Mobility-oriented Agenda Planning as a Value-adding Feature for Mobility as a Service

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Abstract: Due to the global trend of urbanization, the current transportation networks in cities are often stressed and congested. In the coming years, this problem is going to increase further in most areas. In addition, to congestion of roads and public transportation, sustainability and emissions are becoming large factors when regarding mobility. Today's mobility still relies on the usage of private cars in a large part, however, due to the rise of alternative travel modes and concepts such as Mobility as a Service (MaaS), the traditional mobility market may be disrupted. With the help of MaaS and the right incentives, it may be possible to shift users towards a more sustainable mobility behavior, which also relieve the stressed mobility network in cities, when more alternative mobility offers are employed. With this shift towards multimodal mobility, the complexity of searching and booking these mobility offers also rises. Users are forced to look through are large amount of alternative offers and are required to find a fitting one. In order to make this complexity more manageable, we propose a mobility-agenda planning agent that attends to the mobility needs of the users. The concept of mobility-oriented agenda planning may change how people view mobility and may provide a more holistic method of mobility planning. However, this holistic mobility planning method still has unresolved societal and technological issues that need to be addressed.

1 INTRODUCTION

In recent years, the already complex transportation systems in urban areas have not only grown, but also became more heterogeneous and multimodal, further increasing the complexity (Gallotti et al., 2016). This development is mostly induced by two ongoing global trends, urbanization and digitalization. The UN anticipates that the urbanization rate increases from today's 54 per cent of the people living in urban areas to 66 per cent by 2050 (United Nations, 2014). Even today, the main roads are usually congested during peak hours in urban areas. To handle the rising number of city residents the already existing travel modes have to be extended. Unfortunately, the traditional travel modes are already at their capacity limit in certain cities, there alternative mobility concepts, such as car- and bike-sharing, on-demand ridesharing, have been proposed (Cohen and Kietzmann, 2014). In Germany a shift towards to multimodality and alternative mobility concepts has already been observed (Kuhnimhof et al., 2012). These concepts became feasible due to the ongoing efforts of digitalization in the mobility sector (Piccinini et al., 2016). While a larger diversity in mobility modes means more flexibility for the passenger on the one hand, the larger choice of transportation modes also complicates the finding of preferred journeys for the passengers on the other hand (Gallotti et al., 2016). The main difficulty for the passengers is the currently often manual combination of various travel modes and to find journeys that fit to their preferences. One proposed solution to handle the increasing complexity of multimodal transportation networks is the concept of *Mobility as a Service (MaaS)* (Li and Voege, 2017). MaaS promises to integrate the various distinct mobility services into a single platform, providing door-to-door transportation. MaaS is a combination of mobility integration of existing modes, the inclusion of new shared mobility concepts and the usage of (mobile) applications for travel information. For travelers the high level of integration may ease the finding of multi-modal journeys, as the MaaS platform is the single point of entry for mobility needs. On the one hand, MaaS might ease the difficulty of using the

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inter-modal transportation system, while on the other hand, completely new mobility services become feasible, due to a high integration of the available data from multiple sources (Durand et al., 2018). In this paper, we propose one of these new services that become feasible in a MaaS scenario. While a MaaS concept allows the user to find a suitable mobility offer for a single journey, it is still a burden to find suitable mobility offers for multiple journeys throughout the day. Thus, we propose a mobility-oriented agenda planning concept that allows the user to plan his mobility not by planning individual trips, but by planning their agenda by planning the appointments and tasks in a calendar. The proposed agent-based system then searches for suitable mobility offers fitting to the agenda of the users and the user's distinct journey and transportation preferences. This mobility-agenda planning agent should reduce the cognitive load of travelers in a multimodal urban area, when planning the mobility of their daily agenda. We attempt to tackle this problem, by focusing on the agenda of the user and moving the mobility itself more in the background of the planning process. The paper is structured as follows: Section 2 further motivates the usage of MaaS, introduces it in more detail and highlights the current state of the art. In Section 3, we present our approach to mobility-oriented agenda planning, whereas Section 4 highlights the main challenges of MaaS and mobility-oriented agenda planning and also presents possible future work. Section 5 concludes the paper with a brief summary.

2 STATE OF THE ART

In urban areas congestion is not the only problem with today's mobility. Other key factors that must be considered are, among others, sustainability and carbon dioxide and nitrogen oxide emissions of the different mobility modes. Due to a low capacity utilization of private used cars, cars are often the worst way to travel in regard to emissions (Chester and Horvath, 2009). In Germany, the average number of people traveling in a single car was 1.5 (Follmer et al., 2010). While commuting this factor decreases to 1.2. That the currently used gasoline-based cars reached their sustainability limit can also be seen at the example of Germany. While the usefulness of the measure is still debated, many cities in Germany limit the roads on which diesel-based cars may be driven to stay under the legal NO_2 limit (Möhner, 2018). Even when not used, private cars need space in cities, which is already sparse. When regarding commuter traffic, the car not only needs parking space at the owner's home, but also at the destination. Due to the aforementioned reasons, individual car usage is not a sustainable mode of transportation and alternatives for traveling are to be preferred, in particular when regarding societal goals.

One often discussed solution to these problems is *Mobility as a Service (MaaS)*, which includes a multitude of modes, for example car- and bikesharing or on-demand ridesharing. In a MaaS scenario users can either acquire their mobility on a platform, when they need it, or buy mobility packages in advance that entitle them to the usage of various mobility options. MaaS offers an access-based consumption of mobility, meaning that the mobility is based on those services and not on the ownership of a vehicle (Bardhi and Eckhardt, 2012). Access-based offers are already widely accepted in other domains, platform such as Netflix and Spotify offer access to multimedia files after paying a monthly fee. MaaS attempts to apply similar methods to the mobility market. Given the success of platforms such as Netflix or Spotify, there is a huge potential to disrupt the mobility market with MaaS. For some people, MaaS solves all problems with today's mobility, in particular reducing the costs for all parties involved, better management of travel demand, and a reduction of environmental and social problems. There is no consent on the outcome of a MaaS scenario and its influence on the aforementioned factors. For example, when regarding the influence of MaaS on car usage, there are arguments for an increase and for a decrease of car usage. While MaaS may lead to a decrease in private car usage, because people have a wide variety of modes to choose from on the one hand, it also provides access to shared vehicles to people which previously did not have access to this mode of transportation on the other hand.

A survey study which examined numerous MaaS studies concludes that it is especially hard to change the travel behavior of people on their habitual trips, particularly when no outside trigger for the people exists to change their mobility behavior (Durand et al., 2018). The authors see the most potential for MaaS with incidental trips at the moment. Users can be incited to change their mobility behavior, for example, by reducing the costs of their mobility or by offering a service that adds some kind of value for the user. Depending on the implementation of the MaaS offer, value is already added by a larger choice of freedom. For many people, however, the cost factor of mobility is not as important as the convenience factor of the mobility. The convenience of the private owned car is the main reason for the high number of individual vehicles on the roads. When looking at a MaaS scheme, users are not subjected to a form of vendor-lock-in, e. g. owning a yearly public transit subscription or a private car. Once people have accepted MaaS it may become easier to influence their mobility behavior, as the users do not have any invested assets for mobility anymore, only the subscription to the MaaS service. The users of the UbiGo MaaS prototype in Gothenburg in Sweden, for example, adjusted their travel behavior to a more sustainable one in a course of six months (Karlsson et al., 2016).

In the literature, three preconditions of acceptance are listed for MaaS: autonomy, flexibility and reliability (Durand et al., 2018). In this work, we want to propose an approach for improving the reliability of MaaS. While we do not actually make a MaaS offer more reliable itself, we propose an agent-based system, which, among others, watches the agenda including the trips planned trips and informs the user of possible breakages in the trips. Additionally, it offers to search for alternatives. While, the reliability of the transportation itself did not change, we can increase the reliability of the overall mobility by offering alternatives to the user. The first adopters of MaaS are mostly particularly young and tech-savvy urban individuals (Durand et al., 2018), which may also be the audience for a mobility-oriented agenda planning system. While using MaaS, people also had problems with changing between schedule-free and schedule-bound mobility. Especially, when the mobility could not be booked as a package. Schedule-free mobility, such as car-sharing, still has a kind of schedule once booked, the starting and ending time of the usage of the vehicle. As delays in schedule-bound mobility is not uncommon, it may negatively affect the booking window of the schedule-free mobility. A mobility-oriented agenda agent could also be employed to automatically adjust the bookings of schedule-free mobility, if the service provider accepts short-term changes to a reservation, due to delays in the previous trip. Essentially, the mobility-oriented agenda planner, which will be introduced in the next section is a form of adding additional convenience and reliability to MaaS through the usage of integrated smart services.

3 APPROACH

In order for MaaS to be successful and effective, the user needs to perceive added value to the traditional transportation methods and the mobility must not be less convenient, as most people nowadays use their car not because of time or money saved, but because of more convenience (Durand et al., 2018). In a MaaS scenario, however, with transfers between various modes, the searching and booking of the transportation is not convenient at all. Especially, when a multitude of different modes are available and sensible different alternative exists, it is not easy to choose an offer. Given the access-based model of MaaS, each person has access to all modes of mobility included in their mobility package. To ease the usage of MaaS, we propose an agent-based system that handles the agenda and mobility needs of a user. In a well organized calendar, appointments are entered with their respective starting and ending time and their location. In addition to this information, a To-Do list may also be used as input to also partly plan the spontaneous mobility needs of the user. We assume that the agent can learn the user's daily schedule over time, so that its suggestions match the user's requirements. One reason for this is, that the travel behavior of people does not only repeat itself daily, but also on a weekly, monthly or even yearly basis (Kuppam and Pendyala, 2001). In addition to that, the agent should also learn the mobility preferences of the user, e. g. take a shared bicycle to work, but only when it is not raining outside.

The proposed mobility planning agent could not only add value to the MaaS offers, but also change how people view mobility (Wienken et al., 2017). Nowadays people think on a per-trip basis and book their mobility from location A to B. The reason for the mobility need, however, is nearly always an appointment or task at location B. People rarely travel, only for the sake of traveling itself. Even tourists mostly travel to reach certain points of interest that are famous or that were recommended to them. With a mobility-oriented agenda planning the user can plan their agenda, which many people already do anyways in the form of appointments in a calendar (Wienken et al., 2014). The agent-based system can then look for suitable trips that allow the user to complete their agenda on that day. The overhead of this approach is then, that all appointments and optional To-Dos are required to be entered in such a way, so that the agent understand the information. The minimal information needed for appointments are location, starting date and time and duration. For tasks the minimal information required is the kind of the task, so that the agenda planner can search for suitable locations and starting dates and times. Additionally, further constraints such as deadlines, dependencies, location constraints and others can be added by the user. The agent can then construct an agenda from this information, which also includes the mobility between the various locations.

An agenda planning agent, however, not only adds benefits to the user of such a system, but also to people planning and managing the mobility of an urban area. The mobility-oriented agenda planning approach, can also be seen as an attempt to make spontaneous mobility planned. Mobility-oriented agendas of users can be used to calculate traffic demands during the day. Such data may be beneficial to predict congestions in the multimodal mobility network and offer alternatives to the user. Offering another mode of transportation to the user in case of a delay in another mode is called multimodal rerouting. Allowing multimodal rerouting in addition with an access-based MaaS concept may allow to load-balance between different mobility methods in order to better utilize the given mobility methods in an area. This data can also be used to improve the traffic planning progress and to develop stereotypical agendas of identified personas. Such personas can be used when simulating traffic behavior of people in cities to research the impact of either political policy changes or the impact of new technologies connected to mobility.

Agenda constructing problems, which are the main task of the agent-based system, have been researched in the domain of Operations Research. Operations Research is a field that uses analytical methods to help in their decision making process. The *Tourist Trip Design Problem (TTDP)*, for example, deals with constructing multiple tours in cities, which allow the tourist to visit as many points of interest as possible, while reducing the monetary costs or the duration of the trips (Vansteenwegen and Van Oudheusden, 2007; Sylejmani et al., 2017). The problem is closely related to the Orienteering Problem or in a broader sense to the Traveling Salesman Problem and Knapsack Problem. When regarding more general mobility-agenda planning, additional constraints have to be taken into account, such as deadlines, dependencies between agenda items, or optional tasks. A first attempt at modeling the mobility-agenda planning problem builds on the basis of the TTDP and only slightly adapted the approach to incorporate the additional constraints. (Schwinger et al., 2018). This solution, however, does not compute mobility-agendas in a reasonable time, even though insertion heuristics are employed. The main reasons for this, is the large search space, as many suitable locations for each task is evaluated regarding their insertion costs. For example, for the task of grocery shopping, many possible supermarkets are considered, even though the user may already has a specific one in mind. Additionally, the agenda items are not added one after another until reaching a local optimum, but the complete mobility-oriented agenda is attempted to be globally optimized, resulting in a much larger number of calculations. This approach was feasible for the TTDP, where a smaller number of points of interest was regarded, but becomes unfeasible when attempting to apply the solution to a whole country, where the number of regarded locations is several orders of magnitude higher than when only regarding touristic point of interest in a smaller area. For an agent computing mobility-oriented agendas, a long computation time is not tolerable, as the user interacts with the agent and expects answers in near real-time. When limiting the search space, by involving the user and only adding single agenda items in each query to the agent, the computation time should be drastically improved. The drawback of this approach is then, that the algorithm does not converge to a global optimum, but converges towards an local optimum and the order in which the agenda items are added to the calendar becomes vital.

Currently, we are examining multiple different user interaction schemes with a mobility-agenda planning agent. We are implementing and testing a *graphical user interface (GUI)*, a *voice user interface (VUI)* and a text-based *natural language processing (NLP)* frontend. All applications have access to a multimodal route planner and a mockup calendar of a user. The user interactions are similar in each scenario, only the input and output paths from and to the user are different. The user is able to add, remove and change appointments and To-Dos. Furthermore, the mobility preferences and other constraints can be modified. Mobility preferences includes the mode preference, the variables that should be minimized, e. g. traveling time, number of transfers or monetary costs. The GUI, for example, features an calendar, a To-Do list view and a map view, showing the mobility between the different locations of the agenda. In the GUI the complete mobility-oriented agenda is visualized, normally users are only able to see the appointments in a calendar and need to look up traveling times themselves using a trip planning service.

The main feature of the agent, while also crucial, is not the planning aspect of the agenda. The agent should be able to deal with disruptions to the agenda and attempt to offer solutions to the user when certain aspects of the agenda are not feasible anymore. This includes problems with the mobility itself, e. g. the train is delayed and the next appointment cannot be reached by train in time. The agent could then recommend to book a shared-car that allows the user to still reach their appointment on time. Since the agent reacts to real-world events, the agent needs a real-time feed of mobility information. This includes delays of public transportation vehicles, current and prognosticated traffic information and booking availability of shared vehicles. Other problems to the agenda may occur, when the user does not follow the planned agenda, for example, due to a meeting that takes longer than initially anticipated. The agenda planning agent may suggest, for example, to cancel the following appointment or to move tasks that were planned for that specific time slot to a later time. In our proposed solution the agenda planning agent never acts on its own, but only suggests possible actions to the user. The human is always in the loop and can also choose to not follow the proposed actions.

4 OPEN CHALLENGES

When tackling mobility-oriented agenda planning, there are a few challenges that need to be addressed. We grouped these challenges in two coarse groups, social challenges and technological challenges.

Social Aspects. The social challenges address problems that arise when attempting to deploy a mobility-oriented agenda agent. These challenges are required to be addressed to avoid that people either do not want use newly developed system or that they are unable to use it.

Setup. One challenge with the approach of mobility-agenda planning in general is that its usefulness only fully unfolds when combining it with a MaaS scheme. When all trips are completed per car, the added value of a mobility-oriented agenda planner is negligible for most users. Therefore, the concept of mobility-oriented agenda planning is closely connected to implemented MaaS schemes. These offers, however, are not widely available, and the available prototypes are focused on specific urban areas. Furthermore, MaaS offers are only expected to come to urban areas in the coming years.

Mobility Setup. The current research focuses mostly on the potential early-adopters of a MaaS scheme, mostly categorized as urban living tech-savvy young people. Rural areas are, mostly due to cost considerations, left out (Durand et al., 2018). The assumed backbone of the MaaS scheme, public transportation (Kamargianni et al., 2018), is also not widely available in rural areas. In rural areas, schedule-based mobility such as public transportation is very infrequent and therefore no alternative to owning a car (Shergold et al., 2012).

Digital Divide. Additionally, MaaS and also mobility-oriented agenda planning requires the use of digital technologies (Jittrapirom et al., 2017). It has to be ensured, however, that no digital divide occurs and also elderly people can use these new mobility offers. Especially, elderly people, who do not own a car could benefit from the adoption of MaaS (Stein et al., 2017).

Habitual Behavior. Another problem that needs to be addressed by a mobility-oriented agenda planner is that people often prefer the status quo, instead of trying out new things (Ratilainen, 2017). When people book their MaaS package and do not change their mobility habits, the goal of a more sustainable way of traveling is not reached. Therefore, triggers that encourage people to try out new mobility modes must be found. One method would be to incorporate trialability into the offers, so that the user can try other mobility modes for a subsidized price. A gamification aspect, where users are competing for reducing their carbon footprint, could also be added (Kazhamiakin et al., 2015).

Privacy. Another problems with the concept of mobility-oriented agenda planning lies with the privacy aspect. In order to plan the mobility-oriented agenda and offering the user tailor-made mobility, the agent needs the complete calendar information including the preferences of the user. Most people are, however, not willing to share this sensitive data with an external service provider. This is still an unsolved challenge and is required to be addressed in the future and is a crucial question.

Most of the social aspects affect the MaaS concept itself. The main social challenge an approach of the mobility-oriented agenda planner must solve, is the aspect of privacy.

Technological Aspects. The technological challenges highlight the main problems the developer of such a system has to resolve. Some of these challenges are functional, while others are non-functional.

Multimodality. To compute meaningful trips and agendas the optimization algorithm must be able to access a multimodal multi-objective router with real-time information. The multimodality aspect is required to offer multiple different trips to the users, these trips themselves may consist of multiple modes. To allow the user to specify their own preferences about their mobility trips, the router must be able to handle multiple objectives. The user may want to minimize the travel time, the monetary costs, or the amount of vehicle interchanges. Unfortunately, just combining the different objectives using a linear combination and weighted factors may lead to deteriorated results (Delling et al., 2012).

Actuality. As the user interacts with the agent, the various computations of the agent should not take too much time. One non-functional challenge is, to implement the scheduling algorithm and the underlying routing algorithm in such a way that a normal use of the system is possible. Finally, real-time information is needed to address current congestion on the roads or delays in the public transit network. The mobility-agenda planner then knows the current predictions about the travel time from one location to another to compute the agenda in the first place, but also to update the agenda in case of expected delays in some modes. This leads to the next challenge with mobility-oriented agenda planning.

Foresight. Any time unforeseen events may happen during the day and affect the already planned agenda. Certain appointments or tasks may take longer than anticipated, or the trip between two locations is prolonged due to congestion. On the one hand, the agent must continuously monitor the agenda to inform the user of certain agenda-breaking events, on the other hand, the user must also be able to inform the agent to changes to the agenda. Once a change to the agenda is communicated by either side, the mobility agenda must be adapted to become feasible again.

Individuality. Another challenge that needs to be addressed is that the agenda of a user is very personal. The preferences regarding mobility, the location of agenda items, or the time and order of agenda items strongly diverges between different users. One possible solution to this is to learn the user's preferences regarding time and location of appointments and the user's choice of mobility for certain agenda items. Additionally routines of the user can be learned, for example, when and where the user prefers to go shopping. This is a promising approach, as the mobility habits of users tend to repeat themselves (Kuppam and Pendyala, 2001). Various learning methods have been proposed in the literature for recommendations regarding agenda items (Oh and Smith, 2004) or for mobility (Arentze, 2013). For both problems, the user input to the agent can be used as a basis for the learning. Firstly, the user may already explicitly state their preferences when addressing the agent. Secondly, upon returning a result to the user, she is able to manually change parts of the mobility and/or agenda. In this case, manual changes to the solution correspond to non-met user preferences. In both scenarios, the agent can learn from the user interaction in order to improve its understanding of the user's preferences.

The technological aspects can be grouped into three groups. Speed of the computations, quality of the results and quality of the interaction with the agent. Currently our focus is on delivering quality results and designing interaction schemes with the agent.

5 CONCLUSION

In this paper, we have discussed problems with today's mobility, especially regarding their efficiency and sustainability. Given the recent trends, new mobility concepts are required under both aspects. Current transportation methods are at their limit, regarding their throughput and their sustainability. As one promising solution to this problem, we have introduced the concept of Mobility as a Service. We explained the reasons why a MaaS concept may better utilize the already available mobility methods and why MaaS, with the right incentives, may lead to more sustainable mobility behavior of the users. Furthermore, the concept of mobility-oriented agenda planning has been introduced as a way to add value to MaaS in form of a smart service. For this we have illustrated an agent-based system that helps users to find suitable mobility for their agenda and explained the drawbacks of the traditional trip-based mobility search paradigm. In the mobility-oriented agenda planning concept, the user does not plan their mobility directly, but the mobility is rather seen as a way to reach the locations of the various agenda items, appointments and To-Dos. As the agent knows the agenda for the complete day, more reasonable suggestions may be given to the users, compared to a trip-based itinerary planner. Finally, we highlighted the current social and technological challenges with mobility-oriented agenda planning and have shown where future work is required.

For future work, further scenarios for a mobility-oriented agenda planning system could be developed to derive additional requirements of the system. With the requirements the architecture and system design can also be refined. The open social and technological challenges should also be addressed in future work.

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