Towards Data-Driven Planning of Mobile Charging Infrastructure for Electric Vehicles

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ABSTRACT

Electric vehicles are a key technology to decrease carbon emissions and enable sustainable mobility. However, the increasing adoption of electric vehicles imposes challenges on the availability of vehicle charging infrastructure. Especially temporary peaks in charging demand, e.g., during large-scale events, are often hard to address. To alleviate this issue, charging infrastructure providers can offer mobile charging stations that event managers can rent. In this research, we examine the requirements, challenges and chances of data-driven charging infrastructure planning by developing a prototype system connecting event managers and charging infrastructure providers. The tool assesses the demand for mobile charging stations and recommends suitable locations for placement by considering temporal, spatial and contextual data. We assess the system's suitability for charging infrastructure planning by conducting qualitative interviews with experts from the event planning and electric vehicle sectors. Our findings show which data sources are indispensable for a reliable prediction of charging demand or ideal positions.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; • **Software and its engineering** → **Requirements analysis**.

KEYWORDS

Mobile Charging Stations; Prototyping App; Human-Computer Interaction; Event Planning

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1 INTRODUCTION

The transportation sector is one of the major contributors to global CO_2 emission [21]. There are several strategies to reduce the emissions in this sector: Investing in public transportation, improving the fuel economy through policy tools and progressing the usage of alternative fuels, starting with electric vehicles [3]. The adoption of electric vehicles has experienced a massive increase in the last few years in many countries [22]. However, many electric vehicle users suffer from the limited travel range [26] coupled with the insufficient net of stationary charging infrastructure [23]. While electric vehicle charging in urban areas is widely supported [19], the missing charging infrastructure becomes a severe problem in rural areas [8] and during temporary peaks, e.g., caused by holidays or mass events [15]. Mobile charging piles, which can be installed for the short term, are a promising approach to tackle these challenges [1].

Currently, few data-driven concepts for planning electric vehicle infrastructure services exist. In this paper, we want to examine the chances, challenges and requirements that a data-driven software solution for the rental of mobile charging piles entails. We investigate the idea of connecting charging infrastructure providers (CPI) and event managers via a platform for the short-term rental of charging piles for events like concerts, festivals or fairs. We developed a preliminary concept for that platform: The event managers create a charging pile request for an event and look for a suitable CPI to supply them with the necessary mobile charging stations. The selected CPI plans the deployment of the charging piles and sends a contract offer to the event manager, which this one can accept within the platform. Two particular functionalities of the concept use spatial, temporal and contextual data to facilitate the preparation and organisation of the mobile charging piles' deployment. First, we deliver a charging demand estimation algorithm that outputs the number of required charging piles for a given event. Second, we suggest a positioning algorithm delivering places for the mobile charging piles for a given event location. We developed the concept into a click-path tool consisting of screens with the appearance of an actual desktop application. We carried out a proof-of-concept study by conducting five interviews with experts from the event planning and electric vehicle sector. These interviews consisted of a questionnaire and a task block. To solve the task, the testers had to use the different functionalities within the click-path.

We focused on several research questions: First, what is the mentality of our target group? What does their daily work look like?

Second, how does the demand estimation and positioning of the charging stations currently work? Third, could our envisaged electromobility service evolve into a profitable business? Our findings show that event managers wish for a quick solution to accelerate their event planning working progress and a carefree package with all logistics jobs included. The interviews reveal the preference to collaborate with the same business partner permanently. Regarding the CPI, the testing unearthed that the CPI appreciate supporting algorithms for demand and placements but only trust them partially due to their strong domain knowledge. The whole planning process takes a couple of weeks before the CPI can make a final offer to the event managers. The profitability of the tool itself depends massively on the future development of stationary and mobile charging infrastructure. Assuming that mobile charging stations will become more relevant in future, the experts appreciated the tool and could imagine its evolving into a real business platform. The interviewees also delivered many concrete improvement recommendations for the concept and the underlying algorithms. Moreover, they had many ideas on how to expand the concept decisively. We will continue our work by incorporating the recommendations and extending the concept. Our contributions can be summarised as follows:

- We developed a concept for software that connects charging infrastructure providers and event managers to rent mobile charging piles.
- We created a click-path of screens representing the data-driven software tool.
- We conducted a user testing with expert interviews to highlight the concept's chances, challenges and requirements. Our results provide the foundation for further developing data-driven software for planning electric vehicle charging infrastructure.

2 RELATED WORK

Since the user testing took place in Germany, we first focus on research findings in Germany. We extend that view to international results in the second part.

2.1 Development of Electromobility in Germany

In 2013, the German government aimed at having 1 million electric vehicles (EV) licensed by 2020 [6]. As of 2011, only one out of 1,000 vehicles was an EV [7], one persisting research question was what may have prevented potential users from purchasing an EV [10]. Several studies identified high costs and low battery capacities as significant reasons for deciding against acquiring an EV [2, 9, 16, 17]. Other reasons for the weak acceptance were the low range of electric engines, the long charging duration, the unbalanced distribution of charging infrastructure, and the lack of electric charging stations. The research project Rapid Charging on Axes and in Metropolitan Areas (SLAM) examined the potential of fast charging infrastructure from 2014 on by positioning up to 600 fast charging stations across Germany by addressing four relevant layers: 1) user level, 2) mobility level, 3) power grid level, 4) urban planning [11]. Concerning the user level, Krause et al. [10] conducted a survey with early- and non-users to identify relevant fast-charging scenarios alongside seven daily travel purposes [4]. Furthermore, they examined location criteria for fast charging stations. The results exhibit higher levels of perceived benefit of EVs for the travel purpose *leisure time* when charging stations are located near shopping- or leisure areas. Moreover, the authors found that fast charging stations en route may generate lower levels of perceived usefulness in contrast to those located at destinations. Therefore, we examine how the placement of charging infrastructure around event locations is perceived in this study.

2.2 Other Findings

Several studies examined obstacles to the mass adoption of electric vehicles from economical, customer and governmental perspectives. An interview study in the Nordic countries focused on the economic aspects by analysing the selling strategy of electric vehicles [5]. The authors identified that EVs face an unfavourable business model, which results in unaffordable vehicles for consumers. The customer view was examined by a study conducted in the USA [12]. The authors observed the behaviour of plugin-hybrid electric vehicles (PHEV) to analyse their charging behaviour. They found that many drivers charge daily at home if they have the possibility of home charging. However, public charging is perceived as costly and not easy to use. The interviewed PHEV drivers expressed that it is difficult to find the exact position of a public charging station if they are in an unknown area. Another qualitative study on customers in Denmark [24] found that operation cost is one of the key driving factors for adopting electric vehicles. While most users prefer to charge at home, they wish for charging opportunities at work and public locations as a safety net. The authors conclude that the organisation of public fast charging to support longer trips is vital to promote the usage of EVs. In [18], the authors examined how the government can organise this public charging infrastructure. They explain that the government must encourage public and private actors like stakeholders and local businesses to participate in the strategic extension and development of the charging infrastructure. They also state that it is not sufficient to consider an isolated city but that cities have to be connected by electrified corridors.

We aim to examine the requirements, challenges, chances and problems of a data-driven mobile charging station rental service for events. To that end, we first develop a concept idea. Then, we incorporate two data-driven algorithms into the concept. Last, we derive a click dummy consisting of application-like screens from our ideas.

2.3 Platform Concept

We aim to develop a concept for a desktop app or mobile platform that connects event managers and CPI to rent mobile charging piles. The application should be responsive and work both on mobile and desktop devices. The events for which mobile charging piles are needed can be, for instance, music or folk festivals, fairs, concerts, soccer games and other mass events. The principle idea is that event managers post requests for mobile charging stations or contact a CPI directly to negotiate on the platform. When a manager sets up a new event, they must tell the tool the event's name, date, location and category. Here, they can choose between parties, concerts, fairs

and "other events". They also must enter the number of expected visitors. One core functionality of the tool is to use all that information and to output the concrete demand in charging piles for the event. An algorithm performs this estimation and supports the event manager in planning the logistics related to the event. As the next step, the event managers can look for a matching CPI in a selection list in the tool. They can reorder the list by activating filters, e.g., "Increasing price" or "Increasing distance". For each CPI, we provide information on the number of available charging piles, a one-to-five-star review and the price per pile. The more detailed information includes the address, contact data and the service offer. The offered services can comprise (de-)construction, 24-hour support, fast charging piles and commissioning by a technician. The event manager can directly contact the CPI throughout the platform since it contains a chat function. In this chat bot-supported conversation, the users can request the charging piles with a summary of all critical information, send documents like building plans with the appendix function and negotiate the conditions of the offer. Throughout the chat, making and accepting a final offer for the rent is possible.

The concept includes exclusive functionalities for the CPI: When the CP receives a request from an event manager or answers one of the open applications, they can determine the locations for the mobile charging piles around the event. They obtain all the event information, especially the charging infrastructure demand for that purpose. The tool supports the CPI in placing the charging stations around the event location. The underlying algorithm works with spatial, temporal and contextual data like the existing charging infrastructure, free parking places and the distance to the event location. The CPI can investigate the suggested locations on a map with various filter options, such as existing charging infrastructure with plug types, parking places, parallel events, and average traffic volume. Regarding the existing charging stations and parking places, the user can choose between public and private ones. The CPI can then accept or move the suggested charging stations. The final placement of the charging stations can be communicated to the event manager via the chat.

2.4 Supporting Algorithms

Two core functionalities of the concept are performed by algorithms that take spatial, temporal and contextual data as input. The first algorithm generates the demand in charging infrastructure by outputting the concrete number of required mobile charging piles. As input, we use the number of expected visitors and the event's date and location. By consulting additional information like the existing public and private charging infrastructure or the mean station occupation concerning the time of the day, a correspondingly trained neural network can predict the presumable availability of the charging stations during the event. The complete algorithm is described in [20]. An algorithm can then derive the number of additionally needed mobile charging stations from that availability.

The second algorithm delivers the positions for the mobile charging pile, which the CPI rents to the event manager. It uses the event location and the number of required charging piles as input. The algorithm falls back on the existing charging infrastructure, the positions and capacities of parking places suitable for the mobile charging piles. The parking places' information as polygons stems from point cloud data sets from LiDAR measurements as described in [13]. A straightforward approach is then an algorithm placing the charging piles on the parking places with minimal distance to the event location. Including other factors like the charging demand existing independently of the event or different charger types, we can choose the positioning strategy to be more complex. An approach that steers the charging stations' placement by reinforcement learning is proposed in [25] and can be a future extension of our conceptual algorithm.

2.5 Clickdummy Prototyping Tool

Once we had settled on the concept, we sketched our ideas as wireframes to get a rough idea of the application's design and structure. Then, we further elaborated the wireframes by designing them into detailed screen designs. For that purpose, we used the software Figma. The created screens should look as much as possible like an actual application and contain all core functionalities of the concept; see as examples Figure 1 and 2. We then added click areas to the different screens and created a click path so the testers would have the sensation of moving through an actual app.

3 EXPERIMENTAL SETUP

The aim of the evaluation is to test the concept with the help of experts in the charging infrastructure and event domain. To ensure a comprehensive understanding of the feasibility and viability of the prototyping tool's concept, we conducted expert interviews with various professionals from the event management and charging infrastructure provider fields.

3.1 Task Design and Objectives

We concentrate on the following goals in this study: First, we must understand the everyday reality of CPI and event managers. When developing the concept, imagining the daily work life of event managers and even more of CPI is challenging. So, we aim to understand who the target group is, the difficulties in its work, and by which values it is motivated. Knowing the mentality of the target group, we can design a concept that offers solutions to the needs and problems of the potential customers. Second, we need to understand how the charging infrastructure planning is currently organised. Therefore, we want to determine which software tools the CPI and event managers use and how confident they are with the predictions. The hope is to find out about utilised data sources to improve the concept's underlying algorithms. Third, we have the objective to evaluate to what extent the concept could evolve into an actual profitable business platform. We want to know the risks in the current electromobility market and what benefits the software must establish.

We decided not to conduct pure conversation-based interviews but to combine them with the user testing of our application click dummy. When designing the tasks, we focused on something other than the usability or the visual layout of the click dummy since they were not the concept's core. Based on the three objectives, we designed a role-play to frame separate tasks for event managers and CPI. Thus, the event manager should imagine being a manager planning a concert in Hannover, Germany, in 2023, for which she

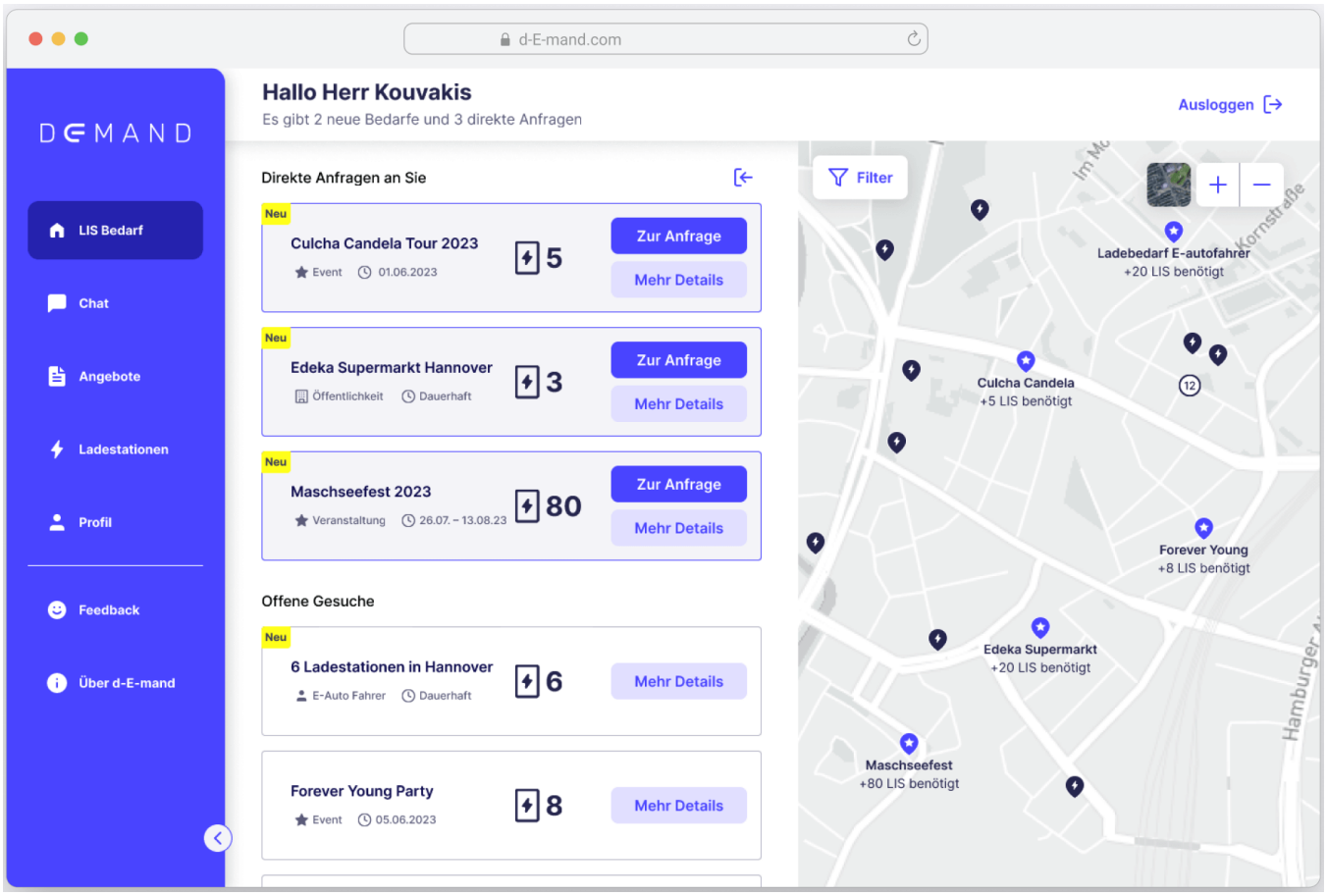

Figure 1: Screen showing the home page for a charging infrastructure provider. In the centre, we see open requests for events. On the right, there is a map which shows the event locations.

needs mobile charging piles. The created tasks made the testers use all core functionalities and all screens of the click path. The CPI started as a fictional CPI from Hannover who receives a request for a concert and has to answer it. We designed the tasks such that there was no right or wrong.

3.2 Experts

As we conducted a qualitative study, we needed a few testers who knew the working area very well. We approached the testers via personal contacts, working places or research networks. Our five experts comprised two experienced event planners and three charging infrastructure providers. The first event planner operated in a bustling urban location with numerous car-related activities. In contrast, the second event planner worked for an annual festival in a rural area lacking charging stations and public transportation. Among the charging infrastructure providers, the first expert represented an energy company and held responsibility for expanding stationary charging infrastructure. In contrast, the second expert possessed a diverse background in various aspects of electromobility. In particular, this tester had worked on research projects in the initial phase of electromobility. Lastly, the third expert brought valuable experience from his previous role overseeing mobile charging stations within an automotive company. The experts were diverse in age, gender, company and working region.

3.3 Interview Form

Each interview consisted of three blocks and was conducted online in a video meeting. At least three people participated in the interview: A moderator guided the person through the interview, a person who accompanied the user testing as a silent observer and minute writer, and the interviewee. In the beginning, the moderator interrogated the expert with several questions about their professional life to get to know them better and to understand their connection to the field of electromobility. The introductory questions included, for example, "What is your profession?", "Which tools do you use in daily work?" and "How long have you worked in the electromobility/event sector?" Next, the testers had to accomplish several tasks. We asked them to think out loud, i.e., to share their thoughts with us. The tasks represented scenarios the target group might encounter daily, such as "You are an event planner planning a concert, and you want to know how many additional

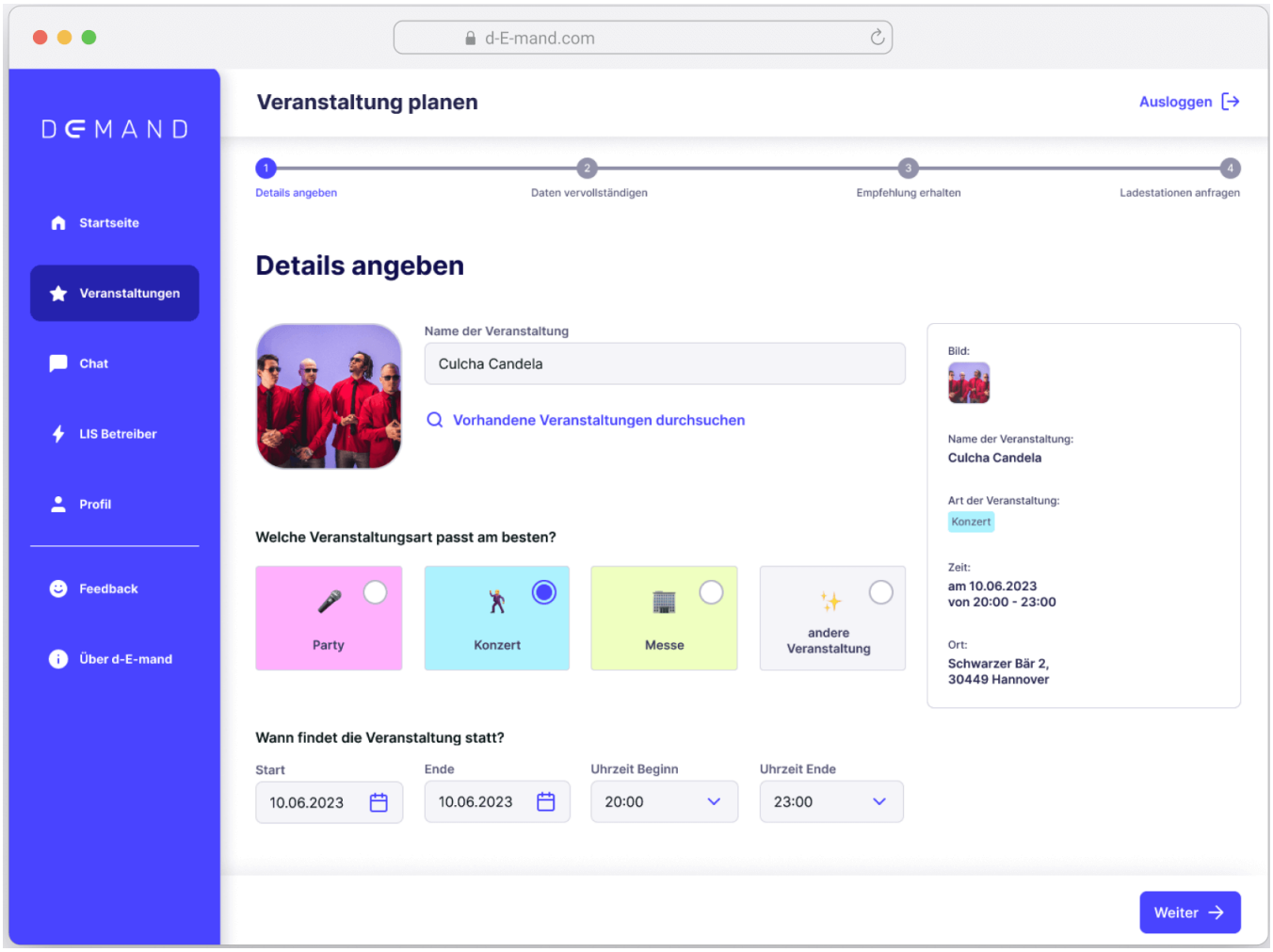

Figure 2: Screen depicting the setting up of an event. The event planner has to fill out the name, date, and location and choose a category for the event. On the right, the information on the event is summed up.

charging piles you will need for it." Another task was, "You are a charging station operator and want to know where best to place the required mobile charging piles to get the most profit." While the priority was to observe the users solving the tasks and their spontaneous reactions, we also prepared supporting questions to encourage the testers to share their thoughts. These questions were, for example: "According to which criterion would you choose the charging infrastructure operator to rent the charging piles?" or "How does it feel to you to accept or deny a contract offer via this chat?". We sent the interviewees an access link to the click dummy prototyping tool so they could work on the tasks during the online interview session. Since the testers shared their screen with us, we could follow them moving through the application. Finally, we asked the interlocutors about their overall impression of the clickdummy. We wanted to know the highlights and shortcomings of the tool and if they would actually use such software if it were on the market. We also discussed financing the service or expanding the business concept. The last questions were on electromobility and the future transportation to and from events. The duration of the interviews varied from 60 to 90 minutes.

3.4 Evaluation Method

We analysed the interviews with the help of the qualitative analysis method [14]. Hence, we categorised the statements in the interviews according to different topics or tasks: We bundled the positive and negative statements and the statements that contained an action recommendation.

4 RESULTS

We present the results of the expert interviews, including positive and negative remarks on the concept, as well as action recommendations. While many small tasks existed, we bundled all results according to some superordinate areas.

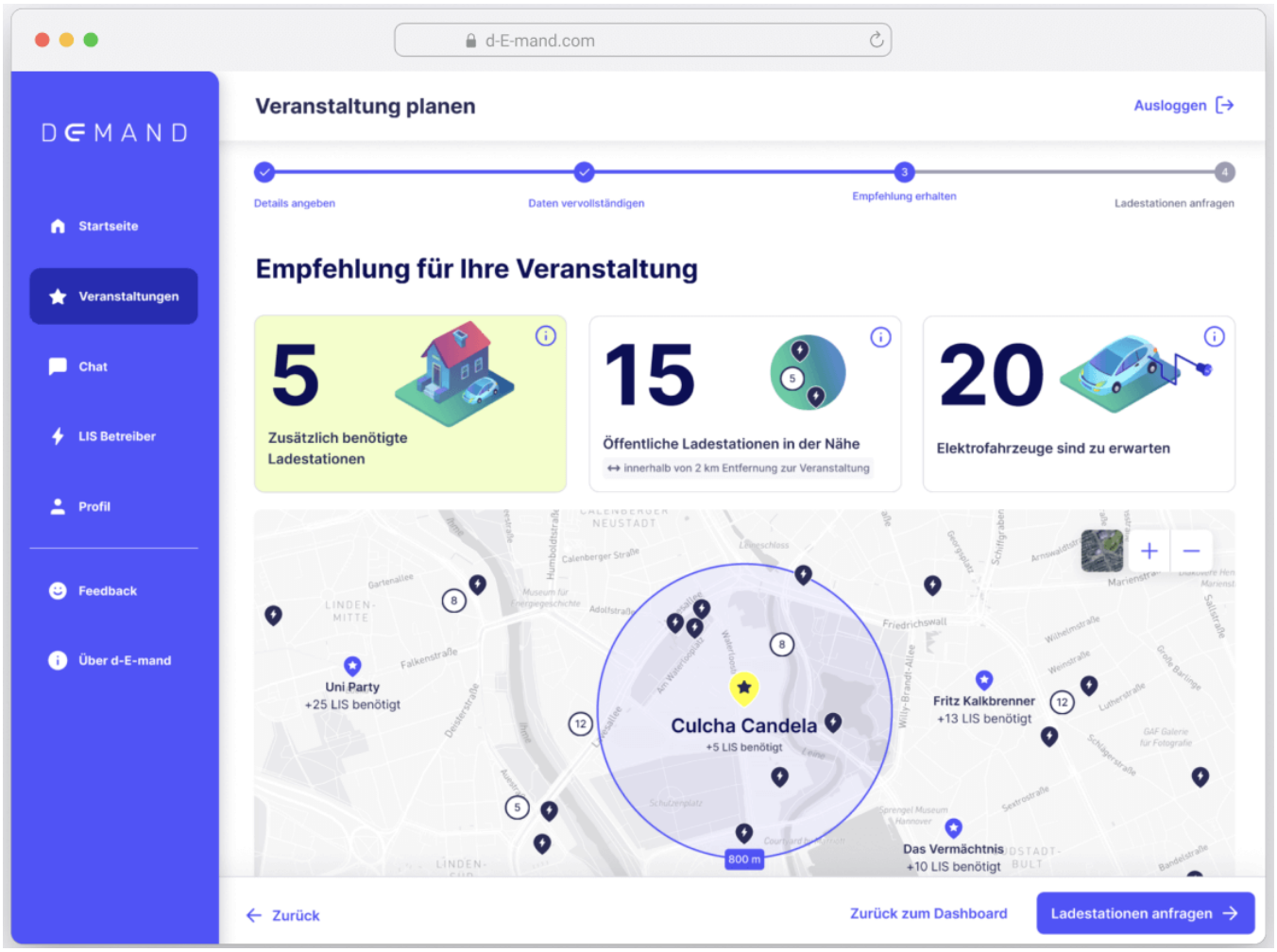

Figure 3: Screen for estimating the demand in mobile charging piles. The right box gives the number of expected electric vehicles. The middle box tells the number of stationary public charging piles. The left number denotes the required mobile charging piles. The black cones on the map indicate existing charging infrastructure.

4.1 Event Posting and Demand Estimation

The event planners must generate and post an event in their first task; see Figure 2. The testers said the selection menu of the different event sorts was sufficient to describe their event. They could handle the present questions like the time and location of the event but said that more differentiation was required: One tester designed the scenario that VIP guests with particular vehicles and, therefore, particular charging plug types would attend the event. Assuming that the charging supply for these guests had to be guaranteed, the event manager would have to ensure that a corresponding charging pile was at the disposal. The tester emphasised that an event manager must think outside the box and prepare all possible scenarios. Therefore, the tester suggested a free text field for special requirements.

In the next step of the task, an algorithm estimates the number of mobile charging piles needed for the event; see Figure 3. We asked the testers how they currently manage to estimate the demand. The testers said in unison that estimating the required mobile charging stations is very challenging. Although they interrogate the visitors beforehand about their transportation means for the event, these queries turn out to be not very helpful for the planning. Therefore, the event managers considered the existence of a demand estimation algorithm as very positive. The users named several data sources they would include in such a demand estimation algorithm: The number of expected guests, their place of departure, the share of electric vehicles at the place of departure, the public transport connection at the event location, and parallel events close to the event location. A weak point in the present concept named by the testers is that the algorithm and its recommendations could be more evident to the users.

Moreover, the testers had difficulties understanding the demand presentation in Figure 3. The three numbers on the screen denote the necessary additional charging piles, the public charging piles close to the event location and the number of expected electric

vehicles from left to right. While the intention is to clarify the algorithm's prediction, some users mistook the three numbers for a selection menu. These findings indicate that the request estimation feature must be accompanied by more explanation.

4.2 Choice of CPI Partner

The event managers have the task of selecting a CPI and to contact them. On the platform, they get shown a long list of many CPI with crucial information. The price was the most important criterion for tester one. As long as the service offer would include delivery, construction, commissioning, deconstruction, return shipment and, most importantly, a 24-hour reachable contact person, tester one would go for the cheapest offer. This tester emphasised that event managers have a vast workload before a mass event such that they need quick work processes with few detailed decisions. The second tester shared this opinion with respect to the services. Tester two suspected that a commissioning technician would no longer be necessary after an adaptation period. In contrast to the first tester, the second tester was more interested in quality and sustainability than price. Furthermore, tester two wanted to invest more time searching for a reliable business partner. Therefore, the tester attributed a higher importance to the one to five-star reviews the CPI had received. With respect to sustainability, tester two regarded the distance from the CPI's working to the event location as necessary. Both testers agreed that the availability of fast-charging mobile stations was an essential information detail about the CPI. Furthermore, both testers would always collaborate with the same CPI if they had made good experiences in a previous rental business. These findings indicate that the needs of event managers diverge such that the present various filter options are essential and valuable to depict this diversity.

Both testers criticised the list feature from which they had to select the CPI. While one tester found the list long, slaying and illegible, the other questioned the default sorting of CPI. Listing a CPI on top would give that CPI a competitive advantage, which could annoy the competitors. The tester formulated the wish to support smaller companies and rejected the idea of sorting the CPI by charging station volume. Last, one tester suggested expanding the review system from pure stars to text reviews.

4.3 CPI Receiving the Request

As the first task, the CPI receive a request from an event manager and have to react to it. To gauge the request, the testers desired information on the number of expected visitors, the place of departure and mobility mean of the visitors, estimated demand, sort of event, event location and a map of the event area. Regarding the sort of event, there is a massive difference for the CPI if the event is public, like a folk festival, or closed, like a concert, because the number of expected visitors can vary strongly in a public event. The testers wished for a visualisation feature that shows if they have enough free mobile charging piles to fulfil the request. That would be of particular interest when serving multiple parallel events.

We asked the testers which events were more or less profitable for a rental of mobile charging piles. The testers discussed that events with a high throughput of electric vehicles are exciting, e.g., a multi-day festival or a dealer presentation of electric vehicles. In contrast, concerts for one evening are less attractive since the organisational and logistic workload would be the same for the long lasting events. Another important criterion is the willingness to pay: Drivers accept relatively high prices for fast charging such that mass events in rural areas are more attractive than placing a charging station in the parking place of a supermarket. The testers debated the question of a reparking service for the visitors. In such a service, the charged vehicles could be removed from the charging pile and replaced by other electric vehicles. However, most interviewees assumed this model would only work in some countries depending on the culture.

4.4 Positioning of Charging Piles

As a second task, the CPI are supposed to choose the locations for the mobile charging stations. They receive a map with algorithm-generated placement suggestions; see Figure 4. On the map, the users can activate features like existing charging infrastructure with plug types, parking places, parallel events and average traffic volume. For parking places and the existing charging infrastructure, the users can choose a differentiation between public and private ones. The testers praised the map and considered all existing filters as necessary. Also, the extensive plugin type choice would be important since foreign visitors can use electric vehicles with charger types, which are unusual in the event's country. The parallel events would be interesting to create synergies when positioning the charging piles. The traffic information is interesting because the more traffic, the more potential customers come by the charging station. However, they missed information on the population density, the density of apartment buildings, construction sites, the parking places' underground, temporary barriers, and accessibility of parking places for disabled people.

We asked the testers how they would proceed in placing the charging piles on their own. First, they use an online map to examine the event's location and surroundings. Then, they employ special location tools to get suggestions for ideal positions. Usually, the CPI complete these suggestions based on their local knowledge. They then use the information on the event to estimate the demand. One of the biggest challenges in the process is to find out who the owner of a specific parking place is. The contact data are easy to find if the parking place is public. However, the search can become relatively tricky when the parking place is private. It would take up to one month to find the owner's contact data, telephone him and settle the modalities. Therefore, a considerable gain would be to have name and contact data directly available for each private parking place. An additional feature for the map could be a review system describing the experiences with private parking places.

Next, we talked with the testers about the positioning algorithm, which suggests potential charging station locations. According to the testers, the algorithm should consider all data features of the map as mentioned above. Significant are the distance to the event location, the distance to the existing charging infrastructure, the connection with public transportation, and the visibility for car drivers. While all testers considered the algorithm very interesting and helpful, they claimed never to trust it solely. Instead, they would always use their own local and expert knowledge in addition to determine the ideal positions. The testers appreciated the

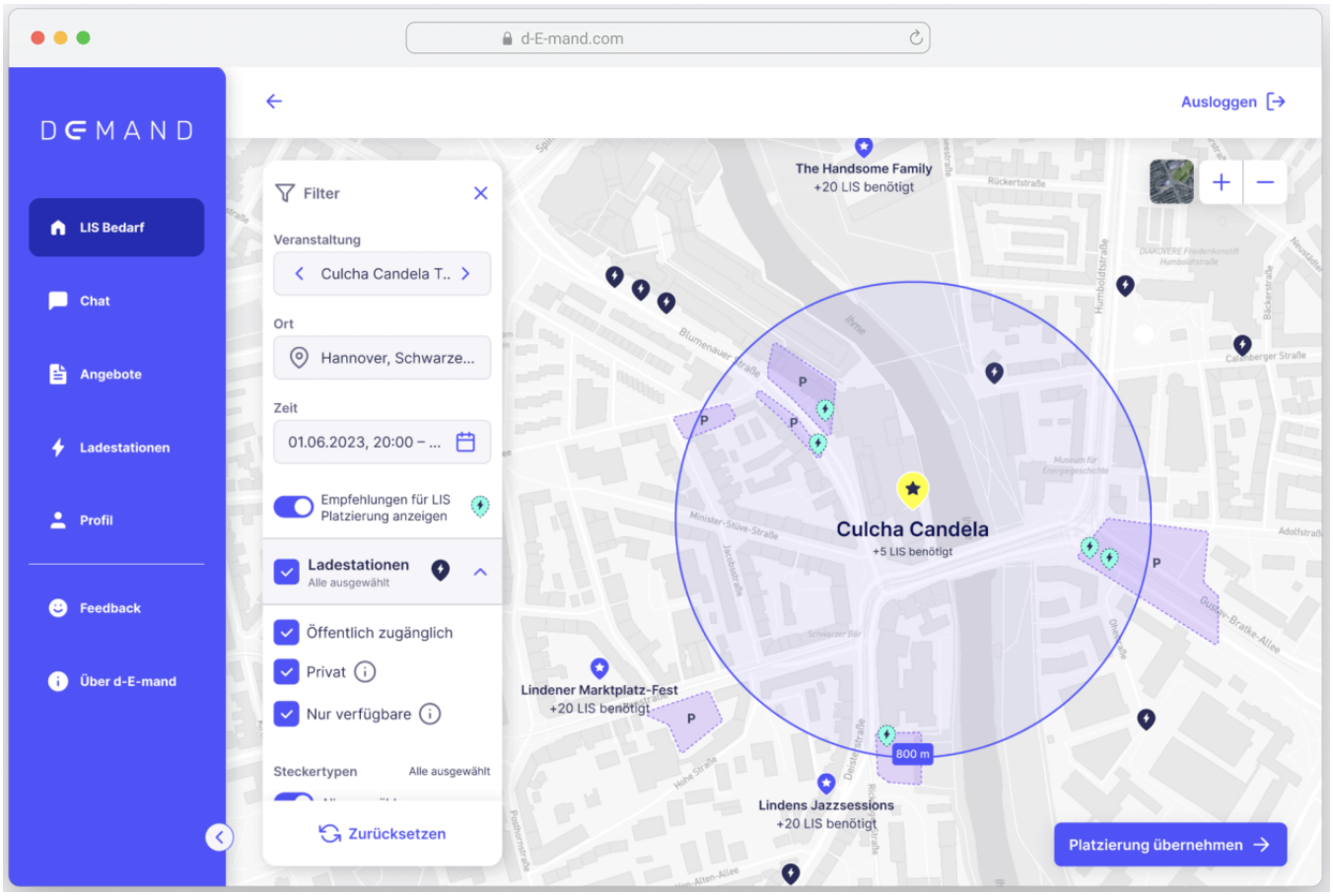

Figure 4: Screen for the placement of mobile charging stations. The black markers show the existing charging infrastructure, while the turquoise ones show the suggestions. The yellow cone indicates the event location. The violet areas with a P are parking places.

information text on the operating principle of the algorithm. One tester suggested extending the map and algorithm by a financial gain prediction for the different locations.

Finally, we observed that the testers appreciated the possibility of changing, declining or accepting the positions of the individual mobile charging piles. However, they attached importance to accepting and declining singular charging piles or changing their total number. Moreover, they wanted to have the possibility to modify the radius in which the potential charging stations are located.

4.5 Communication and Contract Offer via the Platform

On the one hand, the users liked the possibility of communicating via chat. On the other hand, most testers found the chat not serious enough to agree on a contract via it. Nevertheless, they agreed that this should be the long-term goal of the concept. Most testers said that the chat should not be the sole means of communication but should be accompanied by a personal conversation via telephone before agreeing to an offer. One tester appreciated the appendix feature, which enables the sending of construction plans. Most testers wished for the possibility to send all important documents in the chat to their own email address.

It also became evident that all the detailed planning, which takes several months, must be ready before the CPI can propose an offer. The event managers, in turn, told us that they would plan recurrent events like festivals long in advance so that they could plan the charging opportunities for visitors months before the actual event. Moreover, the event managers said they are not very interested in details like the positions but want a carefree package.

4.6 Profitability

All testers agreed that the service has to cost something. The consensus was that the CPI would pay for the service if the rental was profitable. Otherwise, the event manager would be supposed to pay if the rental were more of a favour service. One tester also suggested a subscription model instead of a fee-based application.

The testers also agreed upon the event manager being obliged to advertise the mobile charging piles, e.g., on the event's website. According to the interviewees, making the mobile charging piles

visible in the typical charging applications that electric vehicle drivers use is impossible.

Moreover, we asked the testers for their general impression of the long-term profitability of the tool. While the tool would massively accelerate the search and booking process, the users must weigh the velocity against the established processes. One tester emphasised that the concept highly depends on the development of mobile charging piles. While these are relatively expensive with a high planning effort, their flexibility enables the CPI to supply rural areas or mass events with charging opportunities or to test new sites. However, stationary charging infrastructure will probably oust mobile charging piles in future.

4.7 Usability

The users appreciated the overall visual layout of the screens. However, there were several misunderstandings. Hence, one tester suggested putting an explanatory video on the starting page, which explains the tool for both perspectives, i.e., CPI and event planners. The video should also explain how to work with the tool as a team. Another suggestion was a visualisation of the progress of the rental booking such that the event planner could, for example, see how far the detailed planning of the charging station positioning has progressed. The CPI users suggested an overview of their mobile charging piles on the starting page, which displays the booking history and the present status, e.g. in maintenance. This overview could also show the occupancy and profitability of past rentals.

4.8 Concept Expansion Suggestions

Regarding the concept in general, the testers had different expansion suggestions. The CPI testers proposed to handle all administrative work via the platform. For example, all reports of the preparations or site plans could be stored in the tool. Another proposition was to extend the concept to a third party: A service provider could be responsible for the delivery, construction, and all other logistics around the charging piles while the CPI takes on the administrative tasks. Another idea was to include e-motorcycles into the concept.

4.9 Future Development of Electromobility

Most testers believe that electromobility will grow strongly in the coming years. The construction of the charging infrastructure, particularly fast-charging infrastructure, would be the most critical component for further development of electromobility. Most testers believed mobile charging stations will become less important when the stationary charging network is large enough. One user believed there would be many local providers to rent mobile charging piles until one prominent provider becomes the most significant market power.

5 DISCUSSION

We deliver a discussion highlighting the requirements for event managers and CPI.

5.1 Requirements for Event Managers

Looking at the event managers' perspective, we learned that the event managers require a carefree package that includes all logistics and a 24-hour reachable contact person. They want to finish the task of renting the mobile charging piles quickly but not at the cost of the quality. Then, the event managers are unwilling to look for a new CPI partner for each event. That discords with the underlying idea of the concept to bring CPI and event planners together on a platform. Instead of a contact platform, we need a tool to build long-term business collaborations. This new tool suggests only CPI to an event manager with a good reputation due to the reviews. This CPI should have enough free and working mobile charging piles, offer all logistics services and be interested in a long-term business relationship. The risk is that the event managers only use the tool once to get in contact with a reliable CPI and then use it never again.

The question is whether event managers need planning software for mobile charging stations in their daily working life. Demand planning is one task they have to conduct for each event. The interviews revealed that the demand estimation algorithm facilitates the work of event planners. However, the tool's users must be able to understand which data is used to generate the demand estimation. Thus, increasing the transparency of the algorithm and expanding it with the suggested data sources of the testers would improve the demand estimation feature. Considering that the event managers opted for a carefree package, it is questionable whether they should be the ones planning the demand. An alternative is to hand this task over to the CPI. In this case, the event manager would send all the required information for each new event to the CPI. The CPI would take over all planning of the charging infrastructure of the event. The challenge here is that the event managers could send the respective information via e-mail to the CPI and do not need our software except for the first contact.

5.2 Charging Infrastructure Providers

While the interviews revealed that the event managers were not interested in the details of the infrastructure planning, they also showed the expertise and enthusiasm of the CPI. The CPI can serve multiple events at the same time if they own enough mobile charging piles. As they are open to new collaborations, they could use the tool as a contact platform in the long-term view. Beyond acquiring new customers, the CPI can use the software to plan and organise the rental of the charging piles. As we learned in the interviews, the CPI did not understand where the demand estimation came from when they received the manager's event request. If we handed the task of demand estimation over to the CPI, we would solve that problem.

As for the demand algorithm, we need to increase the transparency of the positioning algorithm. Since the CPI have a high expertise in finding suitable positions for charging stations, the requirements for the placement algorithm are very high. It must work with exact real-world data and output valid suggestions with a very low error rate because the CPI will not use it otherwise. Currently, we have not embedded many of the suggested data sources. Accessing these data, like population density or contact data of parking place owners, takes a lot of work. To incorporate these data, we must also modify the placement algorithm. A perfectly working placement algorithm is one of the software's most essential requirements and simultaneously chances.

The interviews unearthed that the entire planning process takes much longer than we expected when designing the concept. Hence, we should reorder the workflow so that the negotiation between CPI and event managers occurs before the detailed planning.

A chance that we had not foreseen appeared in the user testing: The software can comprise more of the planning tasks for the CPI, like the administration and control of the mobile charging piles. We could extend the platform to third parties responsible for maintaining the charging infrastructure or the logistics. Subsequently, the software would be CPI-centered, and the communication with the event managers would be only one part of the entire tool.

5.3 Summary of the Interviews

The main weakness of the concept is that any concept of its sort depends strongly on the economic success of mobile charging piles. As the rental of mobile charging piles is the core idea of the software, this issue can only be solved by overturning the entire idea. Secondly, another significant weakness of the concept is that most event managers always want to work with the same CPI. We can solve this problem by shifting away from a contact platform to a planning and administration platform for CPI. Then, we can benefit from the concept's strengths, like the demand estimation and the placement algorithms. We could also move from a fee-based service to a subscription-based one for CPI. A strength of the concept is that the tool is easy to use and accelerates the work.

An improved concept for the rental of mobile charging stations needs to focus on a reliable data basis, transparent algorithms and excellent predictions. In summary, the concept can develop into a working business app after a major revision.

6 CONCLUSION

In this study, we have examined opportunities and challenges for data-driven software for planning electric vehicle charging infrastructure services. We investigated the scenario of mobile charging piles rental to event managers for large-scale public events. We have developed a concept, supporting algorithms and generated a clickdummy of screens for this application. Then, we used the clickdummy to conduct a user testing with experts from the electric vehicle and the event area. The interviews have revealed chances, risks and requirements for the data-driven planning of such infrastructure. The main challenge is accessing the real-world data we need for the software to give excellent positioning suggestions for the mobile charging piles. However, the interview experts considered leveraging such data for charging demand estimation highly valuable. Our findings provide promising foundations for the development of data-driven planning of electric vehicle charging infrastructure.

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