or personally prefer, search frequency is inevitably higher than other places. If the mobility platform provides the features for mobility users to save their favorite places, they can quickly find them in their favorite place list without having to search again. Another advantage of a favorite place is that when creating a travel route, mobility users can quickly and easily set their preferred route by selecting from the favorite place list without having to manually search.

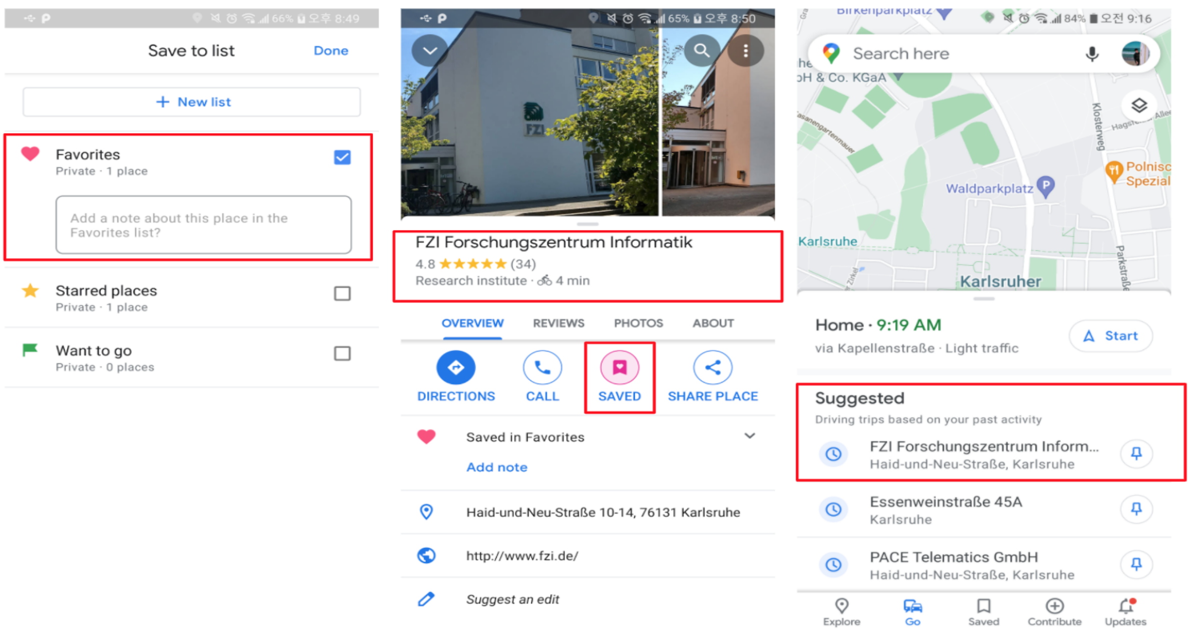

Figure 8: Favorite place in Google Maps [MAP21]

For example, Google Maps API provides a feature that mobility users can set the place as their favorite. This information is delivered to their favorite place list. Google Map API also utilizes this information to suggest places or routes. In this thesis, the user preference service will decide whether mobility users prefer to use features that they can save in their favorite place. Individual mobility preferences stored in relation to favorite place will be used to provide personalized mobility routes in the integrated mobility platform.

Living street

Living street is a road that is secure from public and private transportation except bicycle and electric scooter. The fundamental purpose of designing the living street is to satisfy the needs of city people's lack of daily physical activity. This is a particularly good mobility option for those who prefer to walk around to go to their destination. People using bicycles or electric scooters should be careful when using living street because this street is a road that pedestrians mainly use. If cyclists or scooter drivers need to get to their destination in a hurry, there is a risk of an accident. Therefore using this road may not be a good option for those people. Living street aims to create a way for people to live and breathe together. From the standpoint of nature, living street is eco-friendly. The user preference service will use living street as a mobility profile. Mobility users can directly input their preferences for living street in the user preference service.

Preferred transportation

If there is a feature that can save the preferred transportation of mobility users, the user preference service can provide the best possible route to mobility users. In practice, almost all mobility services provide mobility users with the ability to save their preferred transportation. For example, DB Navigator provides a function that allows mobility users to set their preferences of transportation so that only the preferred transportation is exposed to the search results when they plan to travel. The user preference service will also provide an option that mobility users can select which transportation they prefer more.

Road inclination

Road inclination is a decisive factor in controlling the speed of transportation. In fact, road inclinations are not an important factor for transportation such as buses or trucks. The reason is that they move forward using mechanical engines. Unless the slope is close to vertical, the force remains almost constant, so a bus or truck can move without any difficulty. However, road inclination is particularly important if the driver has to move with relatively weak power, such as a bicycle or an electric scooter. Bicycles are a means of transportation driven by human power. The higher the slope, the more sharply the human power will fall. An electric scooter is a means of transportation that moves using a built-in battery. Electric scooters are relatively weaker in power and lower in fuel efficiency than transportation using mechanical engines. Therefore, when using a bicycle or an electric scooter, it is efficient to pass on a path that is not inclined or flat. If the mobility user can set the preference of the max road inclination of the travel route by using the user preference service, this information can contribute to providing them with the best possible route. In practice, Openrouteservice API provides users with the option to select their desired road inclination preference. The user preference will provide the function to store road inclinations preferred by mobility users and will be used to create personalized travel routes using stored road inclination preference.

Road surface

The surface of the road is designed differently depending on the type of object passing on the road and the purpose of the movement of the object. The influence of the road surface works equally in normal transportation such as buses or private vehicles because they drive only on asphalt. However, bicycles and electric scooters can drive on many different types of road surfaces, such as asphalt and dirt roads and concrete. Road engineers use many different types of materials suitable for the purpose of the road to build roads. The materials used to build the road characterize the road surface. For example, asphalt is mainly used to make vehicle roads. However, paving stones or blocks is mainly used when making a path for people to pass through. Also, in the case of walking, movement speed can be different depending on whether the interval between blocks is narrowed or widened.

In the case of rural areas or developing countries, there are many unstructured dirt roads. Since the dirt road is in its natural state, the road is not flat and the surface is not smooth as there are many stones. In extreme cases, if the vehicle falls into mud or pit, it may be forced to be pulled out. These negative factors are factors that mobility users should consider when planning a travel route.

If the mobility user can set the preference of the road surface of the travel route by using the user preference service, this information can contribute to providing them with the best possible route. In practice, Openrouteservice APIs and Valhalla APIs provide users with the option to select their desired road surface preference such as paved surfaces, cross (rougher surfaces as well as paved), hybrid or city (casual riding on good surfaces), concrete, asphalte, grass, and wood etc. The user preference service will save what kind of road surface mobility users prefer to use. This input information will be used as data to create the best possible route in an integrated mobility platform.

Sharing transportation

Sharing transportation is an economic concept that shares transportation with others. Sharing transportation is popular with people who do not own transportation. For example, KVV.regiomove is a service officially provided by KVV (Karlsruher Verkehrsverbund), which is a local transportation agency in Karlsruhe. By using this service, mobility users can get information on public and shared transportation in Karlsruhe and its surrounding areas. This service is linked to various sharing transportation services such as Stadtmobil, Nextbike or electric-scooter in Karlsruhe. Mobility users can use various sharing transportation services and make reservations by using this service. As another example, shared electric scooter is a type of new sharing transportation. Electric scooters are gaining popularity because they are portable, maneuverable and fit for covering shorter distances quickly and comfortably. Another advantages of electric-scooter are that it is simple to operate and more efficient with less power than bicycles.

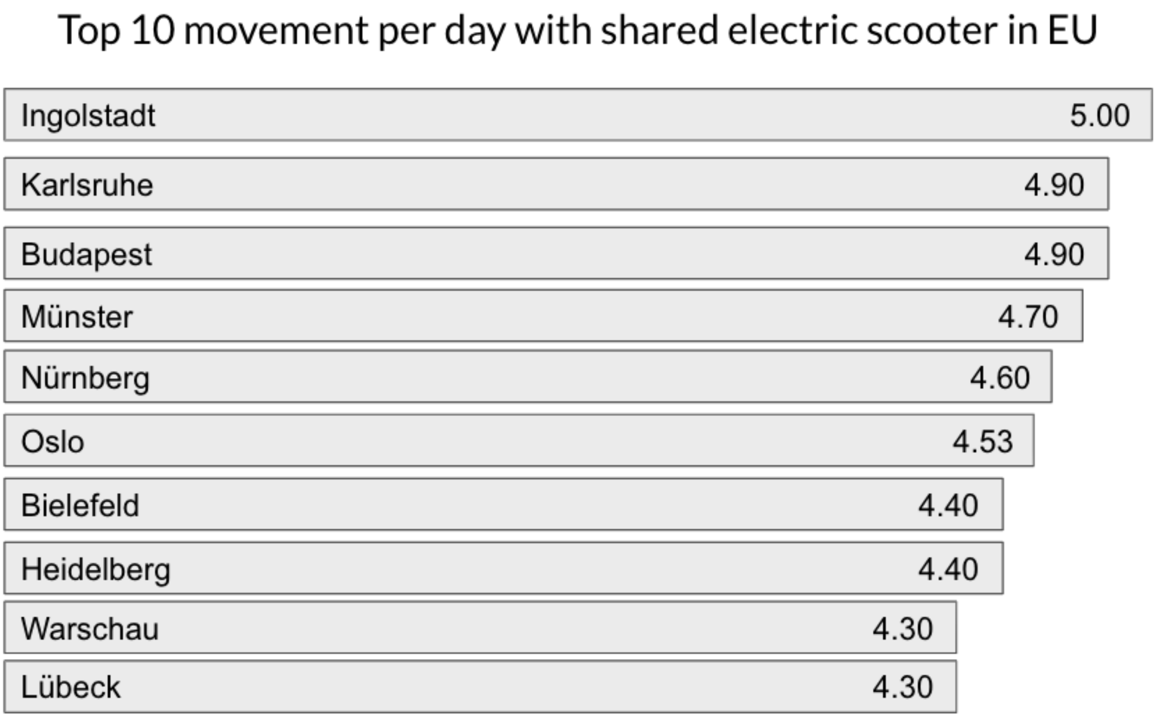

Figure 9: Top 10 Movement per day with electric scooter in Euroean Union [BOC21]

Karlsruhe is one of the cities in the EU where shared electric scooters are actively used. According to the research data by civity, Karlsruhe is the second-highest city in Europe using shared electric scooters per day [BOC21]. As seen in figure 9, people living in Karlsruhe use shared electric scooters more times per day than people who live in other big cities within the EU. As this data proves, shared electric scooters have become really important transportation for people living in Karlsruhe. So, why are there so many people using shared electric scooters in Karlsruhe than in the other big cities in the European Union ? The answer to this question is based on the age group and occupation of people living in Karlsruhe. According to the prior study, the younger generation has a more positive attitude toward electric scooters than the older generation [SUH19]. This study presents the results of a survey conducted on Germans aged 16 and over. The interviewees were divided into 16 to 64 years old (younger group) and over 65 years old (older group). The survey questions consisted of only those that could be answered with either consent or disagreement. The main purpose of this survey is to find out what each age group thinks about electric scooters. The survey questions are as follows.

1. Electric scooters would be a good addition to local public transportation
2. Electric scooters should be registered in Germany as quickly as possible
3. Electric scooters should be banned

The survey results differed markedly by different age groups. Around 2 over 3 of the younger group (16 to 64 years old) responded that scooters could be a good alternative to local public transportation [SUH19]. In contrast, only 29 percent of the older group (over 65 years old) said that scooters could be a substitute for local public transportation. About driving permission of e-scooter, 62 percent of the younger group is in favor, but only 16 percent of the older group. Finally, around 2 over 3 percent of the elderly were in favor of a ban on electric scooters. These results provide new evidence in differences in electric-scooter preference by young and old age groups. In fact, according to the statistics of Karlsruhe city hall, 14 percent of the total population are college students [Kar19]. If this data includes middle and high school students, the proportion of young age groups is a large part of the population in Karlsruhe. To summarize figure 9 and the previous survey, many people in Karlsruhe use electric scooters in their daily life. Also, they have a positive mind on electric scooters. Therefore, electric scooters play a very important role in the mobility of Karlsruhe. The user preference service will enable mobility users to enter their own preferences for electric scooters. The preference they enter for electric scooters in this service will be used to build personalized travel routes.

Capacity utilization of public transportation

Capacity utilization of public transportation refers to the percentage of public transportation currently available to mobility users. The reason why this ratio is important is that mobility users can get support when planning mobility routes. If they know the available ratio for each type of public transportation, they can set their mobility plan easily. For example, according to the statistics research by statista, Deutsche Bahn (DB) steadily increased capacity utilization of long-distance trains from 2006 to 2019 [WUN21]. The rate of capacity utilization of long-distance trains was around 43 percent. In 2019, this rate rose to about 56 percent. However, the steady rise in the rate was completely disrupted by the COVID-19, which resulted in a significant drop in the number of passengers and the start of the lockdown. In 2020, Deutsche Bahn lowered the rate of capacity utilization of long-distance trains from 56 percent to about 30 percent Since a quarter of all available long-distance trains have been reduced from the previous year, mobility users also have fewer options to select.

Capacity utilization of public transportation plays an important role in providing mobility users with a variety of options when planning travel or moving [VOE19]. If mobility users can check the current capacity utilization of each public transportation such as bus or train in real-time, they can choose public transportation with more vehicles available. Having more vehicles available can contribute to creating more diverse and detailed travel routes

For this thesis to apply capacity utilization of public transportation as a mobility profile to the user preference service, the most commonly used public transportation in Karlsruhe has to be selected. This thesis will apply the rate of tram capacity utilization to the user preference service among the many public transportation available in Karlsruhe. Mobility users can enter the minimum rate of tram capacity utilization they want into the input field provided by the user preference service.

Travel purpose

Travel purpose determines not only achieving the goal of the trip, but also the direction of the trip. The direction of the trip is the basis for establishing the overall structure of the trip and making detailed plans. The meaning of travel in this thesis encompasses not only long-distance travel but also daily activities. As an example, things such as daily commute to and from work, shopping, and going to school are also included in travel. The purpose of travel is also related to the type of mobility.

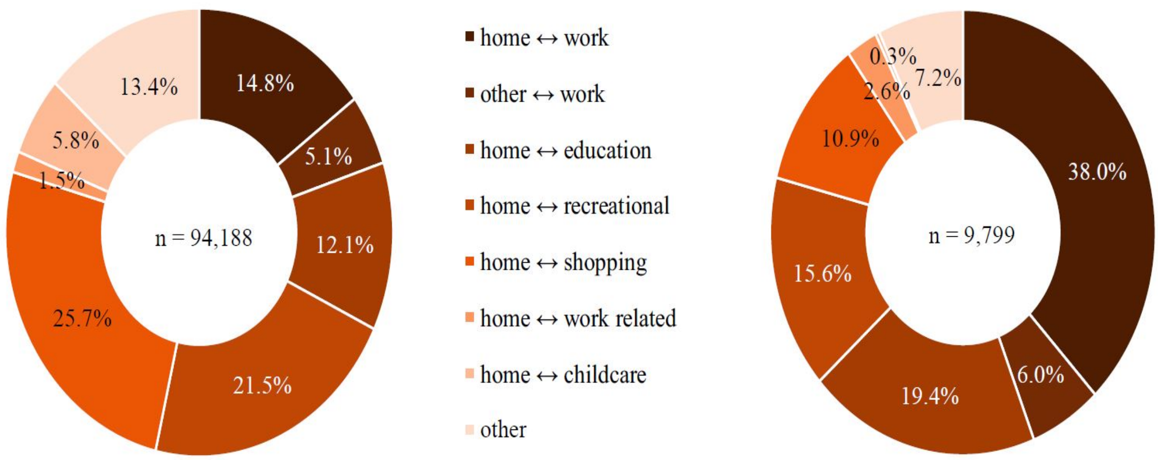

Figure 10: Travel purposes depending on different mobility type [HEI16]

For example, for long-distance travel, unimodal mobility may be better than frequent transfers such as intermodal mobility [HEI16]. Conversely, in the case of commuting or going to school, it may take a very long time if mobility users try to reach the destination at once by using a private transportation because of heavy traffic congestion. In this case, using more than one transportation, such as intermodal mobility, is more suitable for the purpose of travel.

Figure 10 shows unimodal and intermodal mobility ratios depending on the travel purpose in Berlin. The left chart shows the ratio of unimodal mobility and the right chart shows the ratio of intermodal mobility [HEI16]. These two charts show that mobility users choose different types of mobility depending on the purpose of their trip. They prefer to take intermodal mobility than monomodal mobility when commuting to and from work. In the case of education, it appears that intermodal mobility is more preferred. However, it appears that unimodal mobility is more preferred for non-commuting and non-educational. For travel purposes related to shopping and recreational activities, including hiking, camping, and cycling, people prefer unimodal mobility rather than intermodal mobility. The result of this research shows that the necessity of classifying mobility types according to the purpose of travel is relevant for mobility planning. For this reason, the user preference service will ask mobility users what the purpose of their travel is. The user reference service will provide an input field where mobility users can directly enter their preferred travel purpose. The preference for travel proposals entered by mobility users will be used to create personalized travel routes. Mobility users can experience travel routes close to their preferences through the user preference service.

Weather

People often end up having to change their plans depending on the weather conditions. In particular, the weather plays an important role in outdoor activities. In addition, mobility users' choice of transportation can be different depending on the weather. Also, because of weather conditions, unexpected delays or traffic accidents may occur.

For example, mobility users prefer the transportation to avoid the rain, such as buses and trains, rather than walking or cycling. In addition, depending on the temperature, mobility users prefer transportation that is cooler and more comfortable. Figure 11 shows the effect of 5 different types of objects (bike, transit, walk, driver, and passenger) and trip rates with increasing temperature. The most prominent part of figure 11 is the change in the utilization of the bike as the temperature increases gradually. If the number of people who use bicycles for travel increased by about 3 percent in the first 1 degree increase, the rate of increase by more than 5 percent in the second degree increase. A six percent rise in temperature results in a more than 15 percent increase in utilization. In the case of 'transit' and 'walk', the increase in utilization rate does not exceed about two to three percent even if the temperature increases from 1 to 6 degrees celsius. In the case of 'driver', the effect of temperature rise appears to be minimal. In the case of 'passengers', the number of passengers decreased by about 1 percent when the temperature increased by 1 degree. As the temperature increases, the change in the number of passengers decreases.

When the temperature rose by 6 degrees celsius, the number of passengers dropped by more than 7 percent [KEN11].

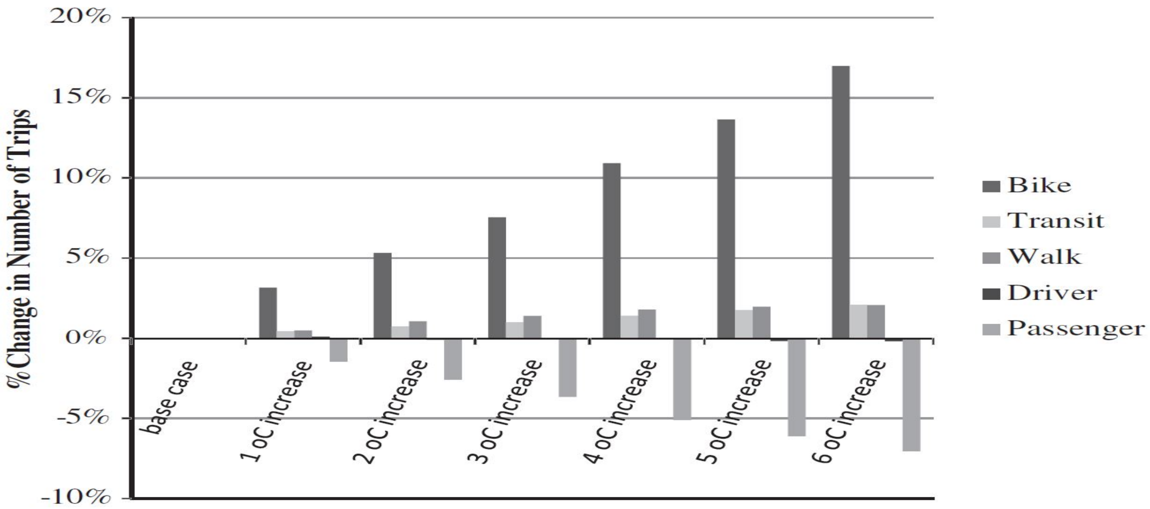

Figure 11: Change in number of trips by each mode under temperature [KEN11]

Figure 12 shows the effect of 5 different types of object (bike, transit, walk, driver, and passenger) and trip rates with increasing rain frequency. If the rain frequency increases, the change in number of each object gradually decreases. On the other hand, as the rain frequency decreases, the change of number in each object gradually increases.

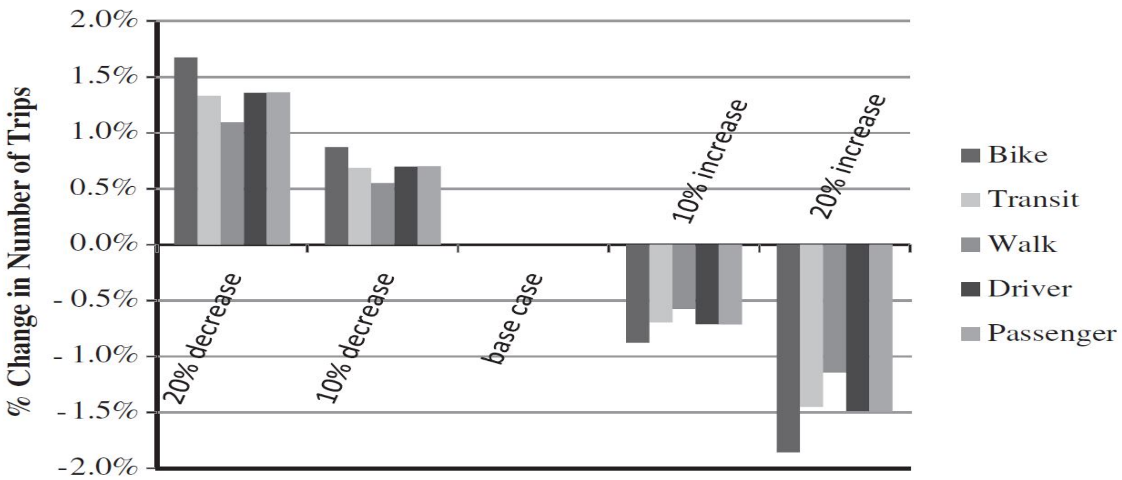

Figure 12: Change in number of trips by each mode under rain frequency [KEN11]

What this thesis is trying to say in figures 11 and 12 is that the weather factor can directly affect the mobility user's travel plan, transportation, and travel routes. Depending on the weather, mobility users decide which transportation to use and which routes to travel to their destination [KEN11]. Mobility users can choose the weather they prefer in the user preference service when traveling. Selected preferences will be stored in the user preference service and used to provide personalized travel routes to mobility users.

Current location

If mobility users set up a mobility plan based on their current location, the current location is the base point for the entire travel plan. Therefore, where mobility users are currently located is one of the most important information to create best possible travel routes. Another important reason for the current location is that if the current location is the starting point, mobility factors that need to be considered while travel planning are heavily influenced by current location. For example, depending on where mobility users are currently located, the choice of transportation changes, the time it takes to get to the destination changes, and the required travel cost is different. In practice, many mobility planning platform such as Google Map or Apple Maps send a pop-up message to mobility users to authorize the application to use their current location information. By providing the current location to the mobility platform, mobility users can quickly set the current location using the GPS linked to the application without having to search for the current location separately when they plan a travel route. However, since providing user location information can lead to leakage of personal information and abuse of data, mobility users need to always pay attention to security for their personal information. The user preference service will ask if mobility users prefer a mobility platform that utilizes current location. Mobility users can store their preferences in the user preference service. Stored preferences will be used to provide personalized travel routes for mobility users.

Traffic condition

If mobility users can check current traffic conditions in real time and make travel plans, they can create more optimized and personalized travel routes. In particular, mobility users will be able to enjoy faster and more comfortable trips if they are familiar with roads and times that are frequently in congestion. For example, according to prior statistics research by TomTom, the traffic conditions in Karlsruhe shows high congestion rate from 7 a.m. to 9 a.m. [Tom21]. This is the time when many office workers go to work. After 9 a.m., the congestion rate of traffic condition gradually decreases. However, traffic congestion rates increase again from 5 p.m. to 7 p.m. rapidly. This is the time when many office workers return home. This traffic condition cycle occurs repeatedly during the week [Tom21]. Due to the large number of private vehicles and public transportation concentrated at a particular time, traffic conditions become congested. Because of bad traffic condition, the travel time takes longer to get to the desired destination than when traffic conditions are good. Many application and mobility services have been developed as solutions to address traffic condition issue at a specific time. Many mobility platform provide current traffic condition. By using them mobility users can check not only the travel routes, but also they can get real-time traffic conditions of the travel route.

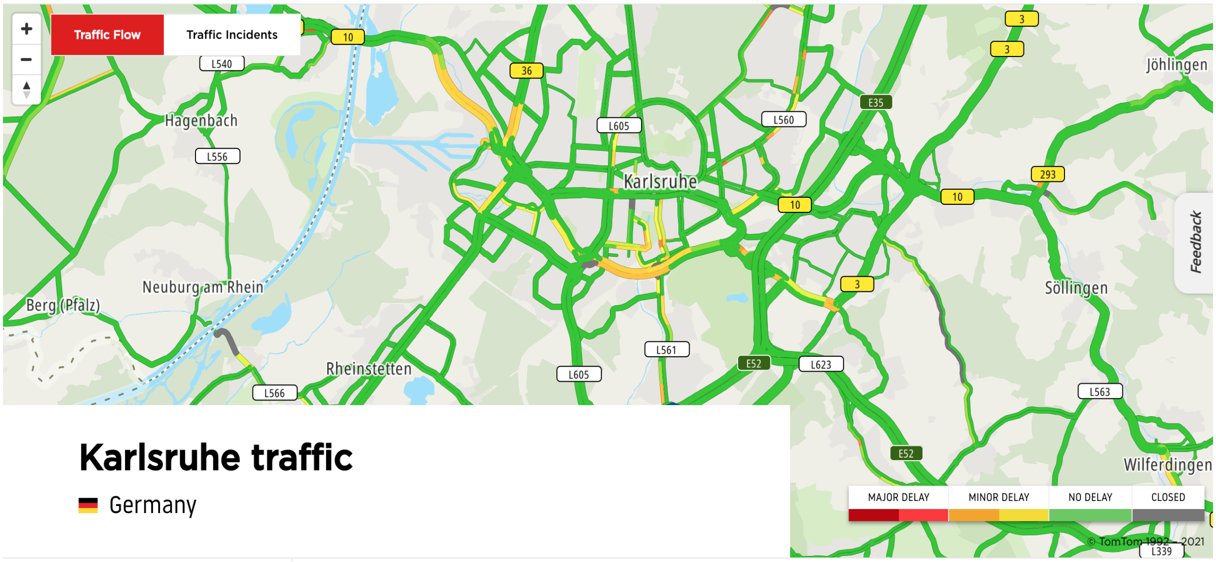

Figure 13: Real-time traffic congestion in Karlsruhe [Tom21]

As seen in figure 13, the TomTom traffic API provides information that mobility users can check out the real-time traffic condition visually. TomTom traffic API divides traffic conditions into four stages and indicates them on the map: major delay, minor delay, no delay, closed. If major or minor delays occur, they are subdivided into two different colors according to the degree of traffic congestion [Tom21]. Not only the TomTom traffic API but also the Google Maps API displays real-time traffic congestion information on the map so that users can check the road traffic situation at a glance. The user preference service will require and store whether mobility users prefer to use real-time traffic condition service. Also mobility users can decide whether to start now or later when the traffic condition of current route is bad. In the user preference service, mobility users can enter their preferences related to traffic conditions. The user reference service will use their preferences to provide personalized travel routes to mobility users.

4 User Preferences Service

In section 4, this thesis will show how to create a prototype of the user preference service, which provides functions for mobility users to store their mobility preferences, view and modify them when mobility users want. Creating a prototype of the user preference service requires several steps. The first step to go through is the requirement elicitation. Requirements for prototypes of user preference service are derived by using many different methods such as ISO standards. Section 4 will describe the elicited requirements in detail, and separate into functional and non-functional requirements. The next step for the prototype of the user preference service is to develop the client and server of the prototype. For that, this thesis will describe many software technologies needed for prototype development such as software architecture, entity structure, different client pages, and API diagrams.

4.1 Requirements elicitation

Requirement elicitation is a concept that refers to the process of eliciting stakeholder requirements. In the user preference service, the stakeholder refers to mobility users. Furthermore, eliciting their requirements directly affects the result of the prototype of the user preference service [DAV03]. Identifying the requirements of mobility users can also solve potential problems which might happen in the future. Therefore, requirement elicitation plays a crucial role in creating a prototype of the user preference service. The key of requirement elicitation is to collect mobility user's opinions and implement them into the prototype of the user preference service as much as possible [DAV03]. For requirement elicitation, it is basically necessary to determine in advance what theoretical background should be used to elicit the requirements of mobility users. In other words, requirement elicitation needs methodology for the prototype of the user preference service. Next subsection will explain which methodology will be implemented in this section to elicit the requirements of mobility users.

4.1.1 Framework

One of the main reasons why requirement elicitation is difficult is due to various target areas and different characteristics depending on the projects or research. A way to solve these problems is to apply a contextual framework to the requirement elicitation. This section will present the framework for requirements elicitation of the user preference service. The framework is based on characterizing typical requirement elicitation and representing functional and non-functional requirements. The framework is a relevant component because frameworks provide logical basis and reason for the requirements elicitation. This thesis selected two frameworks from the research paper 'Framework for Matching Requirements Elicitation Techniques to Project Characters': Goal-oriented elicitation and Scenario-based elicitation [TAM06].

Goal-oriented elicitation is a methodology that derives a requirement based on the purpose of a project or service [TAM06]. In the case of the user preference service, mobility users look for mobility planning platforms that consider their mobility preferences. The user preference service allows mobility users to customize their mobility preferences so that the mobility planning platform can utilize this service to provide personalized routes to mobility users. Under the main goal of this service, there are many sub-goals which are related to each other [TAM06]. This thesis defines all requirements and processes associated with mobility preference data as mobility preference data engineering. Mobility users should also be independent of each other. That is, only authorized users should be able to access certain mobility preferences.

Scenario-oriented elicitation is a methodology that derives a requirement based on the scenario (use case) of project or service [TAM06]. In the case of the user preference service, Studying all the possible use cases that mobility users may encounter when using this service is critical to improving and applying the requirements associated with user interface or usability.

4.1.2 Functional requirements

Functional requirements in the user preference service describe the service features or function of the software system or its components. In other words, function requirements specify what the software has to do for mobility users [KRO09]. The functional requirement to be introduced in the next subsection will be expressed using the abbreviation 'F' which is the first word of functional requirement.

F1: Mobility preference data engineering

Mobility preference data engineering encompasses all mobility preferences handling processes such as customizing, modifying, getting and saving. To enable these processes, the REST API should communicate with the service so that this API is able to flexibly manage mobility preference data in the database.

F2: Authentication

Authentication is the process of identifying mobility users that request access to the server. If the access control of user identification according to credential like username and password is confirmed, then the user preference service will give authentication to mobility users. It means that this service allows mobility users to login with entered email and password. For example, password-based authentication verifies that the password that mobility users enter when logging in matches the password stored in the database. If two passwords match, authentication with this entered email and password is given to mobility users. Password is the most common method in authentication. However, the problem of this method is that mobility users have to enter the login data every time [LUN19]. If there is a token in local storage which remembers login data, they don't need to pass the login process while they re-open this service.

F3: Administrator

Administrator is a specific user account who has a different role and permission right. Unlike other regular mobility users, this user has access to servers and databases. With access to servers and databases, the administrator can manage the user preference service for the mobility users. In order to give this specific authorization, it is important to separate the role of the different users. For example, a page that only the administrator can access should be accessible only to an administrator-authorized user.

4.1.3 Non-functional requirements

Non-functional requirements in the prototype of the user preference service describe specific criteria or guidelines that can be used to determine the functionalities such as usability or reliability of a software system [ZHA19]. Non-functional requirements support function requirements that force constraints on the user-interface or feature implementation such as performance requirements or safety. The non-functional requirement to be introduced in the next subsection will be expressed using the abbreviation 'NF' which is the first word of non-functional requirement.

NF1: Usability

How easy is it for mobility users to use the user preference service? Why do we have to consider user-interface when building an application? All of these questions start with usability. Usability is a feature which enables intuitive interaction between mobility users and the user preference service. The primary requirement for usability is that when the user preference service is accessed, mobility users immediately know what to do to get what they want [ZHA19]. However, if they need time to think about what to do to achieve their goals while they're using the user preference service, this service is not a user-friendly application, no matter how this service is designed. When designing a user-friendly application, the layout of the interface should be as simple as possible. However, this simplicity is different from plainness. For example, the size and color of menus representing the overall character of the application should not be disturbed by other sub-components. At this time, unnecessary elements are excluded as much as possible. Furthermore, visually comfortable colors are appropriately used to secure the clarity of the interface, thereby reducing the time mobility users spend searching and further inducing comfortable use of the application.

NF2: Performance

In a non-functional requirement, performance refers to how fast is the execution time of the user preference service. The execution of this service not only includes how quickly this service processes requests from mobility users, but also returns the results of the request with a response body to mobility users.

4.2 Frontend

Frontend is a presentation layer that shows visual elements to mobility users. In the user preference service, each frontend component refers to an application page that is shown to the client. Each component has different designs and features depending on the purpose of the page. To implement the many different types of frontend components of the user reference service, this paper uses the flutter provided by Google. The flutter is an open-source UI development kit developed by Google.

4.2.1 Landing page

Landing page is the first screen displayed when mobility users activate the user preference service. This page contains a brief description of the user preference service. When they click the continue button, the landing page is redirected to the sign-in page.

4.2.2 Sign-in and sign-up page

Sign-in page provides a function for mobility users to sign in to the registered account. For sign-in, mobility users need to insert their registered email and password. If they don't have their own account yet, they can register their accounts with the sign-up page. At the bottom of this page, the user reference service separates sign-up letters into different colors so that mobility users who do not already have registered accounts can go to sign-up pages directly. When mobility users press the continue button, the user preference service will verify entered email and password data before sending it to the backend. For example, all input fields in this page are mandatory. If mobility users attempt to log in with the empty input field, then warning messages will be exposed to mobility users such as "please enter your email or please enter your password". If the entered email is an invalid form, "please enter valid email" message will show up. If the validity check of the client is passed but the data entered does not match the data stored in the database, the message "please check your login information" will show up. When all validation scenarios are successfully passed on the sign-in page, the entered email and password are passed to the backend via the 'POST /api/login API'. The 'POST /api/login' API will be discussed in detail in section 4.3.2. When the REST API call to the backend is successfully completed, this page is redirected to the menu page.

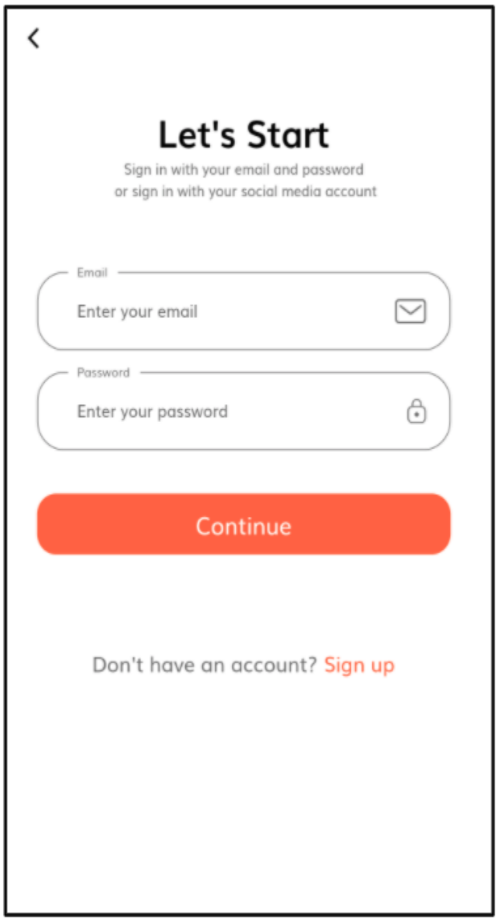

Figure 14: Sign-in page

Sign-up page is a page where mobility users can register their own accounts. To finish the sign-up process, mobility users should fill in the email, password and confirm-password fields. Sign-up pages also require mobility users to enter static user profiles such as gender, age, and payment method. For example, this page provides many different user profiles for payment methods such as credit cards, girodirekt, paypal, and applepay.

When mobility users press the save button on the bottom of this page, the user preference service will verify entered email, password, confirm-password, and static user profile data before sending to the backend. For example, all input fields in this page are mandatory like the sign-in page. If mobility users attempt to finish the sign-up process with the empty input field, then different warning messages will be exposed to mobility users such as "please enter your email or please enter your password". If the values entered in the password and confirm-password fields are different, "passwords don't match" message will show up. If the mobility user sets the password for the account to less than 8 digits, the message "password is too short" will be displayed. When all validation scenarios are successfully passed on the sign-in page, the entered email and password are passed to the backend via the 'POST /api/mobilityUsers' API. The POST/api/login API will be discussed in detail in section 4.3.2. When the REST API call to the backend is successfully completed, this page is redirected to the mobility preference page.

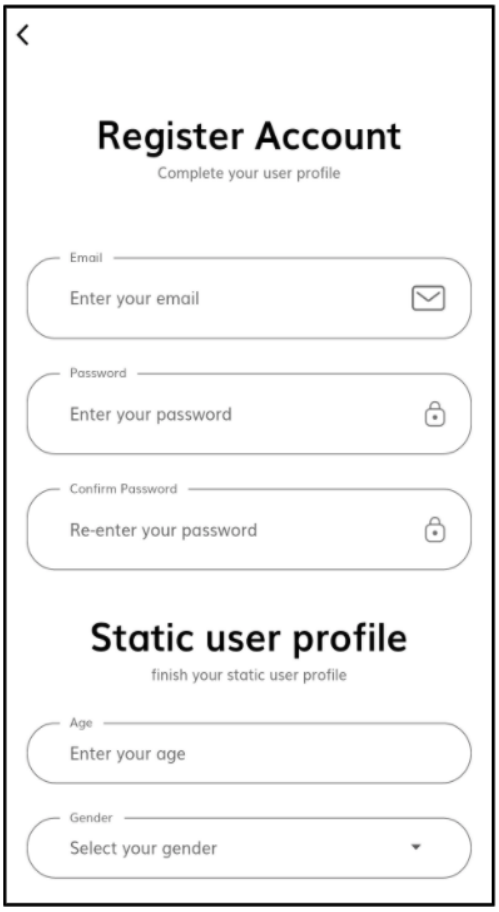

Figure 15: Sign-up page

4.2.3 Mobility preferences and edit preferences page

Mobility preferences page is a page that provides a function for mobility users to select and store their mobility preferences. The functionality of this page is that mobility users can customize their mobility preferences in the direction they want. This page appears only when mobility users first register their account through the sign-up page. Mobility users can customize preferences related to dynamic reference profiles and situational context as defined in section 3.1.3 of this thesis. These pages provide many different types of mobility preference options for mobility users. For example, preferred transportation is a mobility preference in dynamic preference profile. Mobility users have a chance to choose different preferred transportation such as bus, train, tram, and taxi.

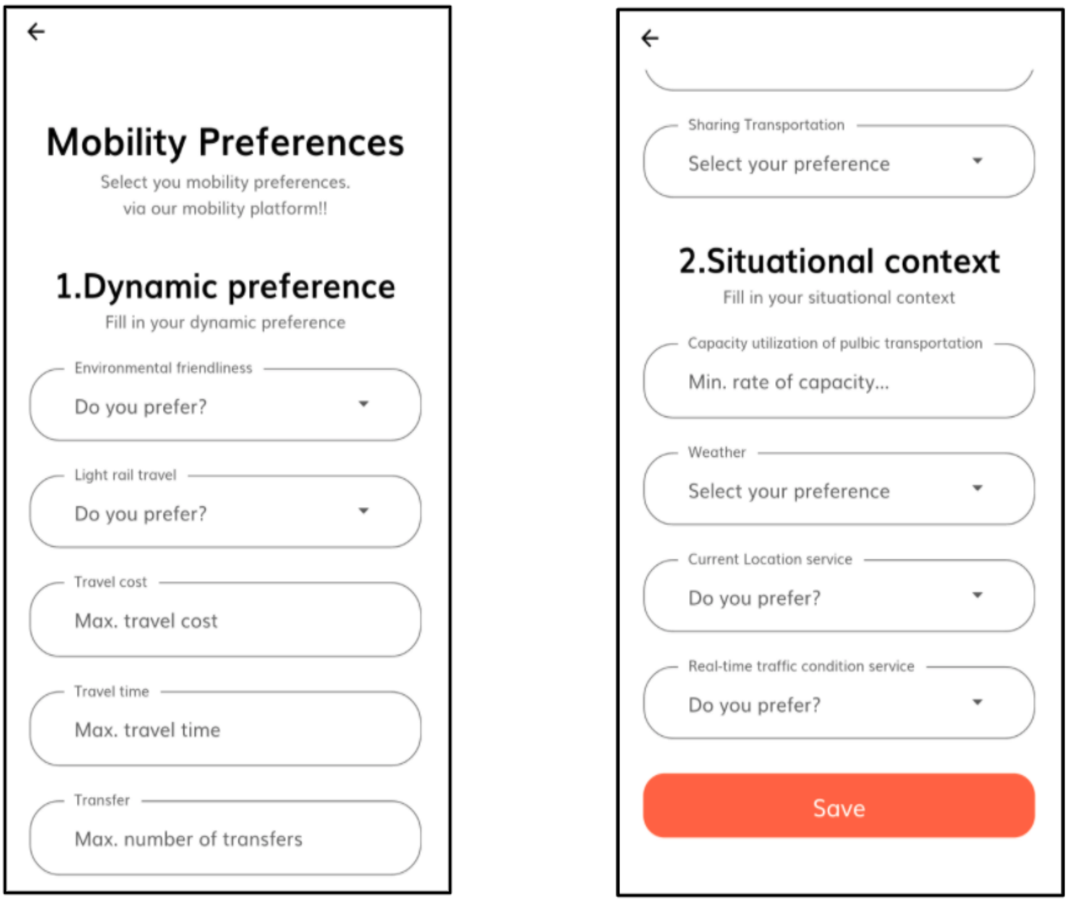

Figure 16: Mobility preferences page

When mobility users press the save button on this page, the user preference service will verify whether all input fields of this page are filled. If mobility users attempt to pass the mobility preference page with the empty input field, then "please fill your preference" messages will be exposed to the blow of empty input field. When all validations are successfully passed on this page, the entered data are passed to the backend via the 'POST /api/mobilityPreferences' API. This API will be discussed in detail in section 4.3.2. When the REST API call to backend is successfully completed, this page is redirected to the success page.

Edit preference page is a page that mobility users can edit and re-save the static user profile created in the sign-in page and the dynamic preference profile and situational context created in the mobility preference page. The edit preference page is essentially a page with exactly the same design as the mobility preference page. However, the edit preference page automatically recalls the preferences that were already saved in the database, directly modifies and re-saves them. When mobility users reach the edit preference page through the button on the menu page, all input fields on this page will be automatically filled through 'GET /api/mobilityrPreferences' API. The 'GET /api/mobilityrPreferences' API will be discussed in detail in section 4.3.2. Preference data retrieved through GET Method can be modified directly by mobility users on this page. When they press the re-save button at the bottom of this page, the user preference service will verify whether all input fields of this page are filled. When all validation scenarios are successfully passed on this page, the modified data will be delivered to the database and overwrite the previous data table.

4.2.4 Success and menu page

If mobility users have successfully saved their mobility preferences, the user preference service redirects the screen to a success page. The success page is intended to inform mobility users that their preferences have been successfully saved. If they click the continue button located in the center of this page, this service will redirect the route to the sign-in page so that mobility users can sign in directly.

Menu page is where mobility users can log out or redirect to an edit preference page where they can view, edit, and re-save these mobility preferences. This page will show up when mobility users successfully sign-in to their registered account. If mobility users click the edit preferences button, the screen will move to the edit preferences page. If they click the logout button, the screen will move back to the sign-in page

4.3 Backend

Backend is the server component in the prototype of the user preference service. It receives requests from the client, handles their requests with internal service logic, and sends back to the client with the response. The response of the backend has a body with the result of processing the client's request. Backend also has a connection with the database that stores the data of requests from the clients. For the technology stack of backend, this thesis will use Java's Spring boot to develop the server for the user preference service. Spring Boot is an open source Java-based framework used to create microservices. The reason this thesis chose Spring boot as the backend development language is because Spring boot Helps to avoid the manual code writing like annotations or complex XML configurations [JAH17]. It also provides easy connection configuration with database and queue service such as MySQL, PostgreSQL, and H2 Database. For the database system of the user preference service, this thesis selects H2 databases. H2 database is one of the types of relational database management systems. H2 database has the advantage of being relatively simple to set up and quickly applied to developing small applications than MySQL or PostgreSQL. Figure 19 shows how software architecture of the user preference service is configured through the architecture diagram.

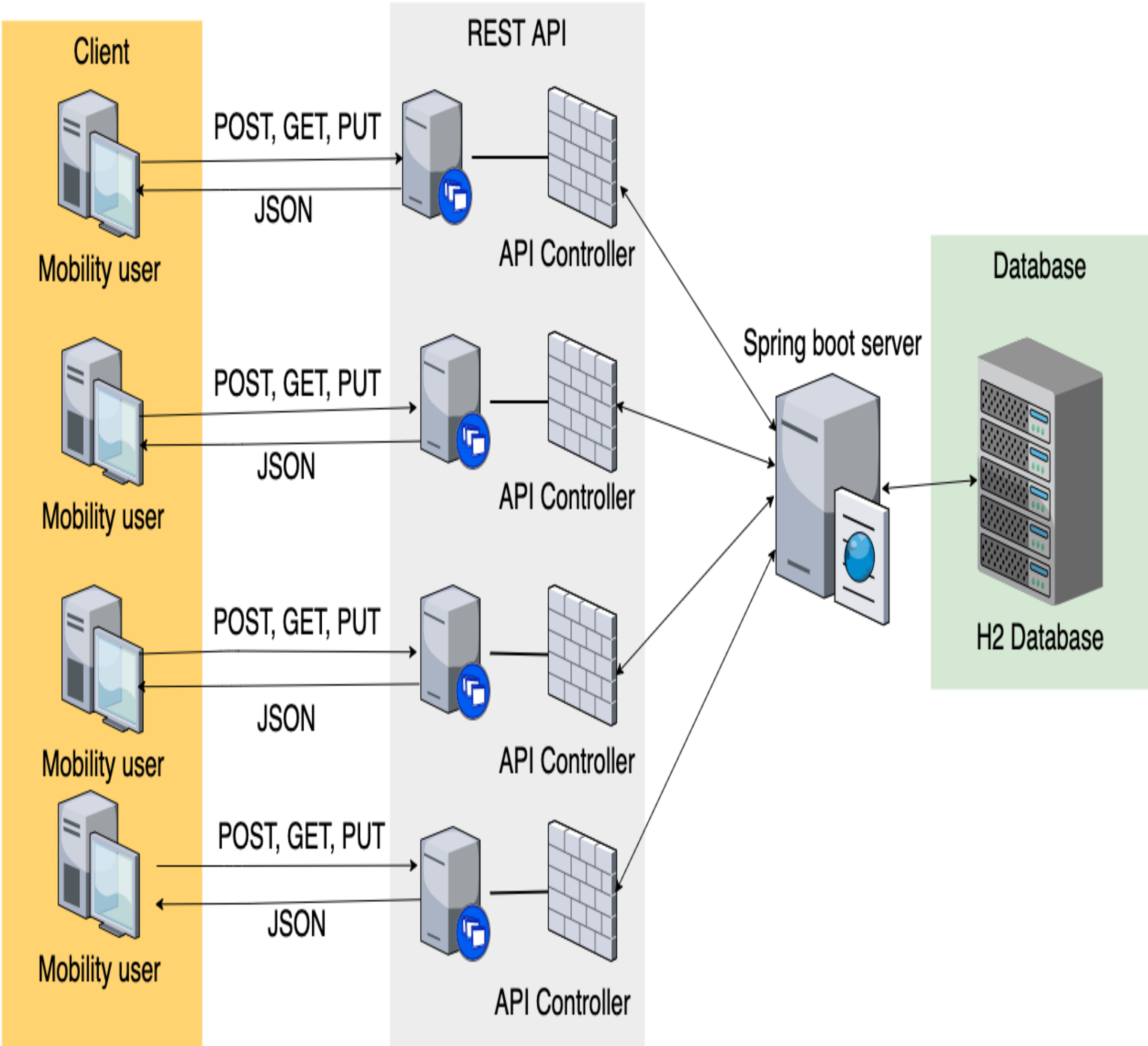

Figure 17: Software architecture of the user preference service

4.3.1 REST API documentation

REST API documentation describes how clients and servers communicate using the REST API in the user preference service. This section is very important to understand this service because each service component of the server communicates with the client differently by using a different HTTP method depending on the situation.

'POST /api/mobilityUsers'

'POST /api/mobilityUsers' is a custom REST API in the user preference service that works when mobility users enter email, password, and static user profile on the sign-up page. When mobility users press the save button, all input data will be delivered by 'POST /api/mobilityUsers' API to the server. Additionally, the async/await pattern will wrap around this API. This pattern acts to prevent a particular event from moving on to the next event until the previous event is completely finished. By using this pattern, the completion of API and sending response body to the client are guaranteed before switching to the mobility preferences page. The transferred data to the server will pass API controller layer, service layer, repository layer, and entity layer. Finally, this data will be stored in the database. If the whole process is complete,then the server will send a response body to the client.

'POST /api/mobilityPreferences'

'POST /api/mobilityPreferences' is a custom REST API in the user preference service that works when mobility users enter their mobility preferences. Basically, the logic of this API works the same as POST/api/mobilityUsers. The difference between these two APIs is that each API operates based on different entity layers. 'POST /api/mobilityUsers' uses mobility users layers. But 'POST /api/mobilityPreferences' uses mobility preferences layers, so the data received from clients is related to mobility preferences such as dynamic preference profile or situational context.

'POST /api/login'

'POST /api/login' is a custom REST API in the user preference service that works when mobility users enter try to login with email and password data on the sign-in page. This API will transfer the entered data to the server. The server will compare this data to the data stored in the database. If entered data matches with saved data in the database, this API will redirect the root to the menu page.

'GET /api/mobilityPreferences'

'GET /api/mobilityPreferences' is a custom REST API in the user preference service that works when mobility users click edit preference button in the menu page. When this page is opened, this page will automatically call 'GET /api/mobilityPreferences'. This API sends a request to the server to get a stored mobility preference. Based on the mobility user information contained in the request, the server sends mobility preference data from the database to the client in the form of JSON.

'PUT /api/mobilityPreferences'

'PUT /api/mobilityPreferences' is a custom REST API in the user preference service that works when mobility users try to re-save modified mobility preferences on edit preference page. When they click re-save button, the modified data will be moved to the server through this API. The modified data overwrites the previous data stored in the database. After that, the user reference service is redirected to the menu page again.

In the following, this thesis will show an activity diagram of REST API for the user preference service. This diagram expresses and schematizes all REST API interfaces used in this service.

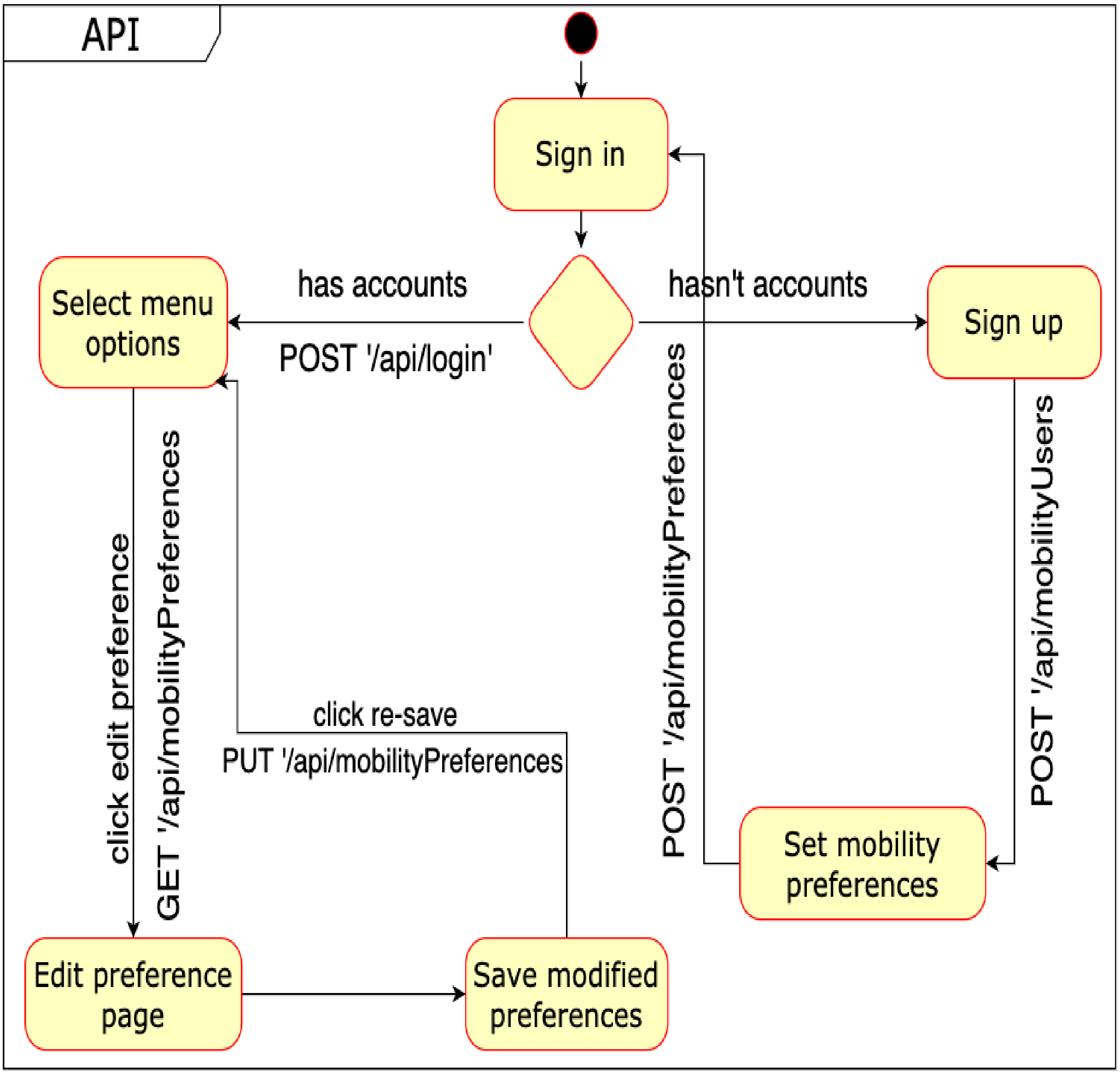

Figure 18: Activity diagram of REST API for the user preference service

5 Discussion

This section is a step for finding all use cases of the user preference service. Also this section will evaluate this service based on mobility profiles and requirements elicitation.

5.1 Use cases

This section will classify the different use cases of the user preference service. Figure 20 describes the number of use cases that mobility users can experience in this service. ,

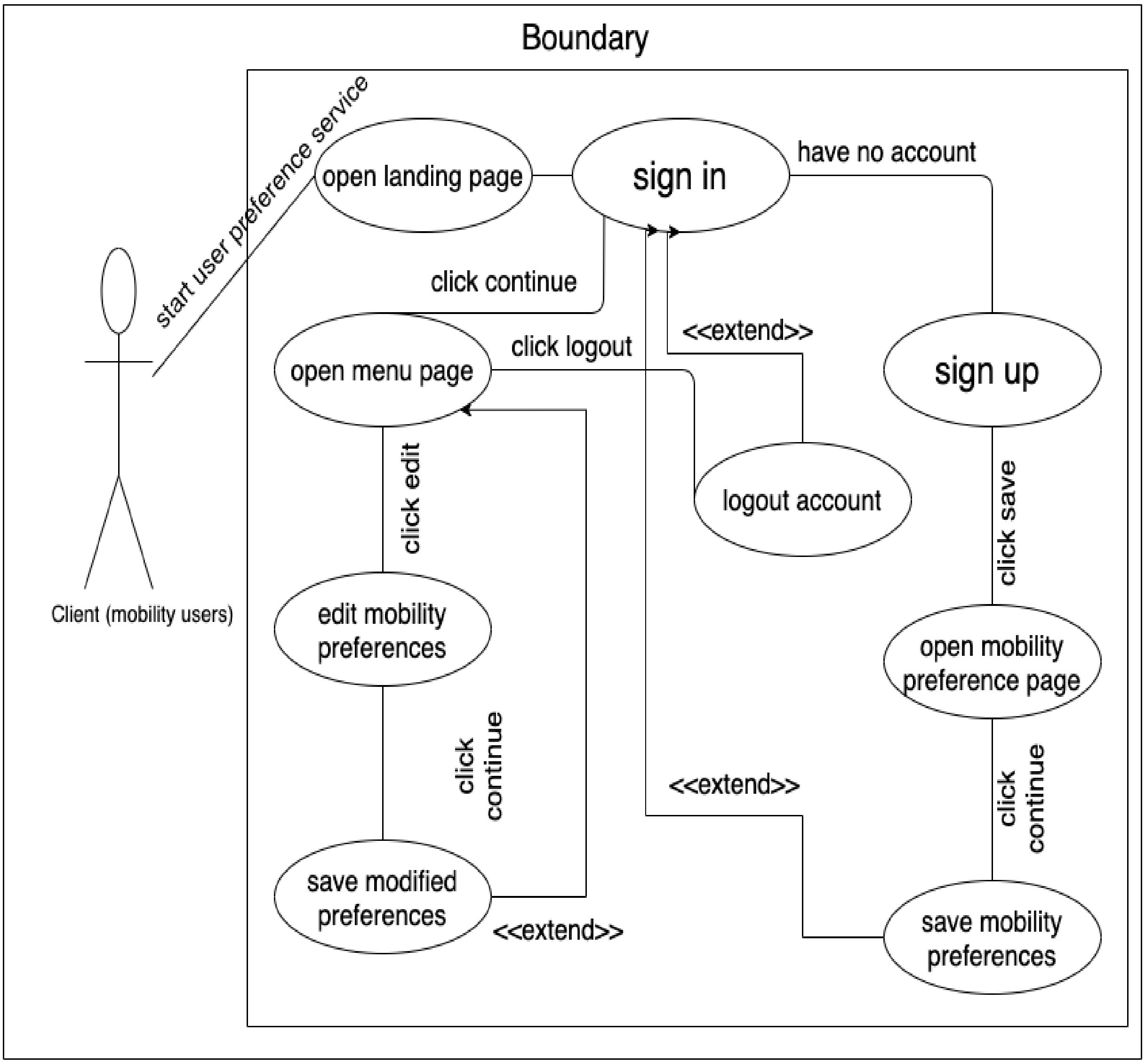

Figure 19: Use cases diagram

5.2 Evaluation

This section will evaluate the previously designed and implemented user preference service based on an exemplary mobility profile. The exemplary mobility profile will be constructed based on the fictitious persona. In this persona, there are fictitious characters and situations. Based on that, this section will infer the corresponding mobility profile.

> John Connor is a healthy student who just turned 20. He is currently living in a single-room apartment in Karlsruhe. His current residence is about 30 minutes away from college by bicycle. Because of the long travel time, he prefers to travel with local public transport every day and therefore has a semester ticket. With this ticket, he can use public transport in the entire KVV network free of charge. However, he usually walks or uses a bicycle when he travels a short distance such as grocery shopping. When he does not use public transportation, he prefers sunny weather. However, he doesn't care much about the weather when he uses public transportation. John Conner enjoys exercising very much. He participates in football training held every Monday, Wednesday, and Friday. The training ground is located about 15 minutes away from his apartment by bicycle. When he goes football training, he usually uses his bicycle. He does not own a private vehicle because he is still a student yet. But he likes to drive and has a driver's license. Stadtmobil is the most popular car-sharing service in Karlsruhe. Not long ago, he also registered for this service. He prefers a road surface that is good for cycling or walking. For example, he prefers bicycle lanes or paved roads. If he travels on foot, he also prefers a living street where only people can pass by or pass by a bicycle that is not fast. John tends to build travel routes or travel plans very spontaneously except for the daily route that repeatedly occurs every day. He doesn't think about the exact route to his destination until relatively late. So he gets lost often. Therefore, he prefers a mobility platform that builds travel routes using the current location of mobility users. When he books a train or bus ticket, he used credit cards that his parents had lent him in the past. Recently, he linked his credit card account to Google Pay. The payment process of Google pay is much easier and faster than before. He usually pursues a life that is close to nature. He always appreciates the importance of nature and has a positive view of nature conservation. He tries to use transportation that causes minimal environmental pollution. He also likes to move to the destination with the minimum transfer.

On the basis of this persona, corresponding mobility profiles consisting of user profiles and mobility preference profiles were inferred. Table 1 shows the exemplary user profile of John Conner. These profiles are constructed based on the model in section 3.1.3.

Table 1: User profile

Profile	Data
Demographic data	Man, 20
Transportation for the physically handicapped	No
Payment method	Google pay, Credit card
Subscription	Stadtmobil, KVV

John Conner is a 20-year-old male. He is physically fit enough to do soccer training regularly. He does not need any support regarding transportation for the physically handicapped. He uses Google pay and Credit cards as his payment method when he needs to pay in mobility services. He defines his mobility preferences by travel purposes: lecture, training, and free time. Table 2 shows the exemplary mobility preferences profile.

Table 2: Mobility preferences profile

	Lecture	Training	Free time
Environmental friendliness	Yes	Yes	Yes
Light rail travel	Yes	No	No
Travel cost	150€ per semester	0€	0€
Travel time	30min	20min	no limit
Transfer	max 1 time	0 time	0 time
Waiting time	max 10 min	0 min	0 min
Preferred transportation	Tram,Bus	Bicycle	Walk
Living street	No	Yes	Yes
Favorite place	University	Training center	Nothing
Road inclination	No	max 15°	max 15°
Road surface	Asphalt	Bicycle lanes	Paved roads
Sharing transportation	No	Stadtmobil	Stadtmobil
Current location	No	No	Yes
Weather	Doesn't matter	Sunny	Sunny

For example, he uses public transportation to go to college to attend lectures. He doesn't care about the weather when he uses public transportation. But in the case of training, he prefers to ride a bicycle. When he has free time to go somewhere he prefers to walk in sunny weather. If the purpose of the trip is free time, John Conner prefers mobility services that utilize the current location. The reason is that he moves spontaneously without any fixed destination at this time. He needs support to know the current location so that he can go back to home easily. On the other hand, in the case of lectures or training, he doesn't prefer the current location. The reason is that the route to go to college to attend lectures or training is a fixed route that he uses regularly. He is familiar with the location of this route. Also, he prefers to use a mobility platform that provides the feature to store his favorite places. For example, it is convenient to set it as a favorite place which he regularly visits every week such as the building where he goes to attend lectures or the football training center. But he prefers to improvise in his free time without any destination. Therefore, the favorite place function may not be essential for him in this case. He also prefers to set a fixed travel time for the route, which he regularly uses, such as a route to college for attending lecture or training center. Because he knows exactly how long it takes to get to the college or training center, it is possible to set a preferred travel time. However, in his free time, it is difficult to choose a preferred travel time because he enjoys his time spontaneously without any fixed destination. Based on the previous persona with corresponding mobility profiles, functional and non-functional requirements introduced in section 4.1.2 and 4.1.3 will be validated.

F1 (Mobility preference data engineering): This service should provide the end user with the opportunity to customize and save their mobility preferences.

John Conner will automatically visit the mobility preference page after he passes the sign-up process. In this page, he can have an opportunity to set his initial mobility preferences such as his preferred transportation or favorite places. If his entered mobility preferences are valid, he can save his mobility preferences to the database via the save button on the mobility preference page. He can view his mobility preferences on the edit mobility preference page. In this page, he can modify his mobility preferences. After he finishes to change his preferences, he can re-save them into the database. They will overwrite the previous mobility preferences in the database. This service satisfies the functional requirements that mobility users can freely manipulate their mobility preferences.

F2 (Authentication): This service should provide the end user with the opportunity to register their account.

When John Conner wants to use the user preference service, first of all what he has to do is account registration. This service offers a sign-up page for registration. In the sign-up page he should enter a valid email and password. It means that the form of email should be valid and the password should be longer than 8 digits. When the whole sign-up process is finished, then he can use his registered account to login. The user preference service fulfills the functional requirement regarding authentication according to scenario 1. However there is one improvement point. This service uses only password-based authentication. It means that this service does not use tokens. Therefore, after the authentication is confirmed, the login status is not saved because the token is not saved in local storage. Every time mobility users use this service, they have to go through a login process. However, the advantage of a token is that mobility users don't have to go through the login process every time if the token is saved in local storage.

F3 (Administrator): This service should be able to provide the function to set up an administrator role to registered mobility users.

Unfortunately, John Conner doesn't have a chance to set administrator roles on his registered account because this service does not support setting different roles like administrator for registered users. However, this function must be added for the development of this service in the future.

NF 1(Usability): This service should provide the end user with a simple user interface so that mobility users don't need any tutorial or guideline to understand how to use this service.

As already introduced in figure 14,15, and 16, the user interface of this service is constructed intuitively and descriptively designed. In addition, all unnecessary decorations or images were excluded for mobility users to use this service. However, to get a more accurate and practical evaluation, this service has to be evaluated by mobility users such as John Conner. The reason is that the problems and improvements of this service can be found in their opinions. Unfortunately, this service isn't deployed yet. So currently there is no chance to get a comment or feedback by mobility users

NF 2 (Performance) : This service should be able to show performance that is not problematic for mobility users to handle requests.

John Conner has 2 methods to evaluate the performance. The first method is to measure page rendering speed using the URL of the deployed service. For example, a web application called 'PageSpeed Insights' provided by Google can be used to measure the rendering speed. The second way is that mobility users use this service and evaluate the performance directly. This method is difficult to represent performance in accurate figures, but it is easy to see which part of the execution performance should be improved through feedback obtained from mobility users. However, the service has not been deployed. Therefore, it is difficult to say that the requirements for performance are fulfilled in this thesis.

Table 3: Requirment evaluation

Requirement	Achievement status
F1 (Mobility preference data engineering)	O
F2 (Authentication)	O
F3 (Administrator)	X
NF1 (Usability)	X
NF2 (Performance)	X

6 Conclusions and Future Works

In this thesis we have talked about the user preference service that helps mobility users to customize their different mobility preferences themselves. The development of the user preference service is motivated with the idea of helping travel for mobility users by using personalized travel routes which are closest to their mobility preferences. Therefore, the primary objective of this thesis is to conceptualize and implement the user preference service. For this thesis to achieve the primary objective, literature-based and existing application-based mobility profile modeling has been used to construct a new form of mobility called unique mobility profile modeling for the user preference service. This modeling approach will serve as the basis for the theoretical and contextual aspects of this service. By using this modeling approach, this thesis is able to build a new mobility profile. This profile is a generic model that can handle many different types of individual mobility preference from different mobility users. By using this mobility profile, the prototype of the user preference service was implemented. For implementation of this service, the process of requirement to identify functional and non-functional requirement has to be executed. Considering different aspects of requirements, this thesis constructed the user preference service that consists of client and server. After that, this service has been evaluated based on the fictitious persona and functional and non-functional requirements.

Based on modeling mobility profiles and requirement elicitation, this thesis achieved the primary objective. However, the result of the evaluation shows some improvement points that have to be worked on in the future. First of all this service can be extended to support new mobility preferences and mobility profiles that will arise over time. For example, there were not many public Wi-Fi in public transportation in the past, but as infrastructure develops, more and more public transportation are providing public Wi-Fi for their passengers. Also, this service has to be deployed to evaluate usability and performance so that mobility users can use this service directly and leave different comments or feedback. By using these feedback and comments, the problem of usability and performance will be identified. In addition, these opinions can be used to further develop the usability and performance of this service. Furthermore, for the authorization of an administrator, this service has to provide an option to set a different role of registered users. The administrator will make it easier to manage the server and database of this service. Finally, the modeling research for finding diverse and meaningful mobility profiles still has to be continued to improve the user preference service.

References

[BER14] S. BERG. Multimodal mobility — intermodal vs. multimodal. *https://multi-mobility.tumblr.com/post/60830879635/intermodal-vs-multimodal-was-ist-eigentlich-der*, 2014.

[BOC21] A. TACK ; A. KLEIN ; B. BOCK. E-scooter in deutschland: Ein datenbasierter debattenbeitrag. *https://scooters.civity.de/*, 2021.

[CAB15] G. BEIRAO ; J.A SARASFIELD CABRAL. Understanding attitudes towards public transport and private car: A qualitative study. *In: Transport Policy*, pages 478–489, 2015.

[CAR17] M. CARLIER. Number of passenger cars and commercial vehicles in use worldwide from 2006 to 2015. *In: Statista - Das Statistik-Portal: https://www.statista.com/statistics/281134/number-of-vehicles-in-use-worldwide/*, 2017.

[DAV03] A. M. HICKEY ; A. M. DAVIS. Requirements elicitation and elicitation technique selection: A model for two knowledge-intensive software development processes. *In: Annual Hawaii International Conference on System Sciences (HICSS)*, pages 1–10, 2003.

[FZI20] Forschungszentrum Informatik FZI. mobility- activity-based planing assistant (mobiplan). *https://www.mobi-plan.de/*, 2020.

[GAR00] D. GARLAN. Software architeture: a roadmap. *In: The Future of Software Engineering, A. FINKEKSTEIN (Ed), ACM Press, 2000*, pages 1–10, 2000.

[HAR13] L. REDMAN ; M. FRIMAN ; T. GÄRLING ; T. HARTIG. Quality attributes of public transport that attract car users: A research review. *In: Transport Policy 25.*, pages 119–127, 2013.

[HEI16] L. GEBHARDT; D. KRAJZEWICZ; R. OOSTENDORP; M. GOLETZ; K. GREGER; M. KLOETZKE; P. WAGNER; D. HEINRICHS. Intermodal urban mobility: users, uses, and use cases. *In: Transportation Research Procedia 14*, pages 1183–1192, 2016.

[JAH17] H. SURYOTRISONGKODEDY; D.P. JAHYANTO. Design and development of backend application for public complaint systems using microservice spring boot. *In: 4th Information Systems International Conference 2017, ISICO 2017, 6-8 November 2017, Bali, Indonesia*, 2017.

[JAK15] C. DIGMAYER ; S. VORGELSANG ; E.M. JAKOBS. Designing mobility apps to support intermodal travel chains. *In: Proceedings of the 33rd Annual International Conference on the Design of Communication, New York, USA : ACM*, pages 1–11, 2015.

[Kar19] Stadt Karlsruhe. Bildung und wissenschaft - studenten- und wissenschaftsstadt. *https://www.karlsruhe.de/b2/wissenschaft_ bildung/studenten_ wissen.de*, page 1, 2019.

[KEN11] S. SANEINEJAD ; M. J. ROORDA ; C. KENNEDY. Modelling the impact of weather conditions on active transportation travel behaviour. *In: Transportation Research Part D: Transport and Environment*, pages 129–137, 2011.

[KRA14] A. KRAMERS. Designing next generation multimodal traveler information systems to support sustainability-oriented decisions. *In: Environmental Modelling Software 56*, pages 83–93, 2014.

[KRO09] H. POST; C. SINZ; F. MERZ; T. GORGES; T. KROPF. Linking functional requirements and software verification. *In: IEEE International Conference on Requirements Engineering*, 2009.

[LEO17] C. RUDLOFF ; M. LEODOLTER. Personalization of routing services: User classification as a method to overcome the cold start problem for personalized models. *In: Transportation Research Record: Journal of the Transportation Research Board*, pages 38–46, 2017.

[LUN19] T. NANDY; M. YAMANI; I. B. IDRIS; L. S. LUN. Review on security of internet of things authentication mechanism. *In: IEEE Access*, 2019.

[MAP21] Google MAPS. Google maps favorite place. *https://www.google.com/maps/*, 2021.

[PET21] J. ANKE ; A. FRANCKE ; L.M. Schaefer ; T. PETZOLDT. Impact of sars-cov-2 on the mobility behaviour in germany. *In: European Transport Research Review*, pages 1–13, 2021.

[RIC15] M. RICHARDS. *Software Architecture Patterns*. O'Reilly Media, Inc., 2015.

[RIE06] J.W. GROTENHUSI ; B.W. WIEGMANS ; P. RIETVELD. The desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings. *In: Transport Policy 14*, pages 27–38, 2006.

[SAF18] N. DRAGONI ; S. GIALLORNZO ; A.L. LAFUENTE ; M. MAZZARA ; F. MONTESI ; R. MUSTAFIN ; L. SAFINA. Microservice yesterday, today, and tomorrow. *In: Present and Ulterior Software Engineering*, pages 195–216, 2018.

[SHA93] D. GARLAN ; M. SHAW. An introduction to software architecture. *In: Advances in Software Engineering and Knowledge Engineering 2, New Jersey ,World Scientific Publishing Company*, pages 1–40, 1993.

[SUH19] F. SUHR. Was die deutschen über den e-scooter denken. *In: Statista - Das Statistik-Portal. https://de.statista.com/infografik/17906/anteil-der-deutschen-mit-folgender-meinung-zum-e-scooter/*, page 1, 2019.

[TAM06] T. TSUMAKI; T. TAMAI. Framework for matching requirements elicitation techniques to project characteristics. *In: SOFTWARE PROCESS IMPROVEMENT AND PRACTICE Softw. Process Improve. Pract.*, 2006.

[Tom21] TomTom. Karlsruhe traffic report / tomtom traffic index. *https://www.tomtom.com/en_gb/traffic-index/karlsruhe-traffic/*, 2021.

[uM20] ADAC Markt und Meinungsforschung. Eine untersuchung zum verkehrsverhalten in 29 mittleren grpßstädten. *In: ADAC Monitor Mobil in der Stadt*, pages 1–45, 2020.

[VOE19] A.I. FADEEV ; Y.V.FOMIN ; S. ALHUSSEINI ; K.V. PULYANOVA ; E.S. VOEVODIN. Standardization of the capacity utilization factor of urban public transport fleet. *In: IOP Conf. Series: Materials Science and Engineering 632*, pages 1–9, 2019.

[WUN21] Dr. F. WUNDERER. Auslastung der züge der deutsche bahn ag im fernverkehr in den jahren 2006 bis 2020. *In: Statista - Das Statistik-Portal. https://de.statista.com/statistik/daten/studie/162886/umfrage/auslastung-der-zuege-der-deutschen-bahn-im-fernverkehr-seit-2006/*, 2021.

[YAN15] Y.C CHIOU ; R.C.JOU ; C.H. YANG;. Factors affecting public transportation usage rate: Geographically weighted regression. *In: Transportation Research Part A 78*, pages 161–177, 2015.

[ZHA19] M. BINKHONAIN; L. ZHAO. A review of machine learning algorithms for identification and classification of non-functional requirements. *In: Expert Systems with Applications: X*, 2019.

[ZIE14] B. LOEPP; S. ZIEGLER. Komplexe präferenzprofile für intermodale navigation. *In: Mensch Computer 2014 – Workshopband*, pages 191–198, 2014.

[ZIE17] B. LOEPP ; J. ZIEGLER. Empirische bedarfsanalyse zur intermodalen navigation und dem einsatz von informationssystemen zur förderung ihrer attraktivität. *In: Innovative Produkte und Dienstleistungen in der Mobilität*, pages 409–426, 2017.

Assertion

Ich versichere wahrheitsgemäß, die Arbeit selbstständig verfasst, alle benutzten Hilfsmittel vollständig und genau angegeben und alles kenntlich gemacht zu haben, was aus Arbeiten anderer unverändert oder mit Abänderungen entnommen wurde sowie die Satzung des KIT zur Sicherung guter wissenschaftlicher Praxis in der jeweils gültigen Fassung beachtet zu haben.

Karlsruhe, September 8, 2021 Kihun Kim