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Quality and Usability

Reiner Lemoine Institut

Bachelor thesis

Implementing and evaluating the user experience in a scientific web-app

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Declaration of Authorship

I hereby declare that the thesis submitted is my own, unaided work, completed without any unpermitted external help. Only the sources and resources listed were used.

Berlin, August 31, 2024

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List of abbreviations

BVG	Berliner Verkehrsbetriebe
IF	Influence Factor
QoE	Quality of experience
RLI	Reiner Lemoine Institut
SimBa	SIMulation toolbox for Bus Applications
SWM	Stadtwerke München
TUB	Technische Universität Berlin
UCD	User centered design
UX	User experience
UXD	User experience design

Abstract

In this qualitative study of two interviews with a user group of bus company employees, a scientific web app that simulates bus fleet scenarios is being developed. The focus lies on the frontend and thus on the user experience, which is being evaluated through a framework analysis with the help of the user experience framework by Mohammad Zarour & Mubarak Alharbi. It uses well-defined pragmatic and hedonic aspects. During the website's development, several usability and user experience methods were used. This work is part of the EBus2030+ project—a cooperation between Reiner Lemoine Institut, Technische Universität Berlin, and Berliner Verkehrsbetriebe. The findings point more to the pragmatic aspects, especially usability, as the key factor in this early stage of development. Even with the limited number of test participants, many common topics recur and convey a problematic but consistent picture of the application.

Kurzzusammenfassung

In dieser überwiegend qualitativen Studie, die auf zwei Interviews einer Nutzergruppe von Mitarbeitern bei Busunternehmen basiert, wird eine wissenschaftliche Web-Applikation entwickelt, die Busflottenszenarien simuliert. Der Fokus liegt auf dem Frontend und damit auf der Benutzererfahrung, die durch eine Framework-Analyse mithilfe des User Experience Frameworks von Mohammad Zarour & Mubarak Alharbi evaluiert wird. Dabei werden wohldefinierte pragmatische und hedonistische Aspekte verwendet. Während der Website-Entwicklung wurden verschiedene Usability und User Experience Methoden verwendet. Diese Arbeit ist Teil des Projekts EBus2030+ – einer Kooperation zwischen dem Reiner Lemoine Institut, der Technischen Universität Berlin und den Berliner Verkehrsbetrieben. Die Ergebnisse deuten eher auf die pragmatischen Aspekte, insbesondere die Usability, als Schlüsselfaktor in dieser frühen Entwicklungsphase hin. Selbst bei der begrenzten Anzahl an Testteilnehmern tauchen viele gemeinsame Themen immer wieder auf und vermitteln ein problematisches, aber konsistentes Bild der Anwendung.

1. Introduction

1.1 Motivation

At the moment, the EU and Germany are still fulfilling their climate change goals. But the newest predictions show that till 2030, the emission reduction will be only 41%, even though the "European Climate Law" specifies reductions of 55% [1]. In order to continue this way, it is of utmost importance to reduce emissions in every sector. In the EU, the mobility sector is the only one to go up in CO2 emissions in the last thirty years. Therefore, the EU passed new countermeasures, like limiting the sale of cars to emission-free vehicles from 2035 on [2]. In Germany, one of the main causes of CO2 expulsion is the mobility sector, which is after the energy economy and industry in third place with 21.5% [3]. For the mobility transition, we have to build up infrastructure and sustainable alternatives that allow every mobility participant to be part of it. These frameworks have to be instantiated by policymakers and companies in the mobility sector. Another example for such a policy is the Clean Vehicles Directive, a guideline by the EU which was introduced into German law in 2021 as the "Saubere-Fahrzeuge-Beschaffungs-Gesetz". It states that the percentage of low-emission buses procured in public transport has to be 45% and from 2026 on 65%. [8][9]

1.2 RLI

In order to make informed decisions, institutions like the Reiner Lemoine Institut (RLI), a non-profit research organization whose self-declared goal is a future with 100% renewable energy [4], develops tools that provide and simulate mobility scenarios that involve alternative possibilities like electromobility, autonomous driving and hydrogen based mobility. To have a fruitful collaborative environment the developed tools have to be open source, which bears advantages to proprietary software, like open standards, no acquisition costs, independence from manufacturer, transparency of the source code and general robustness. [10]
One of these projects is the open source software "Simulation toolbox for Bus Applications" (SimBa), which is a simulation toolbox for bus applications and it can analyze and optimize electrified bus fleets [5]. It is one of the tools in the background that will do the underlying work behind the web application that is presented in this thesis. Unfortunately, some RLI tools are not accessible without some coding experience, which creates an exclusive circle of users and limits the potential of many great projects. Just at the RLI, there are currently 96 repositories but only a handful of applications have a frontend. [6] The web application is part of the EBus2030+ project, a collaboration of the RLI, Technische Universität Berlin (TUB) and the Berliner Verkehrsbetriebe (BVG). Its agenda is to develop strategies for the complete decarbonization of Berlin's bus transport by 2030 and beyond. Therefore, its goal is to develop open-source software for the simulation and design of systems for electric buses. [7]

1.3 Aim, research question and structure

The aim of the thesis is to design and implement a prototype of a frontend under user experience design and then evaluate it in semi-structured interviews with employees of bus companies with regard to its usability and user experience. Instead of focusing just on technical performance, we will examine the different qualities of an user experience. These qualities and experiences matter because we are developing for human users who are more complex and sophisticated than some good functioning algorithm. Of course sometimes it seems like a user just wants to get to the results and nothing else, but it does not quite satisfy all the different

contexts people are in, and assuming the user journey will sooner or later backfire, it is a fact, that only real test participants can give appropriate quality measurement about a system or product. [11]
It will be necessary to find out what quality is in relation to the finished prototype and how we can measure it. The research question behind this thesis will be: “How does a scientific web-app prototype, developed under user experience design (UXD), influence the experience of users in a user experience (UX) and usability context?”, and with it four hypotheses:

1. Users with high domain knowledge, system knowledge or computer experience are expected to have a more satisfactory experience.
2. The motivation behind using the app impacts user interaction and satisfaction significantly.
3. System performance, particularly in terms of speed and reliability, is expected to be a critical factor, because experts value task efficiency and other typical usability components more than UX ones.
4. Users with less domain knowledge prioritize more UX features than usability ones.

In the beginning, the fields of usability and user experience are introduced, along with the consequences they have for the web app. Then an evaluation methodology is presented by mapping out potential users and user types and answering the question what quality for this prototype means. In order to measure the quality of the frontend, a study design will also be developed within the frame of a semi-structured interview. After that, an overview is given of the design and development process, which encompasses the phases analysis, design and prototyping. In the end, the results of the evaluation are analyzed and the findings are presented for further development.

2. Background

Broadly speaking, there are two main objectives in this thesis. First to design and develop a frontend prototype, and secondly evaluating it. Now there are already some problems that need to be addressed:

Who are the users?
What is user experience and how can we ensure it?
What is quality in the context of our web app?
What should the prototype encompass in functionality?
What are appropriate evaluation techniques?

In order to answer these questions, the fields of usability and UX will be visited.

2.1 Bus and simulation basics

In order to successfully switch to electric buses, alternative scenarios have to be simulated. Circulation data is a particularly important part of this, as it creates the basis for the actual routes that are traveled. And this can become extremely complex as the number of routes or buses and lines increases. If additional options are added, such as charging at certain stops with charging points, one quickly loses track. The relevant parameters for the electrification of fleets are diverse and range from vehicle parameters such as battery consumption and bus type, to station characteristics, to various charging strategies. If there are no electrified stops in a scenario, i.e. no stops have corresponding charging points, then the buses can only charge in the depot. This requires a so-called depot charging strategy. However, this can have disadvantages and influence the simulation, as the buses cannot charge while they are driving. However, if there are stations where vehicles can charge, then the vehicles are also more flexible and a so-called opportunity charging strategy can be used.
Before diving into usability, it might be useful to take a look at the basics of the simulation. Like in figure 2.1, the input file is uploaded by the user. The data contains schedule information and comes in different data formats: VDV (Verband Deutscher Verkehrsunternehmen) and SimBa-format. The latter is the project's own creation and uses CSV (comma-separated values). It is a table with rows and columns, where each row represents a single trip and each column a feature like "departure_name", "arrival_name" or "distance". During the input-check the inserted file is scrutinized in terms of errors, wrong features, bad entries and overall plausibility. After a successful checkup the user can modify parameters in the categories of simulation parameters, vehicle types, depots and electrifying stations. Then the simulation calculates the most efficient way to use the vehicles and stations, according to the chosen parameter and presents an overview with plots and key performance indicators.

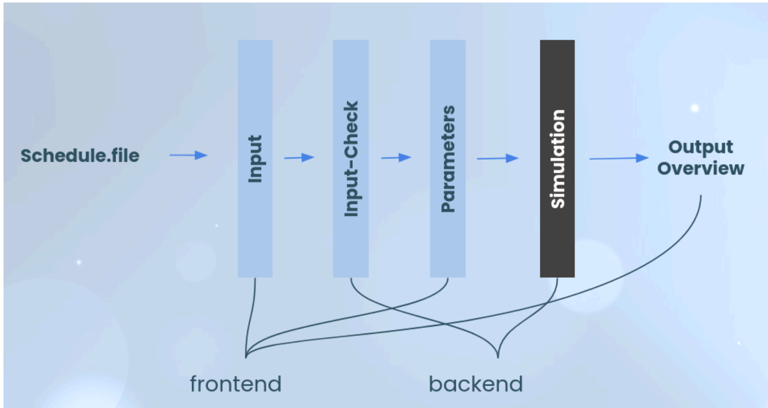


Figure 2.1: Basic simulation

Other things like vehicle and station data are also parsed. In the figure 2.2 are all elements of the simulation visible. These features are in the most basic functionalities already part of the frontend. At the moment the focus of the simulation output is more on the descriptive side of vehicle and depot behaviors. This concerns a variety of plots and diagrams. More advanced and inferential analyses, as the figure 2.2 suggests, are yet to be incorporated.

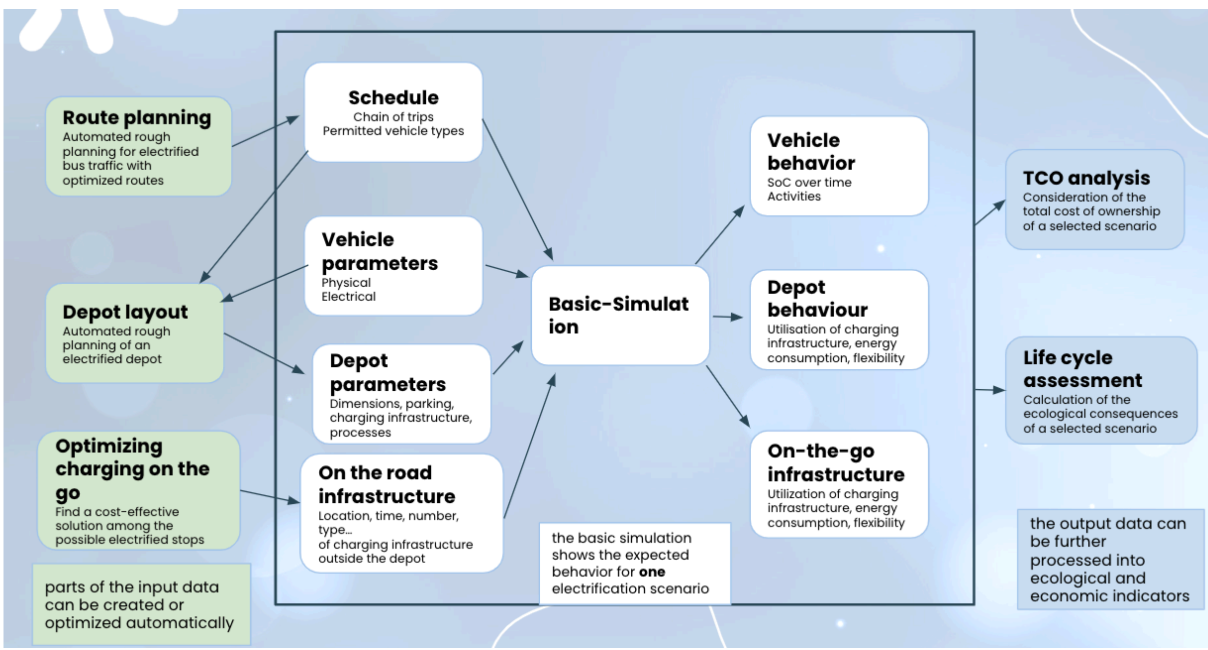


Figure 2.2: Simulation features

2.2 Usability

Intuitively one could think that usability means the effort of making machines and applications more appealing and to reduce human effort in using them. Modern usability originated in the 80s out of the fields of ergonomics and human factors, where it became a necessary tool through

the fall of hardware prices and the subsequent rise of the personal computer. [12] Even though the field exists for some time now the main steps, early focus on users, empirical user studies and an iterative design process, did not change much to this day. [13] For example it was apparent to involve a future user into the development process, to make sure the product will have a high usability. Otherwise clients will leave out of frustration or choose competitors who offer better solutions. The aspect of the user is highlighted by movements like user-centered design (UCD), a philosophy, but also a variety of techniques, which emerged in Donald Norman's research laboratory in the 1980s. It is a process where throughout the design and development lifecycle the focus lies on the people who will be using the product. UCD-provided tools are closely related with usability practices like interviews, on-site observation, walk-throughs and usability testing. [27]
The most common definitions for usability are the ISO standard and the one from Jakob Nielsen. According to the ISO Standard 9241, it is the “extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use.” [14] Nielsen associates it instead with three with five attributes: learnability, efficiency, memorability, errors and satisfaction, which are there to ensure a user-friendly interface that minimizes the cognitive load on users and maximizes the usability of the application. [15] Both definitions utilize efficiency and satisfaction in the same way, but when it comes to effectiveness (ISO), it seems to draw some inspiration from error, learnability and memorability, since these are important for how effective the user is at achieving certain goals.
In order to ensure good usability throughout the development process a system or product needs to go through the usability engineering lifecycle (figure 2.3). Since the thesis has a limit, the whole cycle won’t be necessary, but the first three phases, analysis, design, prototyping and empirical testing, will play a role. In the three level consideration model we can see roughly how the user, the interface and the underlying technology interact. Since we are interested in testing the interface design on users, we need to consider level 1: “the level of principles of human behavior and perception that will determine the interaction” and level 2: “the level of interface design between user and system”. [11]

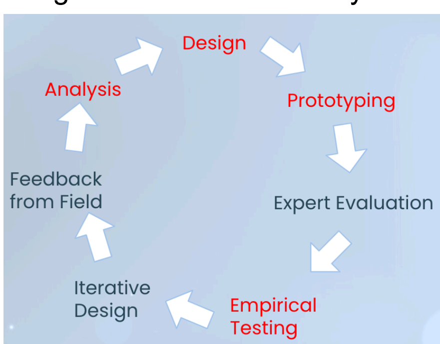


Figure 2.3: Usability engineering lifecycle

Evaluation methods include heuristic evaluation, focus groups, questionnaires, surveys, think-aloud protocol or cognitive walkthrough.

2.3 User experience (UX)

While historically the goal of usability engineering was to develop products with the features of the ISO standard [16], which focuses more on the efficiency and effectiveness of a system, UX encompasses a broader range of factors that influence how users feel when interacting with a product. Even if an application can achieve the user's goals, what determines if it is a pleasant experience? How can one ensure it is for example not boring? Aspects like pleasure, fun or appeal are an important part, when it all comes down to creating a valuable experience hence product. Traditionally, usability is more narrow and focused on specific metrics, whereas UX is broad and holistic in nature. To create a pleasurable experience for the user, we have to find out what an experience is.

There was always much debate about what experience or perception really constitutes. Leibniz and Kant already philosophized about this subject in a similar manner. Leibniz divided perception into three categories: apperception (Apperzeption) is the clear and aware perception, perception (Perzeption) itself is the vague precursor to thinking and "petites perceptions" are the small imperceptible sensations which form the consciousness. [17] In comparison, Kant only uses the term apperception, but in two variations - empirical and transcendental. Former is the consciousness influenced by outside forces and the latter describes the pure original untouched consciousness which is the real identity. [18] [19] Now, during a variable span in time an "experience" involves sensory input which has been introduced through the person's measuring organ which is triggered by some externality that clashes with the inner mental state of a person, where there are conscious and unconscious elements. In the end they form a unique picture of the product which is influenced by the emotional state, prior knowledge, cultural background, preferences, etc. It is described by [20] as "experiencing" and "is the individual stream of perceptions (of feelings, sensory percepts and concepts) that occurs in a particular situation of reference."

The field of user experience design has its origins in various disciplines, including psychology, engineering, human computer interaction (HCI) and traditional design principles. The term "user experience" was coined by Don Norman in the early 1990s when he worked at Apple Computer. Norman introduced the term to encompass all aspects of a user's interaction with a system, product or service. [21] [22] It can be viewed as an extension of the classical usability term, where, depending on the context of use, emotional factors like pleasure, beauty and trust are included. Favorable results of these kinds of qualities can be customers purchasing the product repeatedly or recommending it to others. [25] Overall, UX design represents an expansion of the field of usability, incorporating a holistic perspective that includes the user's feelings, motivations, and values, alongside efficiency and effectiveness. ISO defines it as "a person's perceptions and responses that result from the use or anticipated use of a product, system, or service". [26] And also usability pioneer Jakob Nielsen has a widespread definition: " 'User experience' encompasses all aspects of the end-user's interaction with the company, its services, and its products." [22]

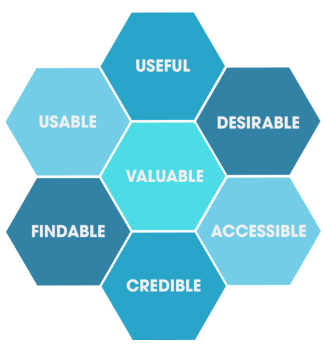
Since its emergence the term gained a growing following where agreeing on a scope has become increasingly harder, and it is not getting easier by ranging from traditional usability to beauty, emotional, hedonic, affective and aesthetic uses. But it is clear that there is a huge interest in the field, and it can be at least partially accounted for by the limitations of traditional usability and UX seemingly unlimited range. [28] [29] In the end the research community seemed to work around four central attributes when it comes to a defining scope:

1. The temporal dynamic of user experience is changing over time.
2. It is context-dependent, so each experience is influenced by the situational characteristics.
3. The user experience is inherently subjective and individual.
4. User experience is something positive, that emphasizes the pleasantness and joy of interacting with technology.

A UX rich tool is not just a medium for something potentially meaningful, it also creates a meaningful experience, no matter how simple the system, product or service might be. [29]

2.4 Usability vs. UX:

In a nutshell, usability describes how easily the interface can be maneuvered by the user as intended and UX portrays the whole experience and all the aspects of the interaction between the user and the application, such as the user's emotions, ideas and preferences, as well as his physiological and psychological reactions. [23] [24] Another difference is temporal, since usability only accounts for the time during the interaction. UX, on the other hand, covers a longer period of time, as both the time before and after the actual use is included. [30] Measuring usability component wise, so either effectiveness, efficiency, and satisfaction, then it is called a summative analysis. Measuring the absence of usability problems is called formative analysis. For user experience there are a plethora of frameworks. Two of them are presented here. First is Peter Morville's UX Honeycomb (figure 2.4). It encompasses the components useful, usable (corresponds to usability), desirable, findable, accessible, credible, valuable. Another one is Hassenzahl's model, where he distinguishes between pragmatic (utility and usability) and hedonic (novelty, change, personal growth, self-expression and/or relatedness).



[31]

Figure 2.4: Peter Morville's UX Honeycomb.

2.5 Usability and UX in websites and web applications

Iterative development is the core feature that follows the main objective, which should be identified early in the development process, in the form of usability specifications. Therefore already during the design stage the goals are set and can be incorporated. And this can be done by so-called “discount usability engineering”, which outlines the easy and affordable techniques scenarios, simplified thinking aloud and heuristic evaluation. [32] Nielsen’s five usability attributes can of course applied in terms of a website:
Web application learnability: the ease for users to understand the contents and services made available through the application, navigation mechanisms are easy to identify. Web applications efficiency means that the user understands at which point of the application she is. Memorability implies that the cognitive load on the user is not too high. Errors are general mistakes in the flow and navigation. Satisfaction refers to the user’s control and comprehension of the page and its functionality. Accessibility has been added to the concept of usability so the value of inclusiveness can be upheld and every human can maneuver any website or application in every possible context. [33] Part of these points and beyond are also represented by Nielsen’s heuristic evaluation, which contains ten usability criterias for user interface design. [34]

2.6 Quality of Experience (QoE)

The approaches and ideas in terms of designing systems have been dissected to some extent. But we have not been talking about evaluation yet and what quality and quality measurement is. In comparison to just an experience, for a user forming her opinion is “considered to be the result of additional cognitive processes on top of experiencing” [11], meaning it is a process of perception and judgement. [35] QoE has, like UX, a common origin but arose from a different research community. Both were in the first place more technical and incorporated over time more hedonic aspects, which care more about the perception and experience of the user than the performance of the system or service. [11] We will be using the definition of QoE from the second chapter of the book “Quality of Experience”:

“Quality of Experience (new) (QoE) is the degree of delight or annoyance of a person whose experiencing involves an application, service, or system. It results from the person’s evaluation of the fulfillment of his or her expectations and needs with respect to the utility and/or enjoyment in the light of the person’s context, personality and current state.” [11]

To understand how QoE is influenced, we have to understand the perceptual space of the user. That is why we will use empirical methods to identify and quantify quality features. A quality feature is a “recognized characteristic of an entity that can be named and is relevant to the quality of the entity.” [35] These perceptual attributes can be UX categories like aesthetics, usability or appeal. If these features are unknown, they can be extracted through methods like multidimensional scaling or semantic differential.This will not be the case in this thesis, since it is our interest to measure the concrete user experience. Given by the developer side, there are quality elements, which are described as “Contribution to the quality of an intangible or tangible product and/or activity or process in at least one stage of the quality cycle.” [35] Touching on influences on the quality, these can be summarized into the term influence factor (IF). IFs are any characteristic which may have an influence on the QoE. There are divided into human, system and user IFs, which can be intertwined. [11]

3. Method

3.1 Analysis

Sometimes UX and usability may be seen as something done at the beginning or end of software development, nevertheless it is rather an ubiquitous and iterative component, which is incorporated in the aforementioned usability engineering lifecycle that starts with the analysis phase. To help the team of software developers to create a useful product and avoid expensive reworking, user research helps to make the right decisions early. This requires insights into the user's behavior and environment, which have to be analyzed so requirements regarding goals and metrics can be extracted.
User research is unfortunately not entirely possible in this project, since there is no time planned for that and there won't be any contact with users yet. What has been accomplished is a list of technical requirements, see the figure 3.1. The points have been gathered through unstructured meetings with employees of bus companies which are the primary future users. Another useful source, which is embedded in the project EBus2030+ from the TU Berlin side, is the master thesis by Stammerjohann, which came with a requirements analysis and general profiles of the interviewed bus companies. [36]

Criteria	Must Have	Could Have
Explaining Elements	Infobox, Pictures, Textdoc	Tutorial videos
Frequency of use	100 simulations a day	
Accessibility	Color design, colorblindness, English, German	Screenreader
Devices	All browsers	Tablets
Functionality	Drag and drop, save sessions visual output, Input with input-check	Save outputs, animation, user account
Concept	Naive mode, expert mode	
Inputs	Number of buses per bus type, charging power for depot and opportunity, different simulation options, schedule, list of end stations, main connection power, charger options	

Figure 3.1: First technical requirements

For each technical requirement there are two modes: must-have and could-have. We will concentrate on the must-haves. This decision is a time and priority question. First, the bus companies made clear that must-haves are more desired, and second, features like accessibility and tutorial videos have a positive effect on users, but don't represent the core functionality. The criteria cover very basic features and requests which do not even mention any kind of user satisfaction or experience. For example the criteria "Functionality" consists of the website features drag and drop for the input file, input check and saving visual output. Drag and drop is rather easy to implement in comparison to the rest. Checking the input requires a lot of

technical knowledge in terms of data format and overall simulation. Firstly, it should be checked that the schedule is without error and appropriate for a simulation. On top, other additional purposes can be added, which might increase the experience like i. e. an estimation for the simulation period. “Inputs” has the most specific description. It touches on the parameters that have to be implemented, depending on the data which is extracted, like the number of buses per bus type, charging power of the vehicles and the stations, endstations and charging options. The green cells mark the relevant features for the prototype. The accessibility requirement is not of immediate importance, because the test participants are all native German speakers with sufficient english skills. It is obvious though, that in coming updates an English version and an appropriate color design have to be implemented to guarantee the accessibility.
Unfortunately the concept of having a naive and export mode (figure 3.1) will not be part of the prototype either. Time and resource constraints limit the development, however in the future, secondary user groups might be a potential consideration. That is why two broad user groups are created with respective characteristics: experts and non-experts (figure 3.2).

	Sub-groups	**Problem**	**Goal**
Expert	- bus employees - scientists in the field - engineers in the field	- no time - need good performance	- simulating bus fleets/scenarios - easy input - flexible output
Non-Expert	- scientists not in the field - decision-makers - mediators - attentive public - interested public	- no expertise in the field - website should be beginner-friendly - need tutorials or tool-tips	- need just a general understanding

Figure 3.2: User groups

Starting from there, many different sub-groups can be distinguished, each with varying characteristics. The primary user group for us right now are the bus employees, who are part of the experts. But also scientists and other engineers in congruent fields with similar skills should be considered experts. They tend to be more interested in achieving specific goals, especially simulating realistic mobility scenarios, which have in the end concrete consequences for their work. Non-experts on the other hand are much wider in interests, since we can’t really point out what their actual goals are. Assumed sub-groups are scientists but with less knowledge in bus-fleets, charging infrastructure or simulation software, decision-makers, mediators, attentive and interested public. These sub-groups are defined in the context of science communication, which are categories of the society, who might have an interest in the topic that is presented by the EBus2030+ tool. [38]
A typical UX technique to get some insight into the user are personas. They help to get a more realistic view of the user by describing the fictional perspective of a user, which gives us the user’s problems, motivation and other characteristics (figure 3.3).

User	Expert 1 (Scientist)	Expert 2 (Bus employee)	Non-expert (Mediator)
Background	Education: Master's degree in city planing Occupation: researcher at an institute	Education: Master's degree in engineering Occupation: engineer at a Busbetrieb	Education: Master's degree in public relations/political science Occupation: researcher at an institute for mobility/city planning/sustainability
User Environment	Location: institute, home office Devices: laptop	Location: office, home office Devices: laptop, tablet	Location: institute, home office Devices: laptop, mobile device
End Goals	Simulating a lot of scenarios for a scientific publication. E1 is probably, but might be not advanced in the field and in scientific tools. So the input process has to be straight forward. And the output should be usable and downloadable for academic and public use.	E2 has to decide in her/his bus company where to implement the charging infrastructure and how many electric buses will be need. E2 probably knows already where to put the chargers and has a budget. E2 has to share some simulations with the team, so they have to be easily available for people with and without accounts. E2 is not fluent in scientific tools bus has a lot of bus fleet knowledge. In the end E2 has to prepare a report of her/his findings.	NE works in a team of researchers and needs to prepare a report on electrified buses. NE needs to verify, if it makes sense to electrify a certain area (cost, consumption). NE has no prior knowledge in the field and needs an easy entry-point, the fewer interruptions and explanations, the better. NE is not interested in the details and needs only superficial information.

Figure 3.3: Personas

Stammerjohann utilized the MoSCoW method, which is an acronym for M - Must have, S - Should have, C - Could have, W - Won't have. It is a method that helps prioritizing. The results, that are relevant for this thesis, can be seen in the figure 3.4. Interesting is that in the "Must Have" category the most important topics are ease-of-use related, so the effort in using the tool is low, privacy issues and the independence from a manufacturer. Other requests, that were gathered by Stammerjohann, won't be implemented yet, because they require non-existent backend functionality. These are features which might be developed in the future, but they entail more than just frontend development. Another challenge is to find out which additional functions should be made available, because the SimBa tool in the backend has a lot of functionality, much more than the first prototype will have. That is why advanced functionality will be introduced gradually, which gives time for iterative development and at the same time permanent users are not overwhelmed by updates.

Must Have	descriptions of file formats when uploading the schedules	Minimize the using effort	open source	Non-disclosure of data	Manufacturer-independent	server in a country with data protection rights
Should Have	simple and effective visualizations	intuitive tool use	preference of own server			
Could Have	adjustable SoC parameter	consideration of photovoltaic in analysis				
Won't Have						

Figure 3.4: Requirements, prioritized with theMoscow method

As the last step of the analysis and to ensure good usability, Nielsen's "10 usability heuristics" are being used. It is a "discount usability engineering method". This means it is highly cost effective, with the potential effect of not being very thorough. [37] [34] Instead of using them during the expert evaluation, they will be handled like design guidelines. For this step a table was built to give every criteria a practical application in the frontend (figure 3.5). The first criteria for example promotes visibility, in case a new user gets lost, since new and especially complicated websites, which use unknown domain knowledge, can be a source of frustration. So the idea of a wizard, a navigation progress bar for the simulation stages, is proposed. The criteria "error prevention" and "help users recognize, diagnose and recover from errors" help to build a robust application. For the represented website there are two features, where errors can happen: input-check and during the actual simulation. If errors are incomprehensible, the user can't solve them, so frequent sources of error need to have understandable messages instead of error codes. And at best, simulation errors should not even occur, because the input-check already avoided this case.

Heuristic	Goals	In Practice	Example
#1 Visibility of the system state	- design should always keep users informed about system status	- appropriate feedback within a reasonable amount of time (ideally, immediately)	- during simulating: waiting bar could show what part of the simulation user is in at the moment - links open new tabs
#2 Match between system and real world	- design should speak user's language	- use familiar words, phrases, concepts, rather than internal jargon	
#3 User control and freedom	- Users often perform actions by mistake, so they need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process	- have Undo and Redo - have a clear exit like a Cancel button	
#4 Consistency and standards	- Follow platform and industry conventions	- use patterns for which users are accustomed	- use standard words for actions and options
#5 Error Prevention	- prevent problems from occurring in the first place	- eliminate error-prone conditions - present user with a confirmation option before committing to action	- good defaults, that can't produce a mistake easily - "Undos" and "Warnings" for the user -> be possible to always go back in the simulation - it should follow platform and industry conventions
#6 Recognition rather than Recall	- minimizing user's memory load	- make elements, actions, options visible - help in context, not just in the tutorial	
#7 Flexibility and efficiency of use	- speed-up frequent actions	- make shortcuts, hidden from novice users	
#8 Aesthetic and minimal design	- avoid irrelevant information	- focus on user's primary goals	- parameters and simulation button should be most prominent
#9 Help Users Recognize, Diagnose, and Recover from Errors	- good error messages	- error messages in plain language (no error codes) - if error, suggest a solution if possible or indicators	
#10 Help and Documentation	- it's best if users doesn't need it - it might be necessary to provide docs (for developers)		

Figure 3.5: Nielsen Heuristics as guidelines

3.2 Design

Before the actual designing took place, a basic prototype on paper with just general navigation, workflow and layout was created. Its purpose was to communicate it with the project team. For the first design the interface design software Figma was used. The landing page has a

permanent navigation bar throughout the application, which contains the RLI logo and next to it four links (figure 3.6). On the right side the login and register buttons were placed. In the center is the project name, a lead text and four buttons with essential links to the registration, a tutorial, the tool and the user's projects. Features like accounts, where hosting and saving scenarios will be possible, don't have full functionality yet, but were visually already incorporated.
The frontend has a flat-design, which is minimalistic and highlights buttons and inputs through color and shape, instead of real-life-looking objects or shadows. The goal is to be not too much "in the way", so a user can discover the simulation flow uninterrupted. Possibly the biggest danger for non-experts is to not understand the tool, which can result in boredom and disinterest. That is why the design has to convey a relaxing learning atmosphere. This reasoning also went into the selection of colors and fonts.

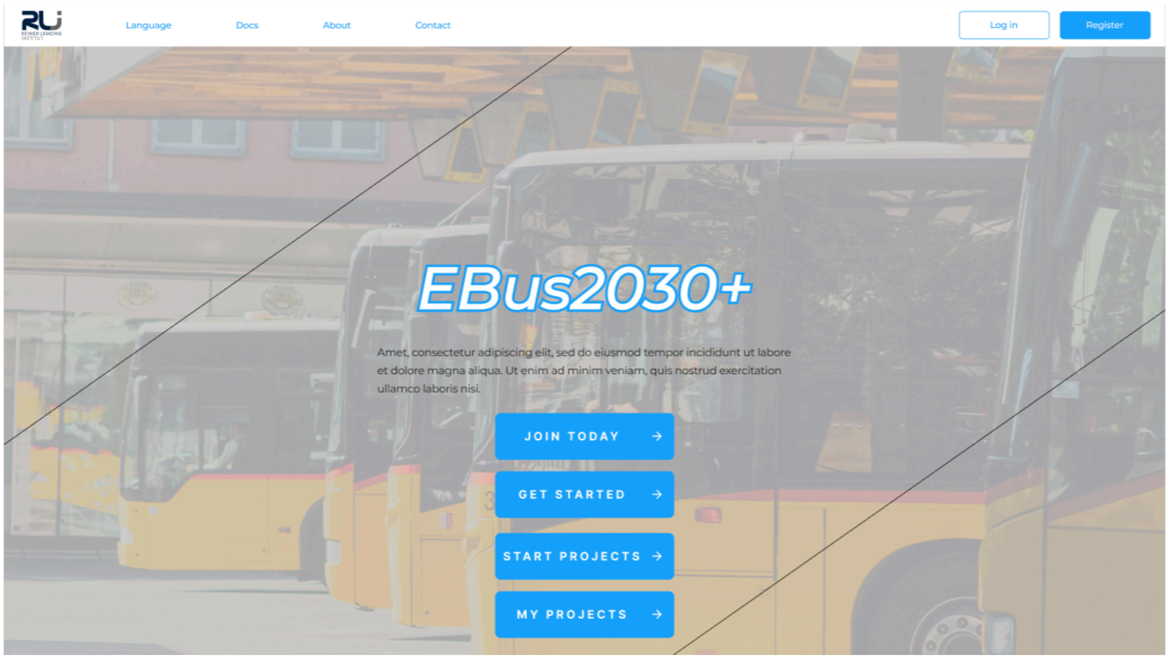


Figure 3.6: Landing page

The rest of the pages encompass the different stages of the simulation, which are in order of schedule, vehicle types, electrified stations and depots. Blue is the main color and varies from turquoise to bright and dark blue. The simulation stages have all the same basic structure. The navigation bar from the landing page remains. On the left is a navigation bar which can be collapsed to a tinier version. The main section has on top a wizard which navigates the user through the different categories of parameters. It makes sure that the user is not confused about the current stage of the simulation, as can be seen in the figure 3.7.

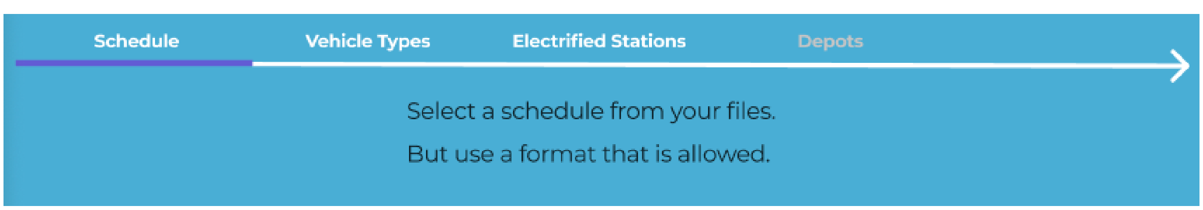


Figure 3.7: Wizard

Under the wizard is a description located, according to the simulation stage. And lastly, at the bottom is the continue button. Like in the technical requirements, the drag and drop function is the main feature during the schedule stage (figure 3.8). Right from the input section the allowed formats are presented and they show a description if clicked.

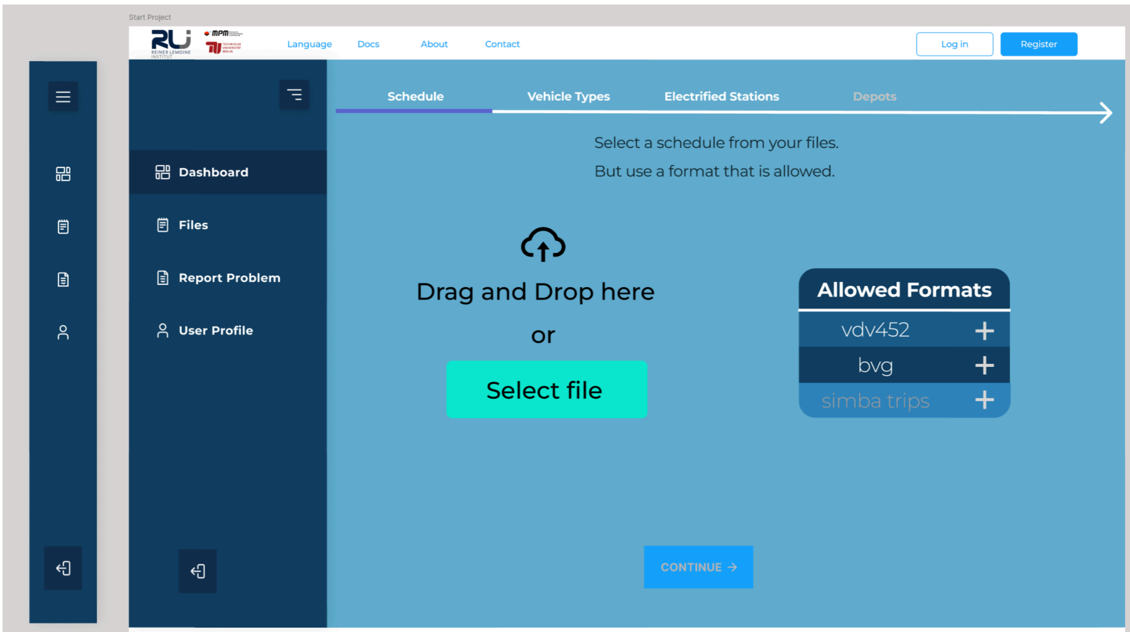


Figure 3.8: Schedule section

When the file is uploaded, the format can be checked by clicking on the respective button. While hovering over a button a description is shown (figure 3.8). This helps to reduce the cognitive load on the user and at the same time the user knows exactly what is happening, a fact that could potentially prevent future errors.

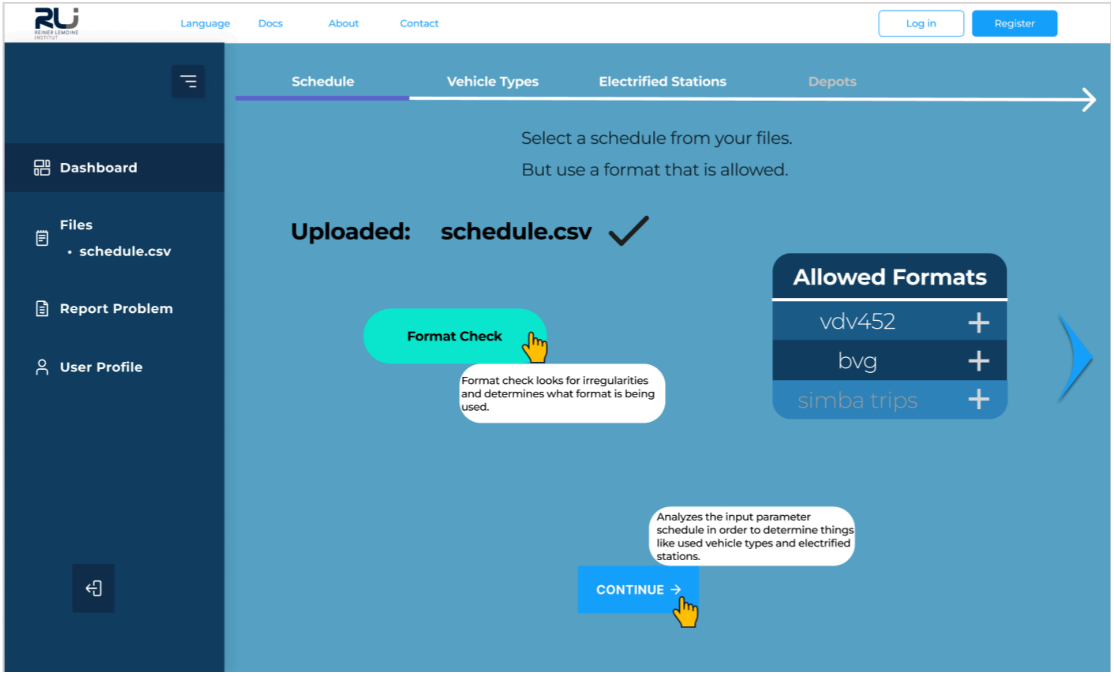


Figure 3.9: Schedule section with uploaded file

When something is processed and the system is unresponsive at a moment in time, a load bar indicates with a text what is exactly happening (figure 3.10).

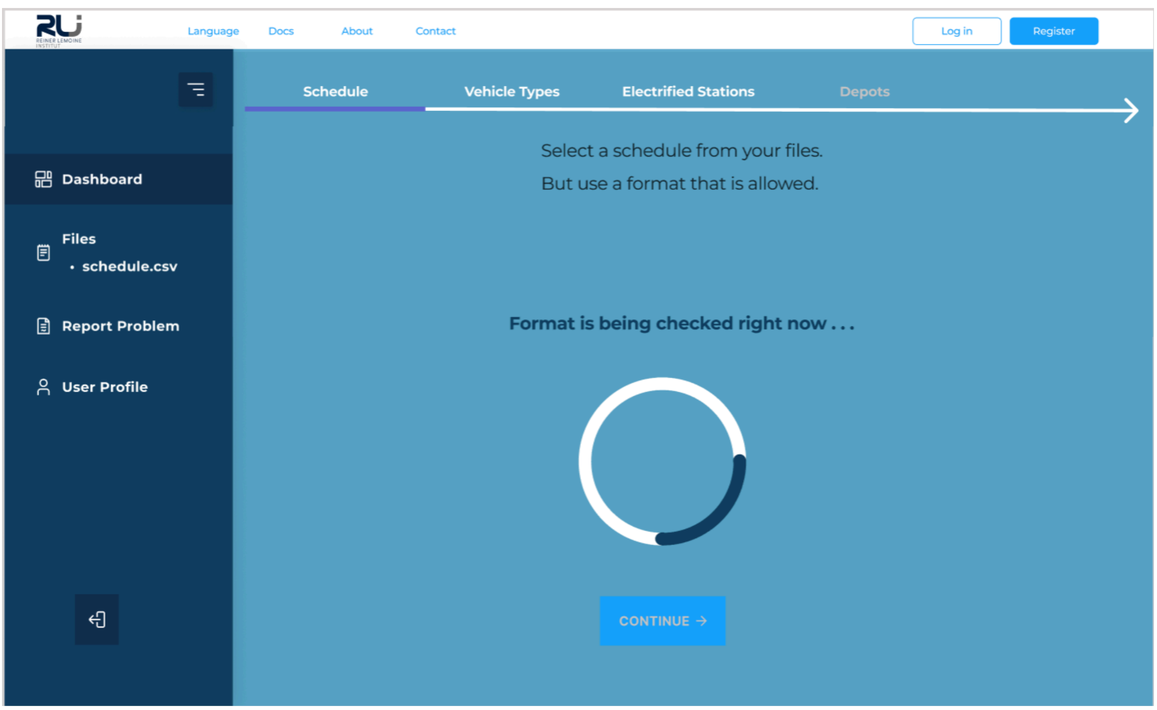


Figure 3.10: Schedule section with load bar

With a clearly signaled popup that indicates an error, an appropriate call for action should be displayed so the user is informed about the current system state and how to proceed (figure 3.11).

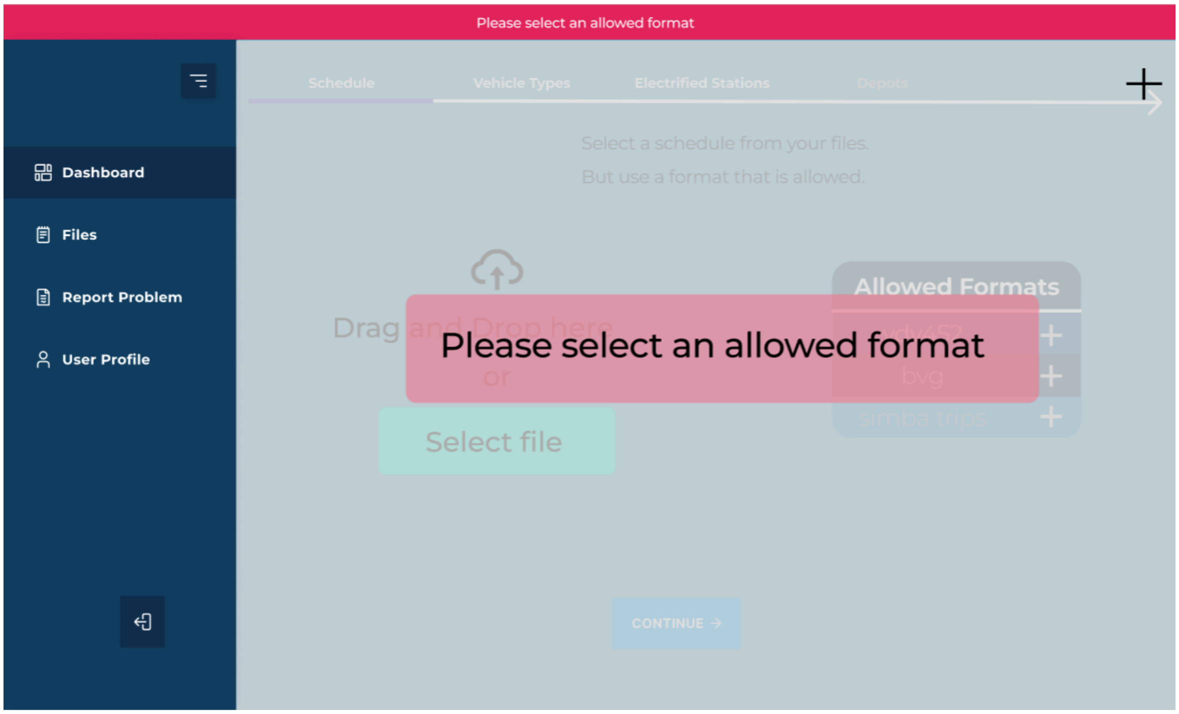


Figure 3.11: Schedule error

The vehicle type page has three sections. The left one represents the vehicles which were extracted from the input schedule file. There is now for every single vehicle a matching vehicle type in the center, that needs to be chosen from a list of default vehicles (figure 3.12). These default vehicles are explained on the right side by clicking the plus icon (figure 3.13).

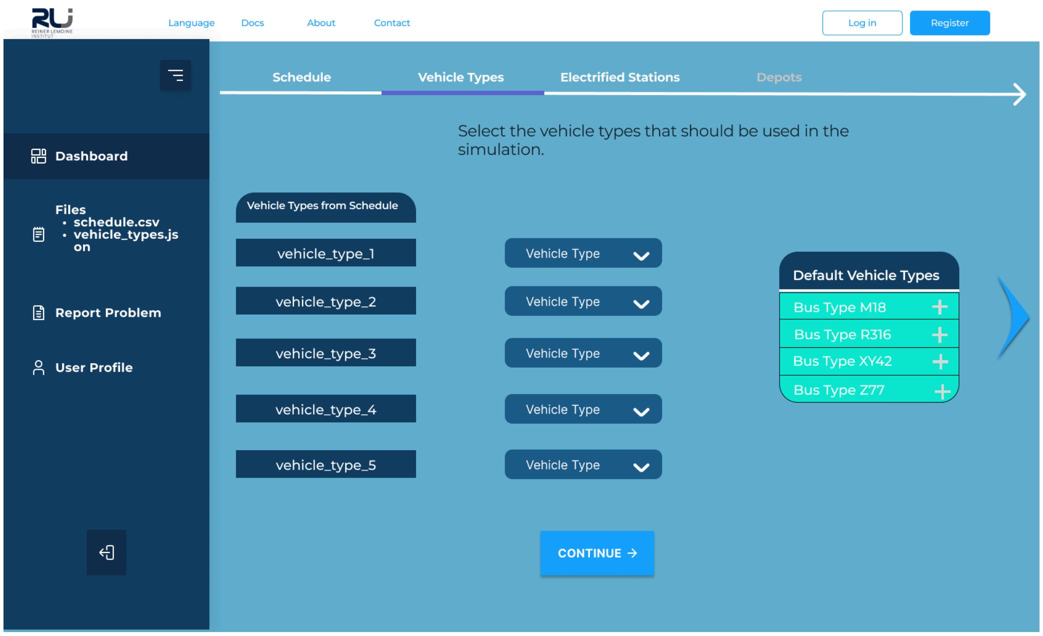


Figure 3.12: Vehicle section

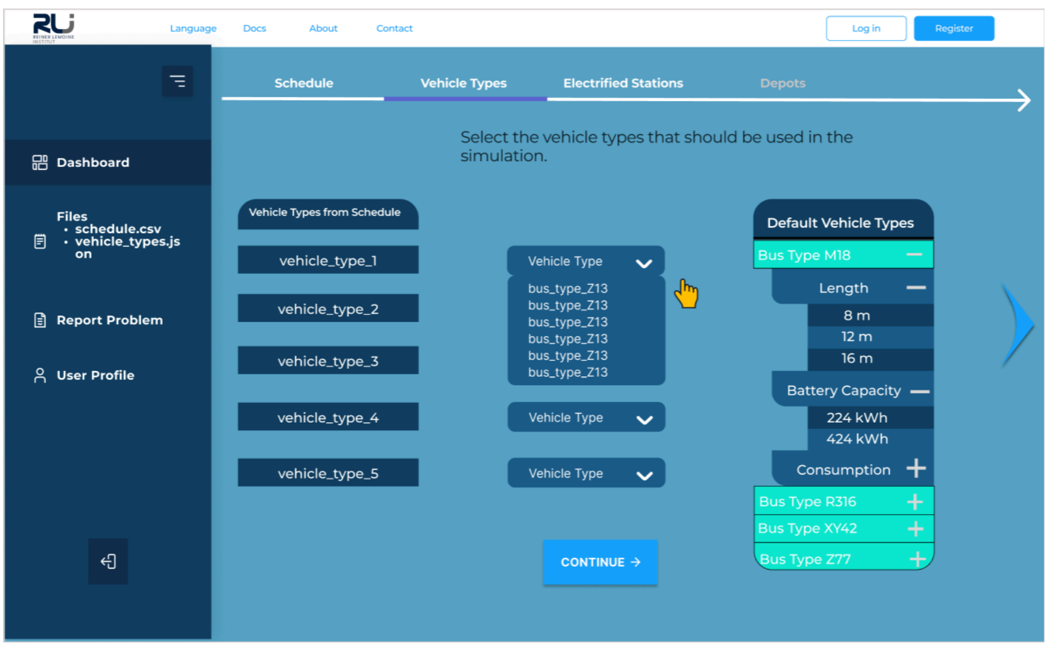


Figure 3.13: Vehicle section with open widgets

Stations that had been extracted from the input data can be accessed by the search bar or alphabetical list search (figure 3.14). Then, by clicking on the respective station, it will be electrified and function as a place where the electrical vehicles can possibly be charged (figure 3.14). The right side provides a list of all the vehicles that have been identified by the input-check. The coming stages are modeled in a similar way. In the last stage, instead of just changing to the next stage, the continue button directly starts the simulation and continues to the simulation overview, where the results of the simulation are shown, like key performance indicators and plots. A concept for the overview has not been designed at this point and would only appear in the prototype.

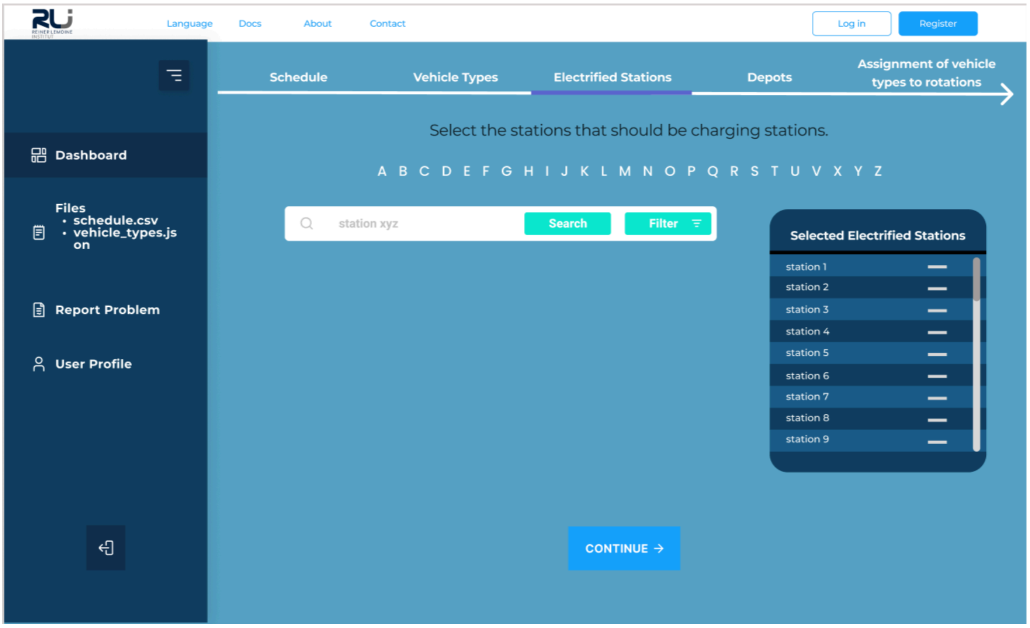


Figure 3.14: station section

Reusable components like a button or a list of objects equip the design with consistency and a high recognition value (figure 3.15).

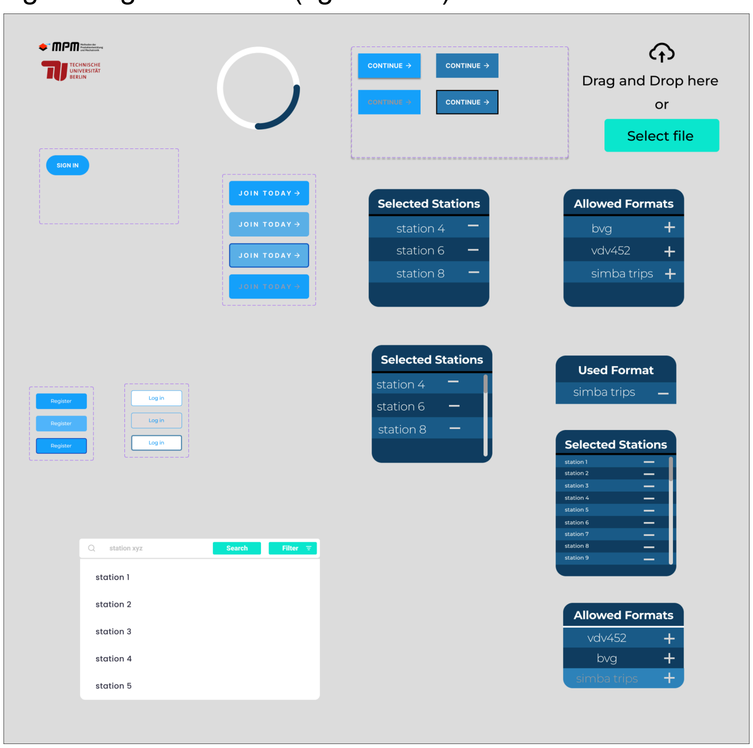


Figure 3.15: Reusable components

Given that this is the initial design, it was inevitable that certain issues would arise. The color scheme, in particular, may not be the most optimal. Specifically, the contrast between the black font and the bright blue background are not easily readable. Furthermore, the design could be characterized as somewhat unrefined and similar to a comic-like aesthetic. However, with this step finished, it is possible to comprehend visually how proposed features could help achieve the user’s goals. And most importantly, the design phase transformed first ideas and helped to determine the prototype functionality and its frontend elements like buttons, inputs, menus, etc.

3.3 Prototyping

User research, personas, requirements have been carried out in order to approach the target user group. By iterating repeatedly and comparing the information that is available, the design has been crafted. From just having a list of technical requirements the designed prototype already reached a state of “high fidelity” as Walker, et. describes: “Prototypes more similar to the final product are ‘high-fidelity’ while those less similar are ‘low-fidelity’.” [39] It is good practice to have the target requirements at the end of the analysis phase, but since the software in the background is capable of much more, it was possible to shift these around till the actual prototype phase. In figure 3.16 the basic tasks are mapped out for frontend and backend.

	RLI-Frontend	RLI-Backend	TU Berlin
Schedule	Format checker button automatic format recognition vs choosing format on upload? => TUB fragen Error return bzw approve schedule	„Pre-simulation“ when clicking continue put schedule in DB => single form for schedule trips.csv has less Info than XML uploads (e.g. Coordinates of Stations) Current solution: dont allow trips.csv create dummy vehicle types with names from schedule	Allowed formats? => Radiobutton/Dropdown
	Specs how vehicletypes are returned e.g. Json Response via ajax? htmx get request? Whole view with template render? Not possible in a one pager setup i think, since rendering takes place before uploading	☐ returns vehicle types used in schedule => need DB function, used on vehicle type page	
Vehicle Types	Vehicle Types from schedule => vehicle type + drop down for default selection list all		
	Unclear ☐ vehicle type defaults from db => div list all info (battery capacity, …) ☐ Continue button	dummy vehicle types get default vehicle type values	
Stations	checkbox: automatic electrification runs simba mode station_optimization list of all stations (Endhaltestellen) with selection option Specs how stations are returned e.g. Json Response via ajax? htmx get request? Whole view with template render? Not possible in a one pager setup i think, since rendering takes place before uploading which filter options can the backend provide? Checkbox to select station to be electrified ☐ default inputs Charging power => default 150 kW? Number of charging points per electrified station => default 1? grid connector per electrified station => default 150 kW? Continue sets selected stations to electrified with values from default input		
Depot	placeholder evtl. coming soon info evtl ausgegraut in Leiste und nicht erreichbar maybe other teaser options as well		
Overview Scenario	overview over scenario Run simulation everything not input here needs to use defaults or things that work with the input data		

Figure 3.16: Prototype requirements

For the prototype a combination of technologies is used. The main framework in usage is Django, a model-template-view framework whose language is Python. It is used for rapid and easy development with a focus on reusability. The frontend is created by a combination of the Django template language, Bootstrap, a popular frontend framework, and HTMX, a HTML library.

The landing page stayed mostly true to its predecessor. On the top left a newly designed logo was inserted and all relevant links are now available on the navigation link “Menü” on the top right next to the language selection (figure 3.17).

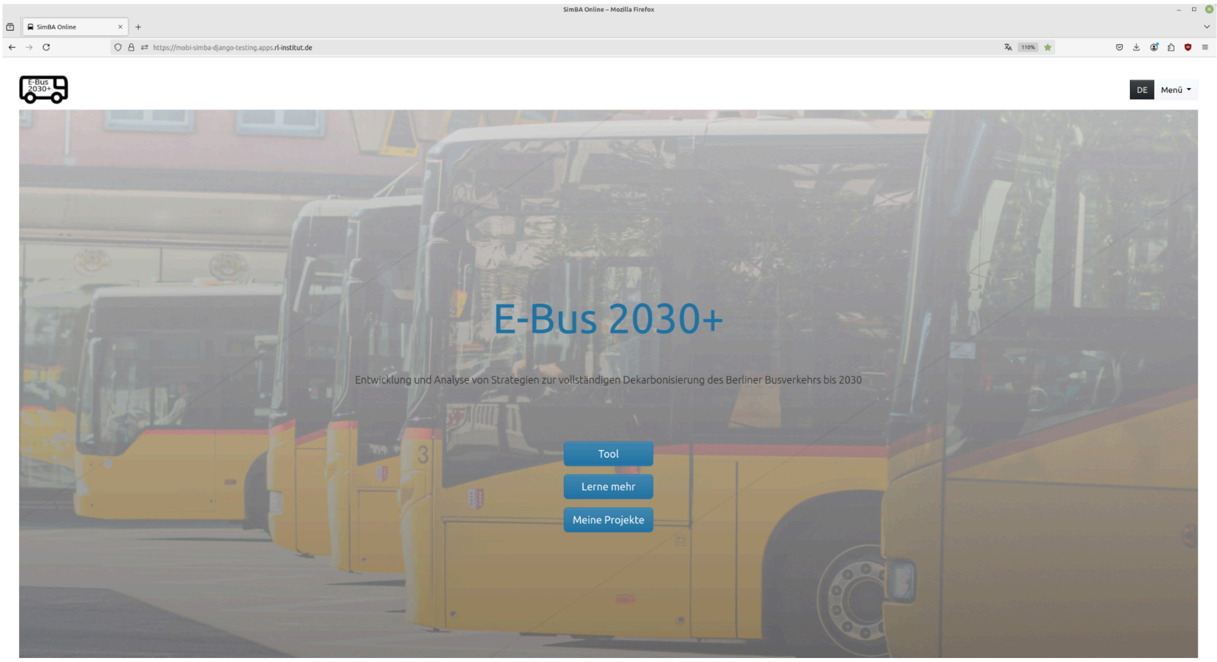


Figure 3.17: Prototype landing page

The rest of the frontend changed to a brighter and more minimalistic design. Instead of relying heavily on intensive coloration, the color changes lie between white, light gray and the rare use of blue. Some features like the left navigation bar were completely left out, since they could cause cognitive overload and distract from the main functionalities. Things like the wizard and lead descriptions stayed as concepts and just got a different style, empowered especially through Bootstrap. And instead of using a hovering effect for explaining the parameters, which are always on the left side of the main section, the right side complements the left with short descriptions of one, two sentences. New features in the schedule page are the simulation scenario naming and the possibility of downloading an example schedule file, which has a simple dummy scenario (figure 3.18, figure 3.19).

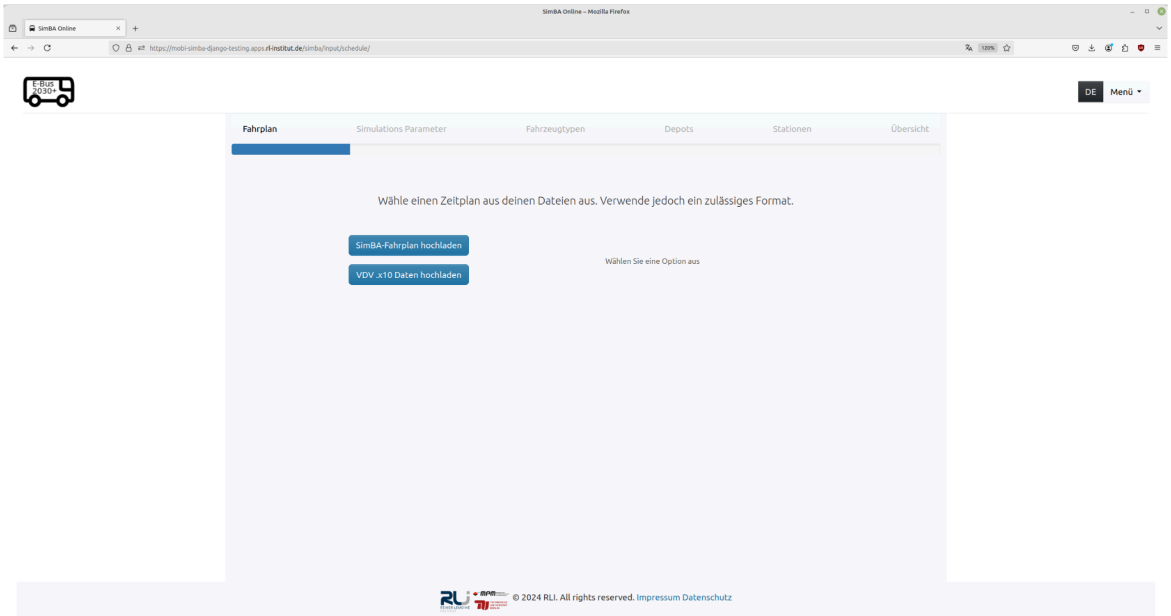


Figure 3.18: Prototype schedule section

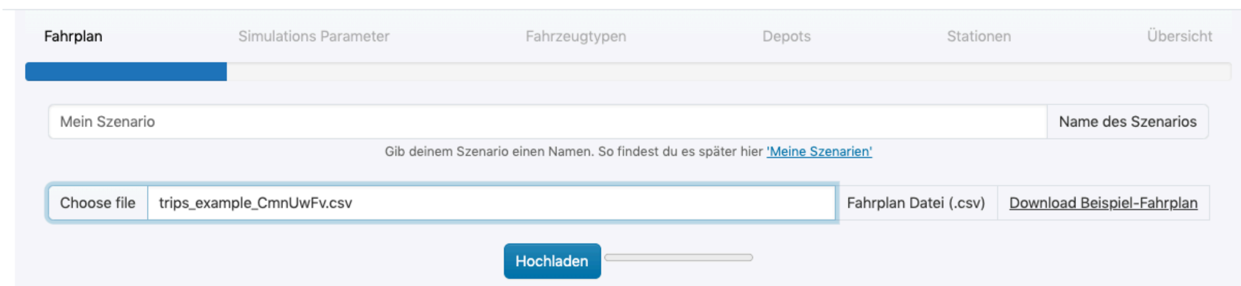


Figure 3.19: Prototype schedule section with uploaded SimBa file

The vehicle page layout-wise is very similar to the first design (figure 3.20), but can now additionally display the usable battery capacity, and it is also modifiable (figure 3.21).

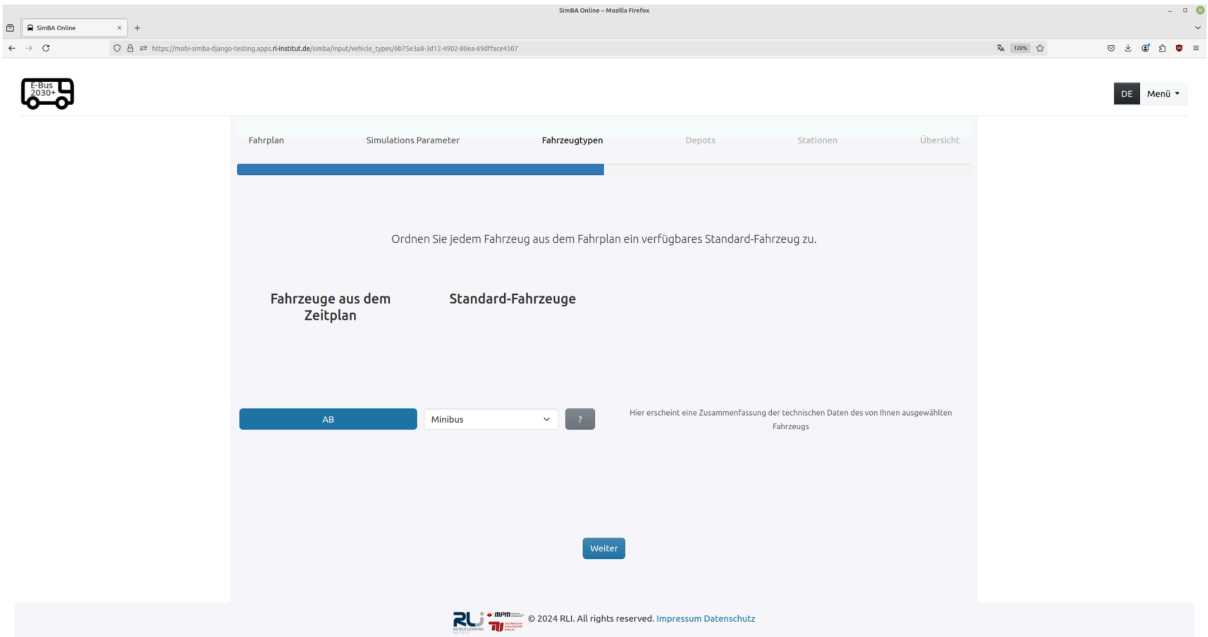


Figure 3.20: Prototype vehicle section

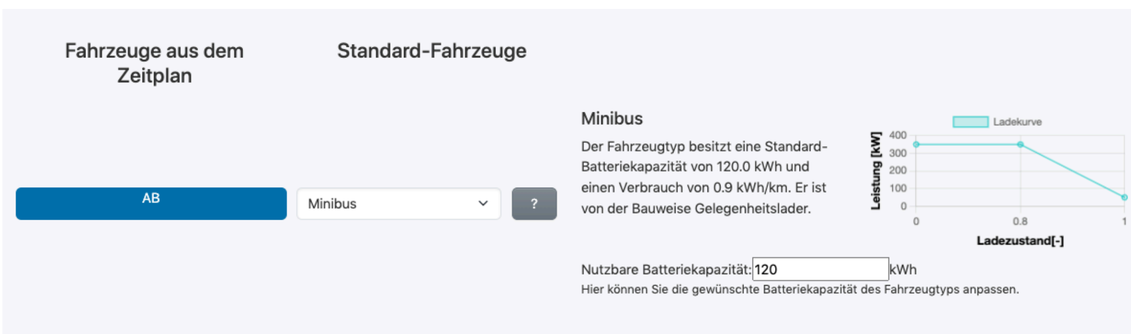


Figure 3.21: Prototype vehicle section with battery capacity

Stations have gotten a different layout, where the search bar is left out for a simpler view (figure 3.22).

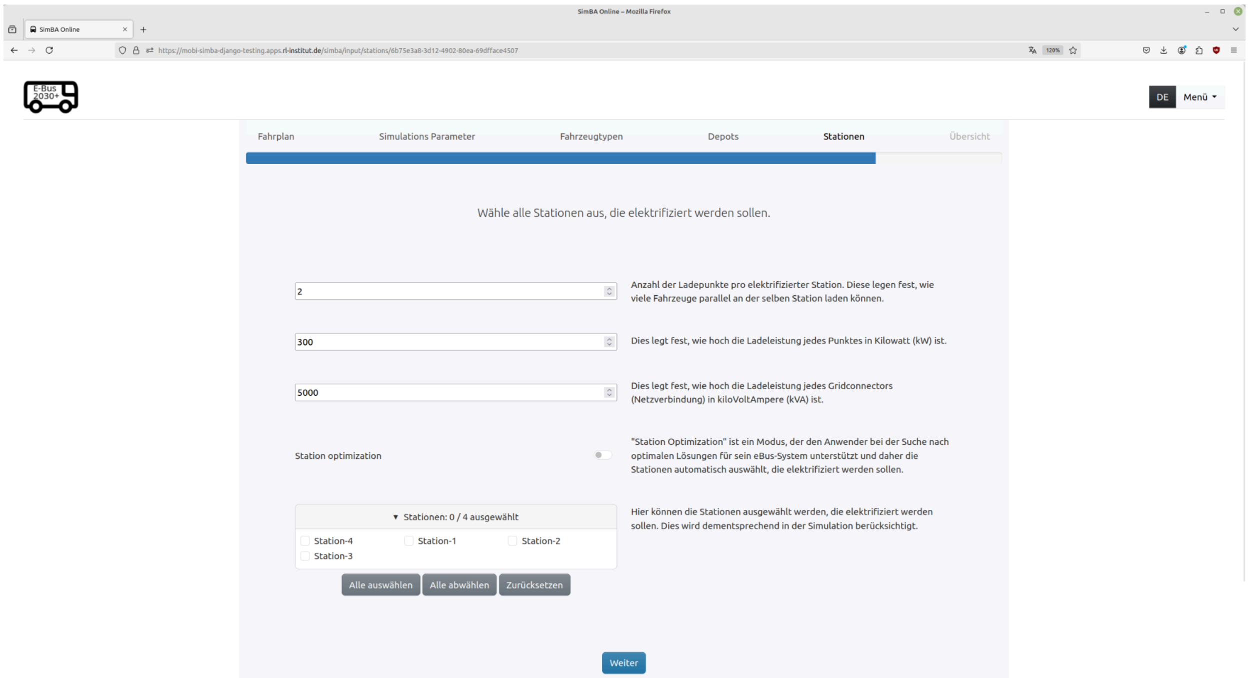


Figure 3.22: Prototype station section

The overview does not start the simulation right away, only by clicking the “Starte Simulation” button (figure 3.23).

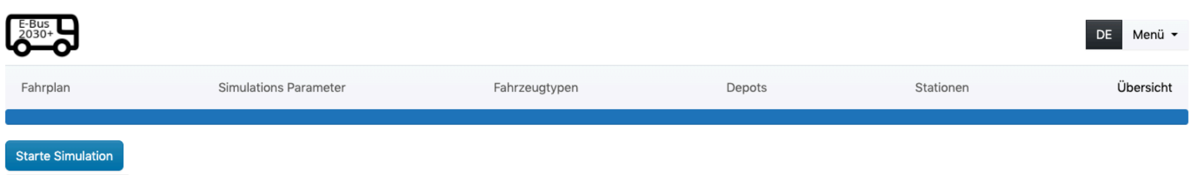


Figure 3.23: Prototype overview with start simulation button

The website gives a confirmation of a successful simulation and presents the pre-simulation plots.

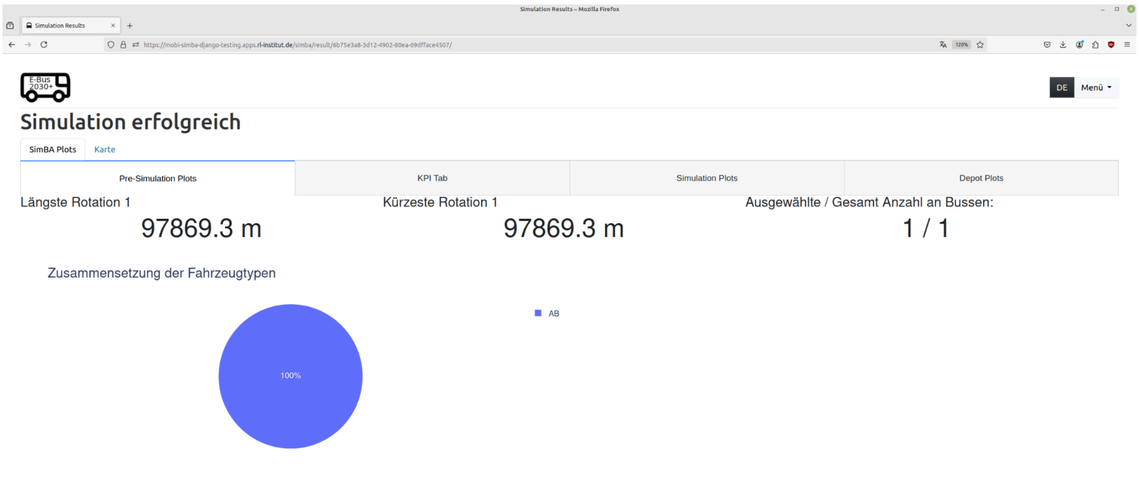


Figure 3.24: Prototype overview section

As can be seen in the figures 3.25 and 3.26, the plots produced by SimBa are separated in “KPI Tab”, “Simulation Plots”.

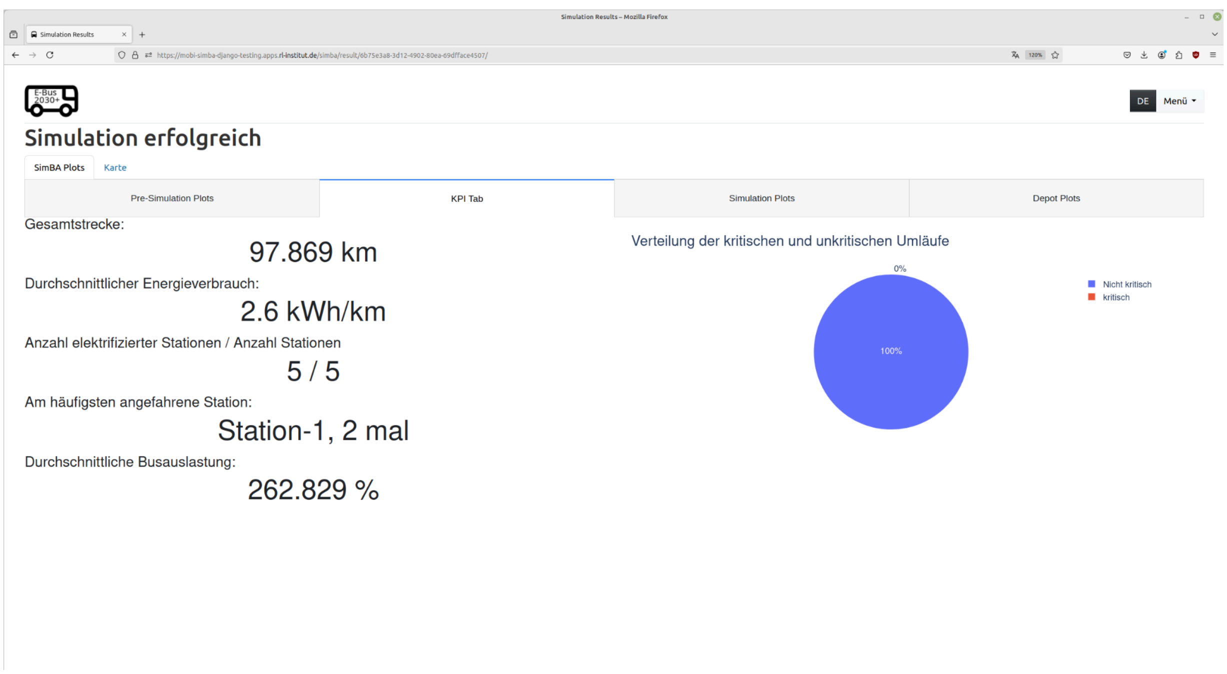


Figure 3.25: Prototype overview section with KPIs

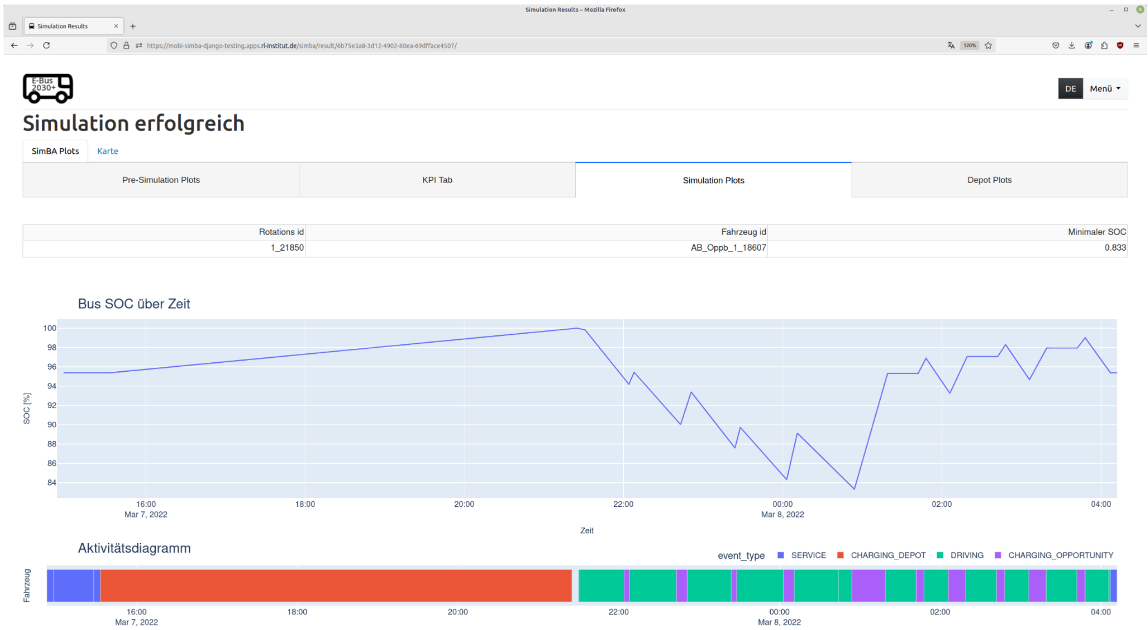


Figure 3.26: Prototype overview section with simulation plots

The last category “Depot Plots” are produced by the TUB backend component EFlips.

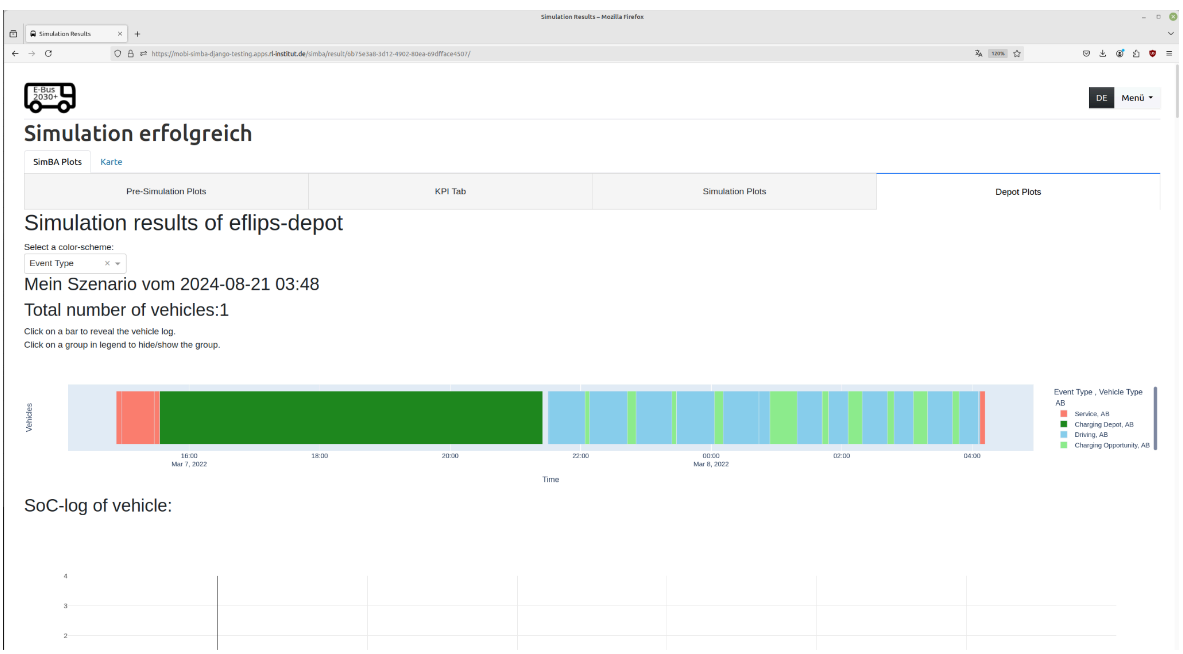


Figure 3.27: Prototype overview section with depot plots

The last feature is a map with the stations, marked if they are a depot (red), electrified (blue) or not electrified (black) (figure 3.28).

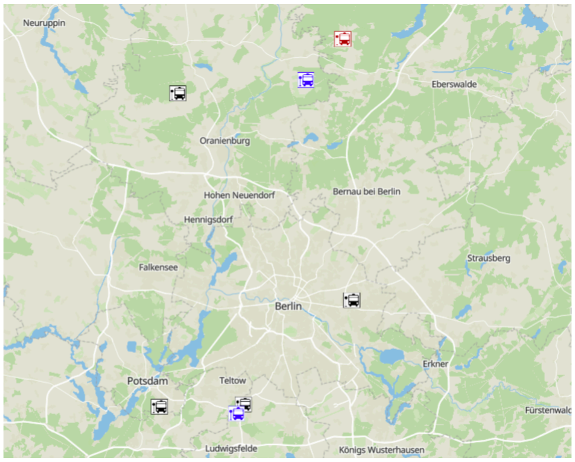


Figure 3.28: Map from the overview section

3.4 Empirical testing

Heuristic evaluation is said to be more efficient in cost and finding usability problems than testing real users, however, it also prevents us from measuring the severity of these problems and reveal unpredictable cases, which can't be that easily found by usability experts. [40] [41] Thus, when applying user testing we are more likely having better results, and a usability expert is not necessary, since the project is not providing such a position at this point of time. Or as described in Möller's "Quality Engineering": User testing "is in principle superior to expert-based evaluation, because here the real – and not the assumed – problems users have with a system become apparent." [35]

What method should be used to evaluate the quality of the website? There are two approaches: empirical and analytical. The first one is based on data usage, derived from user testing. The second one is based on the examination of an interactive system or potential interactions. Thorough evaluation can be a multidimensional process that involves both quantitative and qualitative assessments. This study combines research methods from usability, UX and QoE. First, user types will be generated, which are gathered from three sources - the first technical requirements, the company profiles from [36], and lastly from the interviews themselves. Second, UX aspects are chosen, which are most relevant for the web app. Third, semi-structured interviews are performed, where the test participants will have to do tasks on the website and give general feedback. The fourth and last step is analyzing the recordings of the interviews qualitatively and maybe finding some quantitative data too.

So the influence factors (IFs) are basically the independent variables and the QoE or the UX attributes are the dependent variables. The IFs are there so we can categorize the situation the test participant is in and in the end we will try to match them up. That is done through the quality assessment, which stands between these two sides, like a "translator". [11] With the knowledge of the IFs it is possible to categorize different actions, which can happen during an interview. These are noted as detailed as possible in an observation grid. Now these actions have to be assigned to UX categories, and since the author is limited to two interviews, a qualitative approach is most favorable. The IFs are implied in the matching with the UX aspects from the user experience framework from [44].

3.4.1 Influence Factors (IFs)

This question, who are the potential users, was answered sufficiently during the analysis. The focus lies on the interview partners, which are considered experts and belong to the subgroup of employees of bus companies. In order to obtain the test participant's relevant data and construct user types, a preliminary survey is created. The information that has been asked can be seen in the figure 3.29, where the cells are marked in gray.

Human Factors			System Factors		Context Factors		
behavioural characteristics	**experience**	**motivation**	**device-related**	**web app**	tasks	interviewers	company profile
age	simulation	driven an electric car?	operating system	design	complexity	main	
gender	computer, software		browser	#1 Visibility of the system state	input schedule file	others	
department of work	software development, computer science			#2 Match between system and real world			
position in the department	years of experience in electromobility			#3 User control and freedom			
				#4 Consistency and standards			
		task fulfilment		#5 Error Prevention			
		user expectations		#6 Recognition rather than Recall			
				#7 Flexibility and efficiency of use			
				#8 Aesthetic and minimal design			
				#9 Help Users Recognize, Diagnose, and Recover from Errors			
				#10 Help and Documentation			

Figure 3.29: Influence factors

Company	bus lines	bus line network	no of stops	bus fleet size	electric bus leet size	charging strategy	depots
Stadtwerke München	78	511 km	1013	total 400, solobus 86, Gelenkbus 257, Buszug 57	25 ebuses, ordered another 106	Depot charging with load management system (solo bus charged in 3 hours, articulated bus charged in 4 hours)	E-Busbetriebsbahnhof Moosach (für 170 Busse ausgelegt, momentan mit 56 Ladestationen mit Ladestecker auslegt); Busbetriebshof
BVG	152	1802.9 km	6770	total 1631, 194 double-decker buses, 276 single-decker buses, 922 articulated buses, 138 electric buses	228, plan to electrify all of them till 2030	Flex charging = all buses can charge at the depot and final stops	

Figure 3.30: Company profiles

The human IFs basically cover the user type, because they cover "any variant or invariant property or characteristic of a human user." [6] This includes sociodemographic like age, gender and position in a department. The second dimension experience has been inspired by Nielsen's user cube that tries to quantify the user's skills, which can have an effect on the quality. It is also a much more differentiated picture of the user, since the two opposite sides, expert and non-expert, cover a large space between them. Motivation could stem from not acknowledging the field of electromobility to personal initiative and interest. Thus, the question is asked, if the participant ever drove an electric vehicle. The two modes of answering are "yes" or "no".

Device-related system IFs that are asked from the user are the operating system and browser. The rest of the system IFs are part of the website itself. Thus, we use Nielsen's heuristic aspects, since they describe the design fairly well. Other than the physical context IF of being in the office or at home, it doesn't appear to be very much of an influence. Socially there can be a component of sharing the application, so others find the content understandable and stimulating. That is why there is the idea of having a host user who can send a simulation to others so they can review it themselves. But right now this feature is underdeveloped yet and therefore, won't be tested.

3.4.2 Evaluation

So with a prototype with limited functionality, there is the demand for feedback in reference to the overall quality and the presented features. Likewise, new impressions are needed, that can give fresh impulses to the development. With an application to test, there will be new unforeseen demands, and some things might be even detrimental, even though they seemed like a good idea at first. In the end, the most pressing concern is finding out what users are having issues with. This approach is also not uncommon with just a few participants. Nielsen even goes so far to avoid more than five test users. [43] Two qualitative interviews were conducted, where one of the participants (main participant) had to solve tasks on the website. For the analysis of the observation of the recordings, the UX framework by [44] will be used. It is a complex framework incorporating a variety of "aspects, dimensions, and measurement methods". The aspect categories which are under scrutiny are pragmatic and hedonic. Both have a number of aspects, which are depicted in figure 3.31.

pragmatic	**functionality**	Refers to the state of being functional and can meet the goals of using the product
	usability	Refers to the ease of use and learnability of using the product
	usefulness	Refers to the state of being useful
hedonic	**sensual**	Refers to the experience derived from the sense when using the product
	pleasure/fun	Refers to the enjoyment of using the product, and it has an intersection with emotional aspects
	trustworthiness	Refers to the trust between the user and the organization during the usage of its products, and has an impact on different aspects such as emotions
	aesthetics	Refers to the sense of beauty and how the user feels about it
	Emotional	Refers to all emotions during the product usage, and is explicitly mentioned in some studies

Figure 3.31: UX framework

During and after the interview, different observation grids are filled out. They contain data about the tasks, interactions and general procedure. The tasks grid consists of used features or task completion time. The interaction grid has entries like "verbal expression of frustration/confusion" or "navigational difficulties". From these matrices the different IFs are checked and what they mean for the UX framework from [44].
In addition to the qualitative approach, a usability and a UX questionnaire are handed out after the tasks are completed. These will be compared with the other findings. SUS is one of the

oldest and most used questionnaires in usability history, which should cover classic usability aspects. UEQ-S is the shorter version of UEQ and supplies the more hedonic aspects of the experience.

3.4.3 Test participants

In the two interviews eight (all male, average of around 38 years) participants took part. One participant did not share his information and another only partially, which is why the figure 3.32 is incomplete. The interviews were held in German. Even though our target users are a narrow demographic, when it comes to gender, age and job, there is some variability amongst them, in terms of expertise, department position and subjective preference. They hold positions like engineer, manager, finance manager and coordinator for bus electrification. Both of the main interviewees, gray marked in figure 3.32, have a managerial position and have very similar ages. The obvious facts are that they have a high interest in electric mobility which can be seen by the question, if they already have driven an electric car and their experience in the field, sometimes already for several years (average of 4,83 years). In the category experience, the participants gave an estimation on a scale of zero to a hundred, on how much they feel like they are experienced in a field.

Users		Stadtwerke München				Berliner Verkehrsbetriebe			Average/most frequent	Variance
sociodemo graphics	age								38.33	94.67
	gender	male	male	male	male	male	male	male	male (100 %)	
	department of work	electric bus and charging infrastructure	scheduling	electric bus and charging infrastructure	mobility cooperation	technology and innovation	scheduling	product planning		
	position in the department	engineer	planer	manager	manager	manager	manager	finance		
experience	simulation		0.05	0	0.6	0.7	0.1	0.6	0.34	0.1
	computer, software		0.5	0.65	0.8	0.8	0.5	0.6	0.64	0.02
	software development, computer science		0.5	0	0.6	0.5	0.2	0.2	0.33	0.05
	years of experience in electromobility		5	8	4	3	3	6	4.83	3.77
motivation	driven an electric car?		yes	yes	yes	no	yes	yes	yes (71 %)	
system	operating system		Windows	Windows	Windows	Windows	Windows	Windows		
	browser		Edge	Chrome	Edge	Explorer	Explorer	Mozilla	Edge, Explorer (each 29 %)	

Figure 3.32: User data

3.4.4 Test structure

In this usability test the future users get to test the application in a realistic setting. Before the instructions are given out for the first task, participants are welcomed, their consent is asked to record and they fill out the preliminary survey. During the completion of the tasks, which takes around 45 minutes, the test participants are encouraged to narrate their journey and to give constant feedback, so undiscovered pain points can be revealed. This is called the thinking-aloud protocol, a way of finding more insight into the user system interaction and one of the core methods of usability. Problems might be filtered by participant's responses and interference of the moderators during the interview. [42] Then the interviewees are asked to fill out the two questionnaires. Such an interview situation is an immense advantage, which includes the real-time follow-up on problems, but can also be biased in many ways. In the end there is a time buffer, if any discussions are taking place. The test structure is listed in figure 3.33.

Activity	**Comments/Questions**	**Time**
1. Welcome and introduction	-Welcome -Round of introductions -Explain the purpose of the interview -We give a short introduction to the test procedure	10 min
2. Asking for permission	- personal data, recording	1 min
3. Preliminary survey	https://www.umfrageonline.com/c/yqve3etb	5 min
4. Instructions	- Explain process - think-aloud protocol Oral instruction: "You will be given 3 tasks that should be completed using the website. Don't take too much time, but also think carefully about how to best solve the task. If you have any questions, you can ask us. While completing the task, we like you to narrate your thought process, so we can collect feedback the whole time. After 30 minutes we will complete the task and begin the debriefing."	5 min
5. Test tasks/stimuli and rating	There are 3 tasks to be completed on the website.	30 min
6. Usability-Questionnaire	https://www.umfrageonline.com/c/umdywf3a	5 min
7. UX-Questionnaire	UEQ: https://ueq-online-tool.de/#/q/fill/Ebus2030+-Webseite-156b7e53-136b-4fe4-aeaf-d424aea8edc9 UEQ-S: https://www.umfrageonline.com/c/dat7nxhg	5 min
8. Open discussion	Were your expectations met/not met? What is your goal with this application? What is the order of the simulation? What do you think are the most important parameters? Are parameters missing? What should the workflow be like? What would a simulation ideally look like in your opinion? What steps are missing, for example? What use cases do you have as a user?	30 min
9. Conclusion	"We thank the participants for their participation and valuable contributions. We state that their feedback will help improve the product and optimize their user experience."verbessern und ihre Benutzererfahrung zu optimieren." Wie würde eine Simulation idealerweise nach Ihrer Vorstellung aussehen? Welche Schritte fehlen zum Beispiel? Welche Use-Cases haben Sie als Nutzer?	5 min
		96 min

Figure 3.33: Test structure

Part of the interview are several team members and several test participants. Test environment is a zoom conference with one main interviewer and one bus employee who is sharing his screen, thus, it can be assumed that the test participants are either at their office or at home, hence a realistic environment. Sessions were recorded via Zoom.

3.4.5 tasks

In order to simulate a typical interaction between the test users and the frontend, tasks were defined as can be seen in figure 3.34.

step	Task 1	Task 2	Task 3
1	Download sample file in Simba format from the website	Upload your own timetable	Upload your own schedule
2	Upload timetable	Standard charging type should be “depot charger”	The standard charging type should be “occasional charger”
3	Name scenario	all other settings can be freely selected	All other settings can be freely selected
4	Leave all settings as they are	simulate scenario	Simulate scenario
5	Simulate scenario		Question: How large does the grid connection need to be in this scenario?

Figure 3.34: Tasks

4. Results

A qualitative approach was used, in which 8 participants were part of a semi-structured interview and expressed their view and experience. Each time, one “main” test participant had to fulfill three tasks. The aforementioned observation grids helped to assign relevant actions, views and just in general every kind of feedback, which could influence the findings.

4.1 Findings

4.1.1 First interview

In the first interview the tasks took around 20 minutes, where the last task failed because of technical problems from the application’s side. The rest of the time was spent on discussions, revolving around features and feedback, as can be seen in the figure 4.1.

Procedure Interview 1	Timestamp
Entry into Zoom room, welcome	00:00
Task 1 starts	07:51
Task 1 completed view overview section	10:27
View activity diagram	16:00
View map	19:58
One of the other interviewer shows map with new website version	23:50
Task 2 starts	30:52:00
Task 2 completed, further attempts with "Station Optimization" parameter	35:29:00
One of the other interviewers shows "Station Optimization" parameter	44:05:00
Task 3 starts	46:00:00
Internet connection problems	51:26:00
Resume with task 3	53:23:00
Simulation scenario failed, more attempts by test participant	55:19:00
Discussion	1:00:00 bis Ende

Figure 4.1: Interview procedure

Unfortunately a few task-related problems occurred. The schedule file was not very realistic or rather something the test participants didn’t expect. It caused a lot of problems in the plots, because buses showed extreme behavior and stations had pointless names like “station-x”. Another point was, sometimes the focus was too much on the comprehensibility of the plots in the overview, which could either mean, the plots are important for the users or the interview was slightly misguided.
The most striking aspect is the huge amount of usability issues. It seems that the application still has bigger usability problems than an UX problem, and as long as it is not solved, UX can’t be significantly improved. Things like cognitive overload, features that go unnoticed or intuitive functionality, play a role, often a button or a select option is not visible enough or has an unobtrusive look. This caused problems in later steps, thus confusion, frustration or failure of a

simulation with the additional step starting over again. Particularly the vehicle section and the overview section have the most problems. Choosing a vehicle gets increasingly frustrating with the number of buses (figure 4.2).

Figure 4.2: Too many buses in the vehicle section

The overview section is a “pain point”, that is hard to navigate, it takes the most time to understand and plots are not very obvious or even are hard to grasp completely. Pragmatic aspects in general have more negative points.

Hedonic aspects have less issues. The reason might be the focus of the bus company employees on pragmatic issues rather than fun or joy of use, since it is their profession to deal with buses, fleets and scheduling. The strongest noticeable emotional reaction was confusion, which is understandable, when trying out a new tool. But it also hints at issues like waiting times and the amount of features which were counter-intuitive or didn’t work at all. On another note, the test participant navigated very fast, which can be attributed to the logical workflow of the simulation stages, the minimalist design, which was easy to grasp and not “in the way”. The aspect of trustworthiness is created through cooperation, which means that a lot of this development caters to the users’ needs, and the open-source approach, which is highly cost-attractive for them, since they have experience with expensive proprietary software.

New impulses were made mostly in terms of new features and additional parameters. For example participants asked for map features, where they can see if vehicles are overloaded in the case of opportunity charging, or for critical bus rotations, so they are visualized on the map.

		positive	negative
pragmatic	**functionality**	-overview plots are exactly what tps wanted -impressed by vehicle and battery capacity view	-plots in the overview were generally a little confusing, what frustrated tps -when the example file was downloaded, tp pressed the upload button without selecting the file from his computer --> no proper error alert/message -map feature did not work -landing page: once the background picture didn't render, and when it did, it took a long time and the rendering was very visible -when sceanrio is simulated, it is not possible to change simulation by going back and modify parameters, new upload has to occur --> not very flexible -SOC becoms negative value in case of lack of electrification
	usability	-many navigational components where learned very fast -scenario naming, no problem -example input file (SimBa), downloading no problem -landing page: tp found and understood tool button immediately -upload button is found easily -"weiter"-button is found easily -overview: different tabs are clear	-some functionalities had to be explained to tps -option for depot chargers or occasional chargers as standard charging types were not noticed/ are not very visible -battery capacity selection is not intuitive -can only find the tabs in the overview when pointing (SimBa plots, map, depot behavior) -stations stage: P1 read concentrated the explanation, it took much effort -option of depot and oppertunity in the input schedule stage, went several times unnoticed -"Starte Simulation"-button went several times unnoticed, or when then it felt wrong -general confusion in the overview section --> cognitive overload -some words were strange for tps, like rotation for Umlauf, service and Rangierzeit -can only find the tabs in the overview when pointing (SimBa plots, map, depot behavior) -tp can't find example file -one of the interviewer intervened sometimes, due to confusion or question from tp -uploading the example file was a little long - overview: hard to understand, or it isn't very obvious -overview: plots themselves very not always clear, unknown terms (e. i. service time instaead of "Rangierzeit"), legend couldn't be read -overview: hard to navigate, it is not clear where the map and the depot-behaviours are found - tp only found tabs in the overview when pointed out (SimBa Plots, Map, Depot Behavior) -schedule file upload is not clear, when there is not a file -vehicle section: battery capacity of default buses is not intuitive, because tp only found the right button after interviewer intervention --> "question mark"-button is not obvious -vehicle section: with a lot of buses to modify, it is frustrating to choose for every bus the battery capacity (or in general a parameter) -vehicle section: too many buses to choose from makes it overwhelming and inpractical to choose a default vehicle and a battery capacity
	usefulness	-impressed by vehicle and battery capacity view -progress bars help a lot to show that the system working/doing something	-Overview: there is no end to scrolling down -tps had some new ideas for features and parameters -overview: KPI-tab --> numbers were in m, should be in km, and tp wasn't sure what period was simulated, numbers have english number representation -when electrified, the plots don't show the stations behaviour, only of the depot behaviour
hedonic	**sensual**		
	pleasure/fun	-tp was really fast sometimes with navigation through website, which caused a certain "flow" -impressed by vehicle and battery capacity view	-general confusion in the overview section -plots in the overview were generally a little confusing, what frustrated tps -frustration of tp, because features like the map and "Station Optimization" don't work
	trustworthiness	-cooperation is important, in order to develop a useful tool, that caters to the users -open-source is wished	
	aesthetics	-positive feedback to the minimalistic design -minimal flat design helped to learn features and perform the most relevant actions very quickly -design wasn't "in the way"	-uploading the example file was a little long, where P1 sighed
	Emotional		-plots in the overview were generally a little confusing, what frustrated tps -uploading the example file was a little long, where P1 sighed

Figure 4.3: UX aspects during the first interview

4.1.2 Second interview

During the time between the two interviews a couple new updates were installed. A new section called “Simulations Parameter” comes now right after the schedule upload, where it is possible to select a subset of the simulation time, instead of being forced to simulate the entire schedule. The other new feature is account functionality, which allows to host, conduct and save several scenarios. This time, the tasks took around 28,5 minutes of the time, but task completion times were not necessarily meaningful, since the test participants asked a lot of questions, which interrupted the task flow a lot. Rest of the time has been occupied by similar talking points like the first interview: plots, new parameters and practicality of the simulation.

Procedure Interview 2	Timestamp
Entry into Zoom room, welcome	00:00
Question for test participants regarding work processes	04:31
Task 1 starts	18:20
interruption: vehicle section questions	22:17
resume to Task 1	33:25:00
Task 1 completed, present/explain overview	42:13:00
Task 2 start: Look at an already calculated and realistic example scenario	55:51:00
Overview KPI tab	56:32:00
Overview simulation Plots	57:20:00
Overview Depot Behaviour	59:21:00
Overview Map	01:02:28
Another realistic example scenario	01:05:28
While scenario is loading, main interviewer shows additional future plots	01:10:27
New start with using a schedule file, because the scenario failed	01:14:58
Discussion about realistic simulations and their assumptions to match reality	01:17:07
Questionnaires	01:21:55
General feedback and discussion (service, delay times, parameter, costs)	01:23:00 - 01:37:43

Figure 4.4: Procedure of the second interview

Usability is, together with functionality, the biggest factor. It becomes apparent that core functionalities still face issues. Loading times can be long, especially in the simulation, or it fails entirely. On a positive note, the users were generally fond of the design flow and the data that is provided by the overview section. The overview plots and map invoked emotional reactions like excitement, surprise and curiosity. This happened especially, when in the depot activity diagram a single bus could be chosen and show its SOC throughout the simulation, which can be seen in figure 4.5.

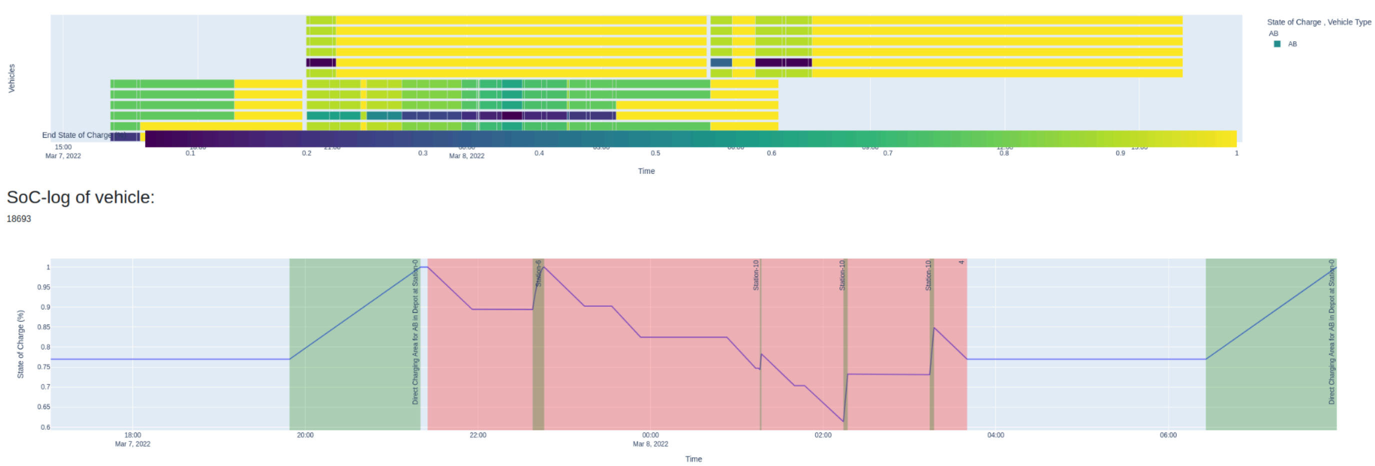


Figure 4.5: SoC log of one individual bus

Otherwise, the hedonic aspects were mostly in the background, for example, when there was frustration with the long simulation times and moving to the depot plots, which caused a blank page for a couple of seconds, or the unsureness of the main participant, when it comes to the upload search bar, which, according to the main tester, is not visible in comparison to its surroundings. It is also a functionality issue, when a mouse click causes a blank page. When the test user clicks on the depot plots, the website is in an unidentified state, if it results in a blank page, so it has to be either optimized or a progress bar should be placed. Also the call for new parameters like preparation and follow-up times for buses, which are asked to be changed, would enhance the functionality of the system. Like in the first interview, the button that starts the simulation got unnoticed, but only the first time. When a scenario failed the user was unsure what to do and clicked in a hurry on the top left icon, which resumed him to the landing page. The user seeked for orientation and relied on previous experience with websites, where such a link is good practice. To this positive usability trade, there are several usability problems that need to be addressed.

The implemented “Simulation Parameter” section caused confusion in terms of potential action. The test participant didn't realize that the timetable is clickable and also had firstly not a clear understanding what the time span is referring to. Even though the page has a clear description, it was not obvious enough to read first. But as a human, it might be natural to stick to reading last and try to find any other leverage that associates with past experience. Only when the time span had been clicked, a timetable appeared, which was easily understood.

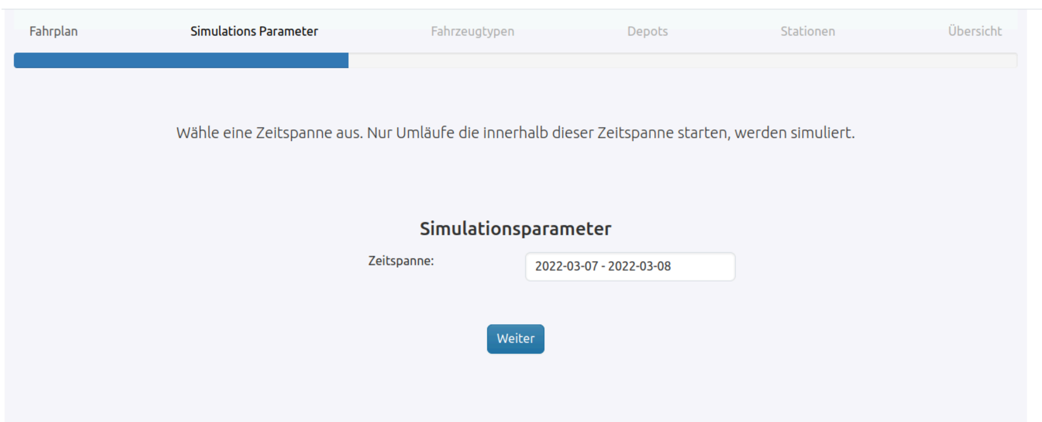


Figure 4.6: Simulation Parameter with closed timetable

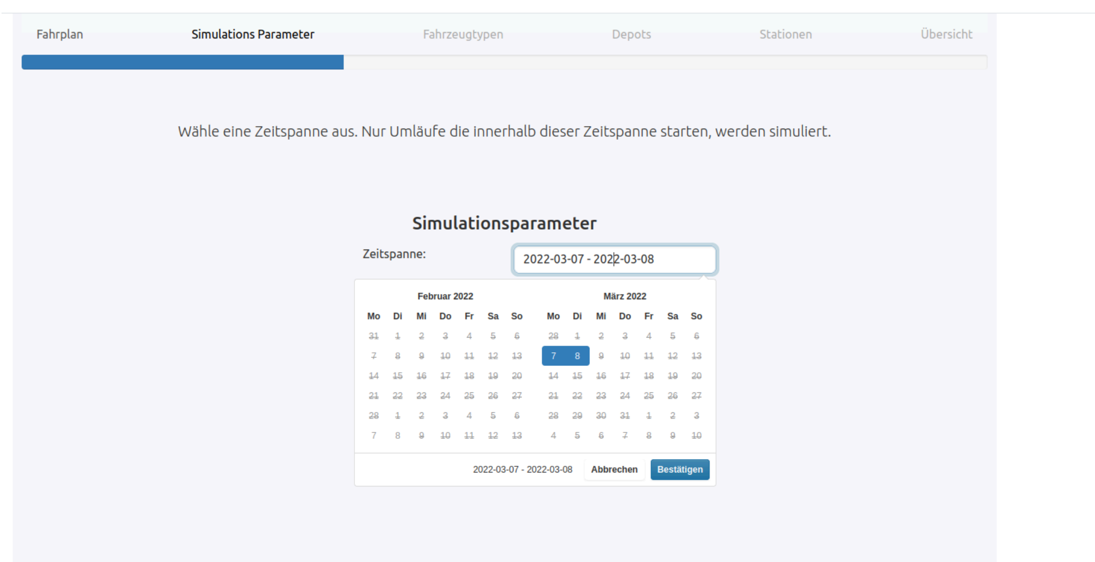


Figure 4.7: Simulation Parameter with open timetable

The feature "Station Optimization" is located on the stations section, which automatically electrifies stations in terms of its charging strategy. The test user verbally expressed that it should be described easier, because it is not obvious what it does. For example if "Station Optimization" is selected, the manual station selection under the feature is needless, but it continues to stay and gives the impression that the simulation can be further influenced. Also, when neither “Station Optimization” nor a station is selected to be electrified, the simulation does a normal depot charging strategy.

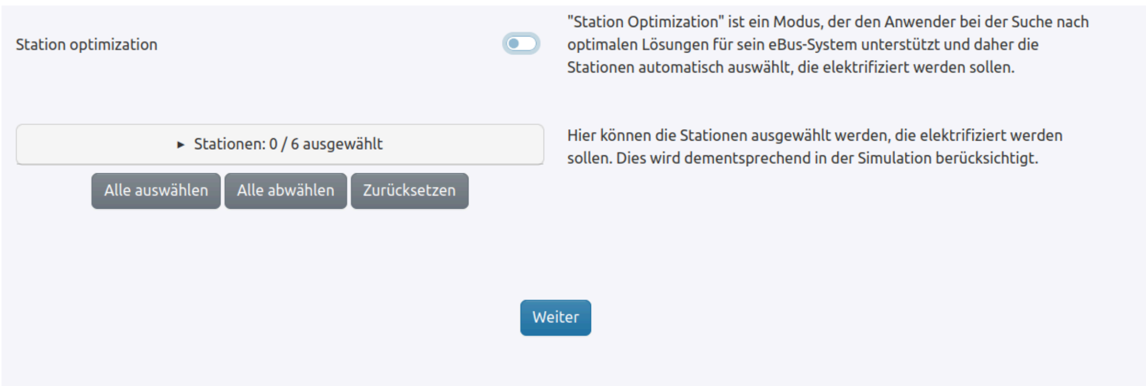


Figure 4.8: Unselected station optimization

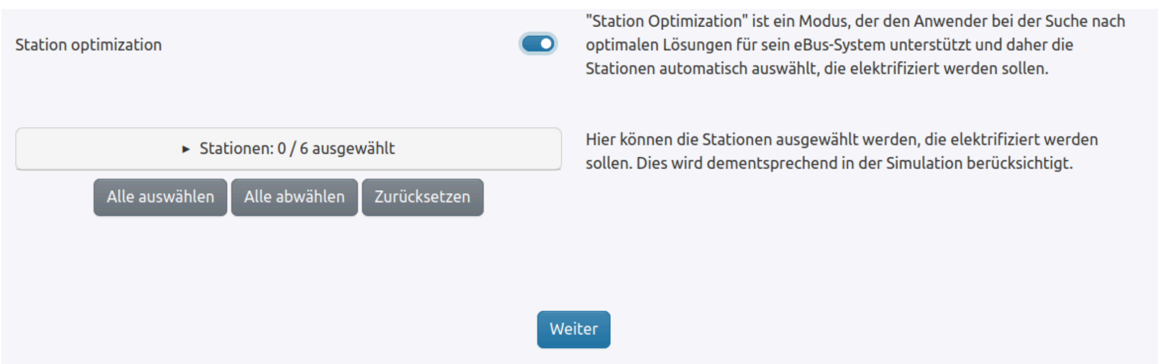


Figure 4.9: Selected station optimization

In this interview, many new parameters are suggested, like vehicle consumption, seasons, driver type, topography and trip steadiness (e. g. stop and go). In the station section, the values for stations, like charging points and charging power per station, always apply for every station in the scenario. But it is obvious that in a realistic scenario not all stations have the same number of attributes. This problem is known to the project team, but it hasn’t been decided yet how to visualize it properly. In addition, the default values don't always make sense, as brought forward by users, thus, it should be described where the value is coming from.
The overview section was again very debated. A high number of buses makes plots to some extent unreadable (figure 4.10).

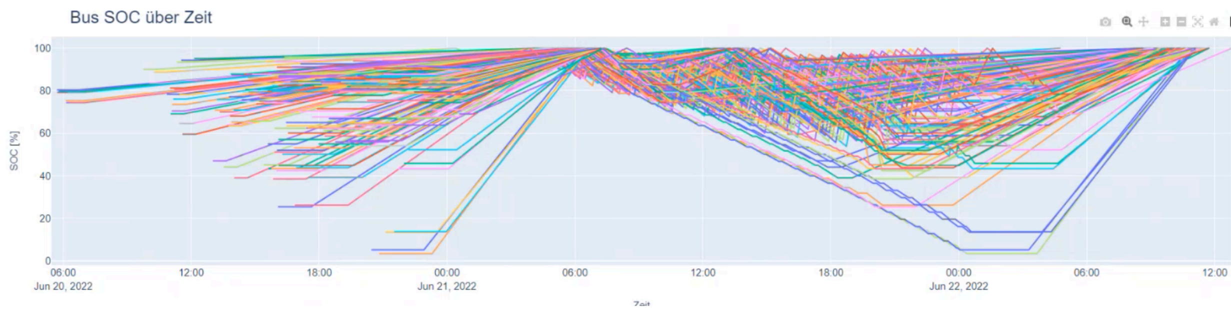


Figure 4.10: Bus SoC plot overtime in the overview section

In spite of the many issues with pragmatic aspects, the overall feedback was very positive, with supporting statements like ”exciting tool”, “good tool”, “it is the right direction” and “I really liked it”. Paradoxically did the overview have at the same time the most problems but also the most praise.
In terms of a realistic simulation, the test users were interested in assumptions of different buffer times (e. g. traffic lateness, service times, stop time). This is covered in the depot software through a cleaning and two charging values, which are thirty and five minutes long. Thus, the question was, what artificial buffers and assumptions are needed to execute a simulation that is close to reality? For their own schedules they use excel to calculate them, which depends on day time, bus line, a delay time value (1-3 min) and a service time value (around 15 min). Lastly in the ending discussion, the topic was bus occupancy. As a cost factor, it is important to consider, for example, how profitable the schedule is, so efforts can be minimized, because the higher the occupancy, the lower the relative costs.

4.1.3 Summary

The minimalist design and light aesthetic allowed good navigation and was not “in the way”. But other than that, any hedonic aspect was fading into the background. The overview page sparked the most controversy, because it is most admired, but also has most problems.
Some problems preserved from the first interview into the second, like an unrealistic schedule file. It caused for some features a lack of understanding, like the “default vehicle type selection”, where, because of the functional bus type name, users were confused, or in the overview section, where extreme behaviors of buses do not align with the participants’ knowledge.
There is an overall positive attitude towards the tool. Many features that are present were partially expected by the users. And a lot of functionalities that are asked for are possible and are to some extent already planned, like smart charging in depots and new modifiable parameters. They just need to be connected with the interface. In hope of cooperation, a supply with steady feedback, the bus companies seem to trust the project, and see in it a great opportunity. This is no surprise, considering we are offering a free open source tool that is in part catered to their needs. In comparison to this, both companies have experiences with bought software, which is either very similar to our tool or is even at a disadvantage.

Realistic simulation is of interest in both interviews, but first one was more interested in using their own bus types, and the second one emphasized this by mentioning different buffer time assumptions, which they are using already in their own simulation.

4.2 limitations

Qualitative research is important for the description of user experience, but like any other researcher, there is a potential confirmation bias that the author might produce. Especially with a framework analysis, the danger is high to rely on one's subjectivity and simplifying complex relationships. [48] This kind of bias is also possible during the moderator, who might influence the users during the interview. [49] Another problem is the low number of just two interviews. Originally between four and six interviews were planned. Nevertheless it is possible to derive some of the most pressing issues, especially in this case, where we interviewed a very specific user group. Application updates that happened between the first and second interview have a possible influence on the experience. It was already mentioned that there is a danger to rely too much on these interviews, which are also just with bus company employees, so the circle of tested users is very narrow, a possible way to neglect other user's interests.

4.3 Research Question

"How does a scientific web-app prototype, developed under user experience design (UXD), influence the experience of users in a user experience (UX) and usability context?"
In a lot of ways, common problems, especially those that would hinder flow and navigation, have been avoided. UX has been a focus point from the early development stages on, with considerations on system visibility, error prevention and cognitive overload, which has resulted in minor UX conflicts. It is important to maintain this approach so future users can use and understand a scientific simulation application without being greatly involved in the field. The influence factors are multivariate, complex, interrelated and changed even between the interviews from the system side and definitely from the user side. In this study, the biggest issues are still usability and functionality-related, hinting at its infant development stage. There is no direct way to answer this complex question since it encompasses all the different influence factors, usability and UX aspects.

Hypotheses:

1. Users with high domain knowledge, system knowledge or computer experience are expected to have a more satisfactory experience.

The first main test participant had, in comparison with the second participant, a very low level of expertise. The second user was seemingly more curious and engaged. He also made the same usability mistakes but did not repeat them. This was in stark contrast to the first test user, who repeatedly overlooked the opportunity and depot charging options, and did not notice the start simulation button. But both had a very similar opinion about the tool and stated repeatedly their interest, thus, there is no clear answer at the moment as to whether the hypothesis is true.

2. The motivation behind using the app impacts user interaction and satisfaction significantly.

Personnel motivation hasn't come up, because all the participants, except the main test participant from BVG, have been driving an electric car. Nevertheless, he was one of the more curious and interested participants in the study, but this could also stem from his high expertise values (simulation = 0.7, computer software = 0.8, software development = 0.5). The main test participant from SWM actually had low expertise values (simulation = 0, computer software = 0.65, software development = 0), but was the person with the most experience in electromobility (8 years). Both have managerial positions at a bus company with big fleet sizes, conventional and electric. With this in mind, there is no evidence that motivation plays a substantial role.

3. System performance, particularly in terms of speed and reliability, is expected to be a critical factor because experts value task efficiency and other typical usability components more than UX ones.

This proves to be overwhelmingly true in this case, being a scientific web app in its first steps. Among the participants, there was not one verbal expression about the design, only a couple of times about the visibility of specific components. Their interest lies much more in the functionality, authentic simulations, usable data outcomes and low-effort use.

4. Users with less domain knowledge prioritize more UX features than usability ones.

At this point, it is not possible to answer this question fairly, since the user group that was studied had either a good amount of expertise in simulation, computers and software development or experience in the fields of buses, charging and electromobility. However, the limited functionality that the prototype offers doesn't allow too many mistakes in the realm of UX anyway. But they shouldn't be neglected, nevertheless, the moment the bulk of pragmatic issues are solved, UX aspects will move to the forefront, and other user groups might not be so focused on usability. And this process could accelerate with their decreasing expertise.

5. Conclusion

The author designed a frontend for a scientific simulation web app. During the development process, UX methods like user research, personas, and UX guidelines were used to ensure user needs were met. The preliminary design culminated in a first prototype. In two semi-structured interviews with a subgroup of assumed experts, data was gathered, which was analyzed with the help of [44]'s framework. It utilizes pragmatic and hedonic aspects. Although it can't be claimed that every problem has been found, a lot of issues with the design have been revealed. One would think two interviews and a qualitative approach could not produce reliable data, but even between the interviews, there appeared to be more similarities than discrepancies. The biggest takeaways are the seemingly solid UX basis, according to bus company employees, paired with even more interesting features and functionalities, usability-wise, which showed the most resonance, but also the biggest obstacles.

In its core, UX, usability and software development are iterative processes. That is why, for the next iteration, interviews or a focus group would be a reasonable step, with a special focus on plots and new parameters. The bus companies help to shape the outcome of every iteration deeply, but shouldn't be the only user group to be considered, since they have their own usage and bias, in order to make this tool more attractive to more non-experts. Hopefully the tool stays easy to use, so there is no need to have a workshop to learn it, since it would be a big advantage for a scientific application to be as easily learnable as possible. A reasonable step would be the use of web analytics to collect quantitative data since the website is already available online and the user base can start to expand. In anticipation of future iterations, the tool might have more and more naive users without any bus or simulation experience. That is why a further focus on these user groups should not be neglected.

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