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Mind the Seat Limit: On Capacity Management in Public Automated Shuttles

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With ever growing automation of public transport automated shuttles offer an attractive alternative in areas where traffic regulations limit the deployment of large buses (city centres) or where low degrees of utilization renders the manual vehicles operation non-economical (last mile). The low capacities of shuttles in combination with the human factor (driver or conductor) makes capacity management a greater challenge for the user. Capacity management describes the allocation of available seats in a vehicle, e.g., when buying a ticket. In this paper, we present the results of series of studies where capacity management in automated shuttles has been tested *via* instruments that are currently available in public transit (audio announcements, in-shuttle displays, booking apps). We found that measures during and after boarding are not sufficient and that capacity management in automated shuttle requires a more detailed planning of pre-boarding stages; when boarding automated shuttles as opposed to non-automated public buses the flexibility is reduced. The paper concludes with discussion and recommendations for an optimal capacity management d.

Keywords: automated vehicles, automated shuttles, last mile, capacity management, public transport, booking app, auditory information, visual display

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1 INTRODUCTION

Be it in the air, on rails, or on roads: transportation has seen increasing degrees of automation which resulted in a lesser need for direct manual control by human operators over the last decades. The work towards automation is continuing, with on-road vehicle automation in particular receiving substantial attention and efforts for both private and public means of transportation. One, and arguably the most important, motivator to automate vehicle operation is that of safety: By reducing the human role in the driving task, the amount of accidents caused by human error is expected to diminish accordingly, with the final goal of eliminating the human factor in the driving process entirely, so that fatal road accidents due to human driver errors are no longer possible[1]

Automation can bring with it a number of other advantages as well, not all of which being strictly related to safety. One of these is the operation of vehicles in areas, where it was not possible to do so before—be it because of environmental hazards or simply due to the high cost of operation. While

[1]See: EU Road Safety Policy Framework 2021–2030 - Next steps towards “Vision Zero”, https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190283-roadsafety-vision-zero.pdf.

there is a risk of endangering the work prospects of professional drivers, there is also a chance to open up new avenues and connect sparsely populated areas and traffic densities—the so-called "last mile".

When it comes to economic viability, the vehicle can only justify its purpose if it is truly autonomous—if there is labour involved in order for the vehicle to operate, then the cost-saving effect due to the automation would be lost. This means that a human driver or conductor should not be present—be it for driving the vehicle or interacting with the passengers.

The interaction with an automated vehicle must be very effective, as interaction with a human driver will be no longer possible. This relates not only to itinerary and relevant connections but also to capacity management. By 'capacity management' we refer to the act of assigning passengers to the seats or spots available in the vehicle, its typically done *via* ticketing. If a shuttle operates constantly under its capacity, then it operates at decreased efficiency, potentially eliminating some of the economical advantages intended to be gained by using such a shuttle. If, on the other hand, the shuttle operates over its capacity, then using it can be a very frustrating experience for the prospective passenger, who might see one crowded shuttle after another arrive, with no way of knowing whether she/he might finally be able to board one with a free seat.

The combination of full automation and low capacities of the last-mile shuttles can likely result in the latter scenario. Effective capacity management in automated shuttles is, it appears, not a trivial matter, yet it is still a poorly researched subject in the current academic landscape. We intend to address this gap with the present paper.

In this paper we present the results of a series of studies that were conducted within the Austrian flagship project Digibus®Austria[2]. The project‘s objective was to investigate the integration of automated shuttles into an existing traffic infrastructure as the last-mile solution, i.e., to connect remote and/or sparsely populated areas to the public transport infrastructure. Passenger interaction and capacity management was one of several focal points within the project. The studies we are presenting here dealt with additional passenger requirements due to the automation as well as how existing means for capacity management work for the automated context or whether adjustments/changes are necessary.

In the following, we first present literature relevant to the topic of automated shuttles, automated vehicles and the last mile, as well as capacity management in (automated) public transport. We outline the overall research goals and the process of the three presented studies. After describing each individual study (setup, procedure, and results), we conclude with a broader reflection and a number of resulting requirements and recommendations for capacity management in public automated shuttles.

2 RELATED WORK

Capacity management in public transport is either done *via* booking (e.g. railway) or based on heuristics and experience (e.g. bus schedules). What they have in common is, that there are no precise models how many passengers will be exactly riding on a train or in a bus at any given moment. This is possible due to the fact that trains and buses typically are capable of transporting a relatively large amount of people in one train or bus. Thus, capacity management in relation to public automated transport is still insufficiently researched. Especially when the maximum capacity is low—as is often the case with automated shuttles—the fact that only few people are able to board at a time can quickly become a logistic challenge.

Booking apps for individual and shared rides have been introduced on a large scale when mobility service providers such as Uber or Lyft also peer-to-peer rides emerged and fixed route shared public transit have been investigated Kumsila and Phithakkitnukoon (2018). These studies typically include mobile passenger and driver application and (sophisticated) dispatch system. For automated shuttles in a first/last mile scenario such booking apps have not been introduced yet.

For automated shuttles, the primary research focus from a user-centered perspective has been on acceptance of and User Experience (UX) with automated shuttles [e.g. Bernhard et al. (2020); Distler et al. (2018); Nordhoff et al. (2018b); Wintersberger et al. (2018); Chen (2019)]. Additional research foci are interaction with vulnerable road users (VRUs) [e.g. Verma et al. (2019)] and passenger interaction in fully automated shuttles [e.g. Fröhlich et al. (2018); Mirnig et al. (2019)]. While capacity management is related to the latter, it is rarely in the focus of passenger interaction efforts with some exceptions [e.g. Mirnig et al. (2020b)]. Available literature related automated shuttles is primarily concerned with the acceptance of such vehicles and passengers' willingness to use them. Literature specifically on the issue of capacity management in automated shuttles is comparably sparse overall.

There are several works, which have investigated autonomous mobility on demand (AMoD) approaches. Distler et al. (2018) found that the general acceptance of such a service is often not based on the actual experience of riding a shuttle. It should be noted that in the booking app used for that study, essential booking options (e.g., pick up time and number of passengers) were available but withough any advanced capacity management functions (e.g., specific seat assignments, resolving conflicts, etc.,.). In Main, Germany, the automated bus EMMA drove on a test track in a public space [Bernhard et al. (2020)]. Passengers expressed a positive attitude towards the bus in relation to safety and eco-friendliness. However, due to a very low number of participants, the bus was operated under-capacity throughout the study, so effects of capacity issues or (in) effective capacity management on passenger experience or acceptance could not be drawn. Participants, who experienced an automated shuttle in Berlin were reported to be willing to share rides with other travellers [Nordhoff et al. (2018a)], but capacity management addressed was also not addressed further in that study. Other studies identified factors such as speed [Chen (2019)] or service quality [Nordhoff et al. (2019)] to be crucial for the acceptance of automated shuttles in general.

Liang et al. (2016) modeled the optimal number of automated taxis for last miles scenarios. To do so, they differentiated between

[2]www.digibus.at

two concepts. In the first concept operators could accept or reject trip reservations to increase profit. In the second concept, all reservations had to been accepted. Their results for the city of Delft, Netherlands, resulted in an optimal fleet size of 40 vehicles for concept one and 60 vehicles for concept two. Their model is based on one taxi per reservation and is transferable to a limited extent to the capacity management of shuttle buses with more than one passenger. Araldo et al. (2019) have modeled the optimal number of pick-ups and drop-offs for automated vehicles and simulated it in a Mobility on Demand (MoD) service scenario.

Other approaches to better estimate needed capacities include monitoring automatic fare-collection at entry such as in New York City, United States [Reddy et al. (2009)] or using mobility data form cell phones or high tech vehicles, and smartcard readers as in Shenzhen, China [Zhang et al. (2015)]. Lamotte et al. (2017) separate conventional and automated vehicles on freeways. Drivers of conventional vehicles could choose their own departure time, whereas users of automated vehicles had to book their rides in advance. Their results suggest that smart algorithms for allocation needs to be found to balance profit and welfare-maximizing strategies. Merlin (2017) compared automated shuttles with conventional buses in a Ann Arbour, United States, the comparison hass been based on a simulation. Results show that automated shared-ride taxis were superior in terms of service, cost and carbon emissions to a conventional bus system.

One main aspect of taking an automated shuttle over a car is the last mile scenario Yap et al. (2016). Shen et al. (2018) have investigated how automated vehicles can support the public transport system of a city such as Singapore by tackling the first-mile problem during peak hours. The examined automated vehicles were traditional taxis carrying up to four passengers thus allowing for shared rides. No conclusions regarding capacity management could be drawn. Nonetheless, service quality improved and a reduction of street traffic could be effected. Ma et al. (2019) have presented a taxi booking system for automated taxis. The application matches GPS locations of automated vehicles and customers, who use a mobile application when requesting a ride from the current locatioon to the chosen destination. Capacity management was not addressed.

Design oriented research has yielded several approaches of how to use apps in and for automated shuttles; again the challenges of capacity management have ot been addressed. Ayoub et al. (2020) have presented an application that allows parents to get in contact with their children in an automated bus by enabling chat, tracking, and contact features.

3 STUDIES OVERVIEW

The three studies that we will describe in the following sections were conducted over a period of approximately 2 years within the project. **Figure 1** shows a general overview of the studies and the flow between them.

The following **overall goals** were pursued throughout this research:

1. Identify the challenges and barriers towards capacity management due to automation and lower overall capacity in shuttles,
2. Investigate the viability of existing tools in public transport for effective capacity management in automated shuttles,
3. Identify additional requirements and derive implications for design of capacity management tools in automated public shuttles.

The first study was conducted early in the project and was primarily intended to confirm whether and/or to what extent the shuttle's low seating capacity was a problem in terms of passenger interaction. A secondary goal was to investigated whether the infrastructure already available in the shuttle (in this study: acoustic announcements) could be used to support in-shuttle capacity management. Study 2 was a direct follow-up and it centered on the evaluation of the booking application that has been adapted for shuttles with the aim to supplement the on-board information with capacity management tools in the process of pre-boarding. Study 3 investigated the final implementation and an iterated booking application as well as an in-shuttle monitor for capacity management in a real traffic deployment. The shuttles used were the EasyMile EZ10[3] Generation 2 (Study 1) and Generation 3 (Study 3) models. All three studies were conducted in Austria with German speaking participants. Parts of screens or interfaces and study materials appearing in figures throughout this paper were translated to English specifically for this publication. All interfaces used as well as written information presented to the participants were originally in German. In the following sections, we describe each study and its results separately, and will then discuss the results and lessons learned from all three studies together at the end of this paper.

4 STUDY 1: IN-SHUTTLE AUDITORY ANNOUNCEMENTS

The goal of this study was to conduct an initial investigation into capacity management in a driverless shuttle. We wanted to investigate 1) how critical capacity management in the automated context differs from the context where the human factor—driver or conductor - is available. 2) whether standard means already available in public transport can be used for effective capacity management in automated public transport.

For this purpose, we chose to focus on capacity management during the boarding process (= in the vehicle), as we presumed that step to the most directly influenced by the absence of a human driver. For the modality and interface, we focused on auditory announcements that are commonly used to broadcast warnings or information related to extraordinary, unexpected occurrences (e.g., cancellations, delays, etc.,) whereas visual

[3]See: https://easymile.com/solutions-easymile/ez10-autonomous-shuttle-easymile/

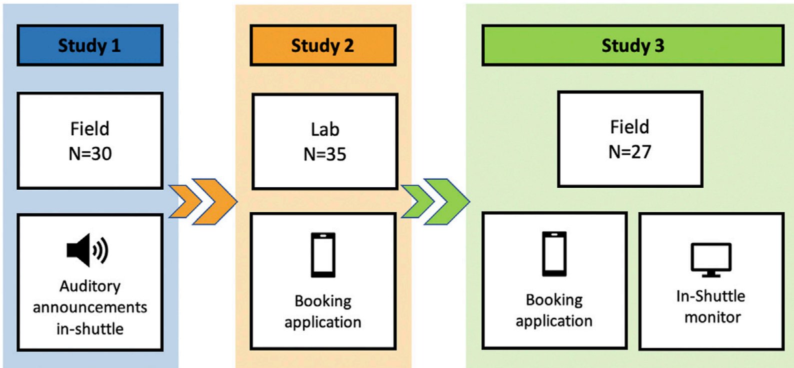

FIGURE 1 | Overview of studies, employed capacity management means, and the number of participants per study.

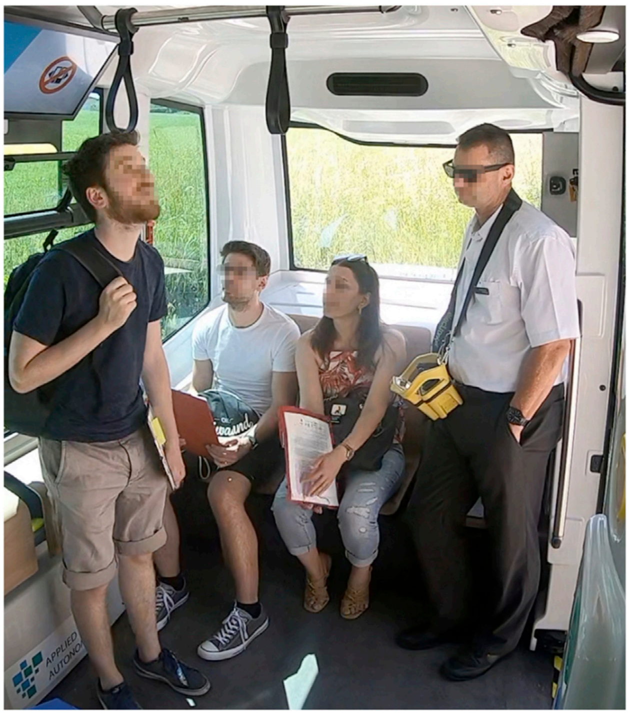

FIGURE 2 | Study 1: Shuttle over capacity—one group of passengers tried to see whether the shuttle would depart when one was standing.

interfaces usually display standard itinerary information, and being mostly secondary carriers of information related to exceptional events.

4.1 Study Setup

The EZ10 features standard functionality for broadcasting auditory announcements before departure and before arriving at the next stop. For the purposes of this study, this functionality was disabled and replaced with a fully controllable Wizard-of-Oz-setup [Dahlbäck et al. (1993)], where any single item from a set of pre-generated auditory items could be broadcast at any time. This was done *via* a simple web interface on a tablet, which could activate the announcements by sending https-requests to an intercom in the shuttle, on which the audio files were stored. We chose this approach, since we added announcements specifically for capacity management purposes to the standard itinerary-related information and wanted to ensure consistency among all auditory announcements. In addition, the capabilities to automatically broadcast auditory information *via* the EZ10's built-in systems were limited to very few trigger events at that point. Therefore, we chose to pursue a Wizard-of-Oz-approach to ensure the necessary flexibility.

Apart from standard messages to welcome the passengers, announcing upcoming stops, and safety-related information, we added the following announcements for the capacity management:

- "There are too many on-board passengers in this bus."
- "please note that this bus can only seat a maximum of six passengers."
- "The bus can not resume driving as long as there are too many passenger on board."
- "Passengers without a seat are asked to leave the bus."
- "The next bus will arrive in 24 min"
- "please note that standing is not allowed on this bus."
- "We ask for your understanding."

These announcements would be broadcast in the order shown here every time the maximum capacity of six passengers was exceeded. The procedure could be repeated if the announcements had no effect the first time. In addition, individual announcements could be played as needed to simulate an intelligent vehicle (e.g., "please note that standing is not allowed on this bus," when a participant steadied him/herself by holding onto the pole in the shuttle. It was also announced that the next bus would arrive in 24 min. This was done specifically to add an opportunity cost to not being able to board the current bus, so that the participants had to weigh whether they would be willing to wait for the next one.

For the study, we recruited groups of participants with the aim of having each group *over* the shuttle's capacity. One seat was permanently occupied by the wizard, a second one by a fallback-operator, whose presence was a safety requirement. The primary operator was standing and did not occupy a seat. This resulted in a maximum of 4 available seats. We recruited groups of 5-6 participants and had one researcher on standby disguised as regular passenger to occupy one additional seat, in case there were dropouts that would reduce the number of participants to 4 per group. This way, the group had always at least one individual more than the shuttle's capacity allowed.

The purpose of this setup was to investigate whether these auditory announcements could be used to handle the capacity management for this specific case by having each group take a ride between two bus stops in a real deployment.

4.1.1 Procedure

The bus was deployed in the small rural town *Koppl bei Salzburg*, where it circulated between two stops—one at the edge of town and one at the center.

Each trial began at the stop in the town center, where the participants were briefed and asked to fill in the first questionnaire. During the briefing, the participants received standard data processing and safety-related information along with the instructions to simply take a ride between the stations. In addition, the participants were told that the wizard was logging technical data for the shuttle manufacturer and that the operators were not allowed to talk or be talked to during operation for reasons of security and liability. Both of these were not true but were done in order to simulate a driverless context as closely as possible. The truth was explained to the participants after the ride and the collection of the data.

After the briefing, the participants waited for the shuttle to arrive and boarded, once it arrived. Once the shuttle was over capacity, the wizard activated the auditory announcements until only the maximum allowed number of participants (or fewer) remained in the shuttle, after which the shuttle departed (**Figure 2**). After driving to the second stop and back, the previously remaining participant(s) boarded and the shuttle drove another round.

Once the remaining participants got off the shuttle, the interaction concluded and the participants filled-in a second questionnaire. We then conducted a group interview with all participants, after which they received their compensation and the trial ended.

4.1.2 Questionnaires

The participants received two questionnaires each—one before and one after the ride. Before the ride, the participants were asked to provide basic demographics (age, gender, experience with public transport) and indicate whether or not they suffered from impairments (auditory or visual) that could affect the interaction. After the ride, participants were asked to rate their driving experience on a four-point scale with respect to satisfaction and safety after the ride.

The participants had to indicate their view on seven criteria (reliability, safety, comfort, modernity, sustainability, cost-efficiency, and necessity) related to the autonomous shuttle bus both before and after the ride to find out whether or not the ride had an influence on their evaluation of and attitude towards the shuttle. The answers were given on a four-point scale ranging from "strongly agree" to "strongly disagree". They could also choose the "I don't know" answer. Finally, the participants could indicate, for which occasion they would use automated shuttle busses (multiple answers were allowed).

The questionnaires were part of a larger investigation and intended to provide a general assessment of the passengers' experience. They are only indirectly related to the capacity management aspect. We have included them in the analysis for the demographic variables and under the hypothesis, that adequate or inadequate capacity management can positively or negatively reflect on the overall interaction experience and attitude towards automated shuttles as a result.

4.1.3 Group Interviews

The interviews were conducted in the same groups as they had been assigned to the capacity management interactions and were semi-structured. There were two overall questions, to which all participants were asked to answer in as much detail as they wanted to. These questions were:

1. How did you experience the situation when there were not enough available seats?
2. What did you do to resolve the situation?

Depending on what the participants said or did not say during their answers, the following additional questions had been defined:

1. Was there any information available to you in the shuttle itself, which helped you in resolving the situation?

2. Which information [to resolve the situation] would you see as necessary in the future?
3. How or based on which factors do you think available seats should be assigned?
4. Why did you leave the shuttle?
5. How did you feel in that situation?

The goals of each interview were to assess:

- a possible impact of low capacities on acceptance or intention to use of automated shuttles,
- which strategies were used ton allot available seats among the participants within each group,
- whether the participants felt adequately supported in resolving the issue with the information available to them and, if not, which additional information they would have required.

Each interview lasted approximately 20–30 min and was moderated by one researcher, while the second researcher took notes. The interview began by the moderator asking the first of the two overall questions and invited everyone to share their views and discuss among each other. The additional questions were asked on-demand, depending on whether the participants had addressed them in their original answers or not. This procedure was repeated for the second overall question, after which the interview ended.

4.2 Sample Description

We recruited a total of 30 participants (8f, 22 m) for this study. Their age ranged between 10 and 70 years, with 80% being younger than 44 years (M = 30,1 year, SD = 15,9 years). About 45% ($N = 13$ of 29) of them reported to have a visual impairment: Ten of the participants indicated to be short-sighted, one person reported to be short-sighted and having astigmatism, and two were far-sighted. 16 participants (55,2%) stated to have no visual or hearing impairments, one person chose not to answer. No hearing impairments were reported. Only three (10%) of the 30 participants had previous experience with autonomous vehicles, while the vast majority (90%) approached the study without prior exposure to AV.

The participants reported to be rather frequent users of public transport. 18 out of 28 (64,3%) indicated to use public transport on a daily basis, while only two reported to have never travelled *via* public transit. More than a third ($N = 22$, 36,7%) indicated to use route planning applications like Google Maps on their smartphone on a daily basis, while again only two (9.1%) participants reported to never have used such applications. 19 of 22 (86,3%) participants stated to always ($N = 14$) or at least most of the time ($N = 5$) make use of their smartphone to look up travel information, such as departure times or connections, while only two (9.1%) indicated to never do that. Nearly three quarters of the participants (72,7%, $N = 22$) also indicated to at least sometimes purchase tickets for public transport on their smartphone. Overall, the sample could be characterized as technology-savvy with respect to smartphones and apps, and with public transportation as a commonly used means of travel.

4.3 Quantitative Results

26 of the 29 participants stated they enjoyed ($N = 15$) or even very much enjoyed ($N = 11$) the ride with the autonomous shuttle bus. Only three participants (10,3%) indicated to have not enjoyed the ride much, and no one reported to have not enjoyed it at all. Participants also felt quite safe during the ride with 25 of 29 participants (86%) reporting the either having felt safe ($N = 14$) or very safe ($N = 11$) during the ride. Only four participants indicated to have felt a little anxious, while no one felt very unsafe while sitting in the bus.

The graphs in **Figure 3** show the changes in participants' assessment before and after the ride. In general, the comparisons of pre- and post-ride data show that the "don't know" assessments of participants have decreased noticeably for most criteria after the ride, indicating that the participants were able to make up their mind and form an opinion on the automated shuttle bus after having actually experienced a ride in it. Only for sustainability and cost-efficiency this was not the case, as these criteria not so much depend on one riding experience but rather on information on actual specifications and maybe over-time experiences during which operating distance, a change in air quality due to an exchange of fuel-powered with electricity-powered vehicles, and the like could be experienced.

What is also noteworthy, is that the reliability of the vehicle was rated lower after participants had experienced a ride, with only 5 people not agreeing to the statement that automated shuttle busses are reliable before but 12 after the ride. Although not quite as pronounced, the outcome was similar in terms of the general necessity of automated shuttle busses. While 6 participants rather not agreed to the statement that automated shuttle busses are necessary before the ride, 8 rather not agreed to it after the ride, and while 13 rather agreed to it before the ride, 11 rather agreed to it after the ride. To sum it up, the shuttle was rated highest with respect to being modern (which 21 people fully agreed to after the ride), and sustainable (which 19 people fully agreed to after the ride), and lowest with respect to being reliable (which 12 people rather not agreed to after the ride) and necessary (which 8 people rather not agreed to after the ride).

Regarding the application fields of automated shuttles, commuting ($N = 18$), daily errands ($N = 15$), and leisure trips ($N = 15$) were ranked highest, while a lower number of 7 individuals thought that automated shuttle busses could serve as delivery service vehicles (**Figure 4**).

4.4 Qualitative Results

During the group interviews, the participants mentioned a number of requirements in relation to capacity management:

Pre-trip information (at bus station): The information about how many free seats are available at the moment in the approaching shuttle should be provided at the bus stop (*via* a display or similar). Also, alternatives (other means or connections) should be provided in case of insufficient capacity. The in-shuttle audio messages did not fully fulfill the participants requirements in this regard.

Redundancy of information of limited capacity should also be given on displays (at bus stops and in the shuttle), not only because of potential comprehension problems due to

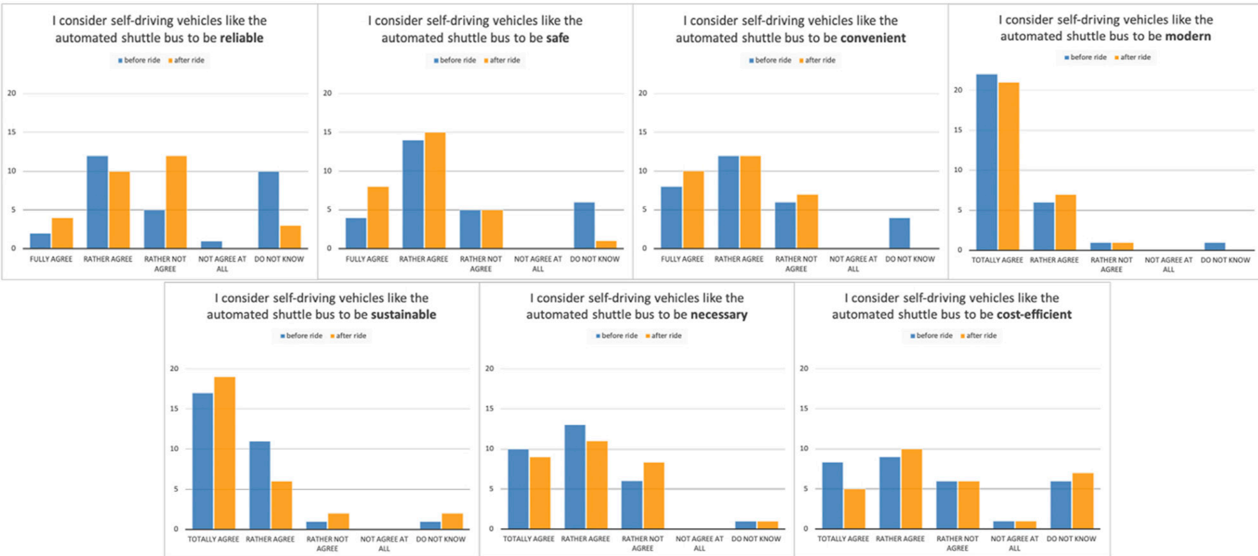

FIGURE 3 | Study 1: Participants' assessments before and after using the shuttle.

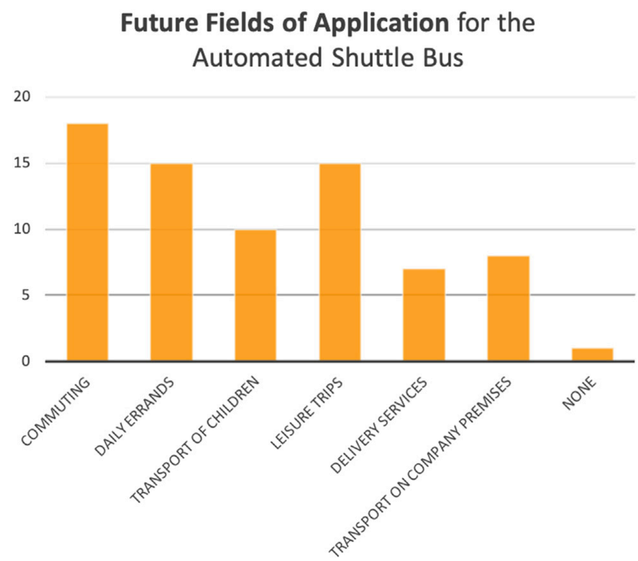

FIGURE 4 | Study 1: Responses regarding future fields of application for the automated shuttle bus.

surrounding noises (talking of other passengers, air conditioner of shuttle) but also to include individuals with hearing impairments.

Precise and consistent information: Information about what needs to be done was stated to be not sufficient. Clear instructions on exactly *which* individuals should act and how they should act was often expressed. As one participant mentioned: "The information that only 6 people are allowed to travel is not clear enough. There need to be instructions like:"Two people must leave"."

Repetition of audio messages was not considered as helpful, as—despite the previous requirement—there were generally few to no problems related to the audibility or comprehensibility of the announcements. Capacity-related information should also be additionally provided *via* the shuttle's screens. Some participants also mentioned to display communication or display guidelines for capacity management, if they exist, e.g., in form of a priority list (priority for older or impaired individuals).

Training for using automated vehicle: While the participants stated auditory information to be suitable for providing trip-

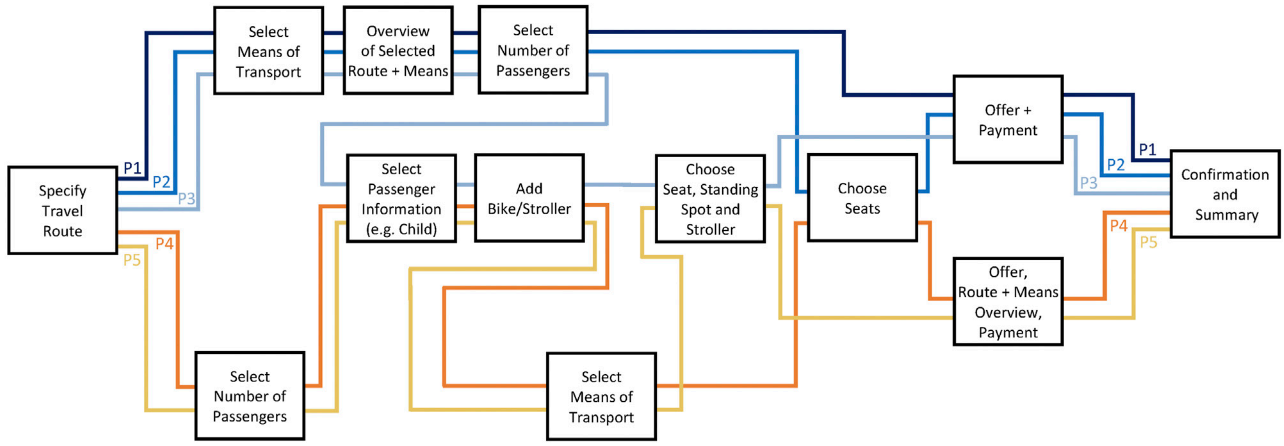

FIGURE 5 | Study 2: Overview of UI similarities and differences between prototypes P1-P5.

related information (both in normal and exceptional situations), some participants stated that they would find the presence of a person, who is well informed how to use an AV and its communication tools as helpful; either official company staff or co-travelers who are already familiar with AV.

During the observation and interview, we also identified *five general strategies for organising the seat distribution* by the participants; these were:

- *Needs-based justice strategy*: Small groups who had to travel together—in our case parents with their children—were given priority.
- *First-come-first-serve strategy*: Those who were closest to the shuttle door entered first and took the available free seats.
- *Politeness strategy*: One of the participants offered his/her to a standing person and got off the bus (without additional motivation by e.g., the needs-based justice principle). In cases of overcapacity of >1, another person would quickly follow this example until only six passengers were left in the shuttle.
- *Cooperation strategy*: The passengers in the shuttle tried to solve the situation together, without being able to pinpoint the behavior clearly to one of the other principles: "We were eight passengers inside, so two of us got off. The bus did not immediately react, so we tried to see if it would work if just one of us got in, which it did not. We were confused at first but then decided to stay outside."
- *Diffusion of responsibility strategy*: Some passengers just stayed in their seat and remained inactive to see if someone else would react to the situation, "I was not sure what to do about the bus not leaving the station. I had a seat, so I did not feel like it was on me to take action, so, I waited if someone else would come up with some clever idea." We found a similar effect in a concurrently conducted study with a focus on emergency management, where some participants had behaved in a very similar fashion Mirnig et al. (2020a).

Overall: With regard to the study setting itself, some participants were initially confused by the setup and thought the researchers had made a mistake during recruitment, which resulted in the overbooking.

In combination with the unfamiliarity with the situation and the need to take action to resolve it, this, might have led to the reported decrease in experienced reliability after the ride, as the participants felt kind of left alone with the task and felt that the detail of information they were provided with was not sufficient with respect to finding a satisfying solution to the situation of having too many people on board. Consequently, they experienced the shuttle bus to be not reliable in coping with overbooking but that they had to rely on their own strategies to continue the ride.

Interestingly, although, the situation was demanding for the participants, the role of the wizard was not questioned by a single one of them and the observation and interviews showed that the participants kept to not communicating with wizard or operators as instructed.

In summary, these results confirmed capacity management challenges in automated shuttles and substantiated that on-shuttle management *via* audio announcements after boarding alone were helpful but not sufficient. Thus, for the next step we wanted to focus on the ticket booking process, i.e., before boarding and in how far existing booking applications can be used for effective capacity management in automated shuttles and which modifications or adaptations would be necessary.

5 STUDY 2: BOOKING APPLICATION

The contents of this section summarize work that has been previously published Mirnig et al. (2020b). We outline the study purpose and setup, as well as summarize the results and discussion only in as far as they are relevant to the research goals that are the subject of this journal publication.

For additional details, please refer to the additional publication.

Based on the results from the first study, the efforts that eventually resulted in the second study focused exclusively on the ticket booking process. The primary interest lay in investigating, in how far a standard ticket booking application with or without reservation capabilities can address capacity management in an automated shuttle context. If this is the case, then there is little to no need to innovate and potentially overdesign as a result. If this would turn out to not be the case, however, we wanted to identify the deficiencies of existing standard booking means and how these could be addressed.

We decided to investigate the following three research questions:

1. How important is the ability to choose a particular seat for passengers using an automated shuttle?
2. How important is the capacity (current and maximum number of seats) for passengers in an automated shuttle?
3. Would groups of passengers be willing to split the group over several shuttles and which factors influence that decision?

The prototypes were designed to be used on an iPhone 6. For the purposes of the study, we also implemented a start screen, from which the researcher could choose the prototype and sub-condition (A-C) based on a randomization protocol to avoid order effects.

5.1 Study Setup

The study was setup in a controlled lab environment following a within-subject design approach (i.e. each subject had to interact with each of the five conditions.

5.1.1 Questionnaires

For the data recording before, during, and after the interactions, we used a *pre-questionnaire*, a *post-questionnaire*, and a semi-structured *interview*. The pre-questionnaire contained demographic questions (age, gender), questions about prior experience with technologies commonly used to book public transport (smartphones, computer, tablet) and questions regarding participants' preferences when using (accessing itinerary information and booking) public transport. The post-questionnaire was a translated version of the System Usability Scale (SUS) Brooke (1996). The SUS was used to provide a quantitative comparison between the prototypes and scenarios, based on the hypothesis that inadequate booking options could have a possible impact on the system's usability. In addition, it could explain effects due to an inadequate implementation or otherwise badly designed UI.

5.1.2 Interviews

The interviews contained several questions regarding booking and travel preferences as well as interaction experience during the interactions with the prototypes. For the purposes of this paper, we will focus on the following questions from the interview:

1. Which of the booking variants you interacted with today (fixed seating vs. free choice) do you prefer?
2. Is the driving direction a relevant criterion for you? If so, why?
3. What do you think of the possibility to book a group journey with several shuttles? Could you imagine doing this and if so, under which conditions?
4. What do you think in general about small to medium sized shuttles? Would you use them and what influences your decision to use or not use them?
5. How do you feel about last-mile transportation and do you find automated shuttles to be suitable as last-mile solutions?

Questions 1-3 directly address RQs 1-3, whereas Questions 4 and 5 were intended to gather additional insights regarding the participants' attitude towards shuttles and in particular for last-mile contexts.

5.2 Procedure

In order to be able to more directly compare preferences more directly with regards to booking options, we designed a booking app click dummy in five different variants for use in a laboratory study. In line with the research goals, the booking app variants primarily differed in regard to the freedom of choice when booking seats. These variants were as follows:

P1: seats preassigned.
P2, P4: free seating.
P3, P5: choice of seat, standing spot, stroller.

Variants P4 and P5 came about since a secondary aim of the study was to investigate the viability of a "standard" vs. a chat-like booking interface; thus, P4 is effectively P2 with chat, the same is true for P5 and P3, respectively. P1 served as the control interface and received only one variant as a result. Since chat-interaction is not within the focus of this paper and booking capabilities were otherwise unchanged, these prototypes were grouped for the subsequent analysis unless there were effects or results found to be specifically caused by the chat-functionality. The three different conditions realized within each prototype were the following:

Condition A: All shuttles have sufficient seats/spots available.
Condition B: No seats available in the first shuttle; sufficient availability in shuttles two and three.
Condition C: Insufficient (but >0) seats available in shuttles one and two; sufficient availability in shuttle three.

Figure 5 highlights the differences between each of the five prototypes by showing the seat selection (P2-P5) or confirmation (P1) screens. **Figure 6** shows the interaction flow for each prototype. The main differences lay in the seat selection interfaces and resulting extra steps. P3 and P5 required to entry of passenger information. P1-P3 started at the selection of means of transport, as that was also the starting point in the commercial app "Wegfinder"iMobility GmbH (2018), which the prototype was based on and which featured a similarly chat-like interface. For P4-P5, this was switched to selecting the number of passengers first, followed by route and means selection, which is more commonly

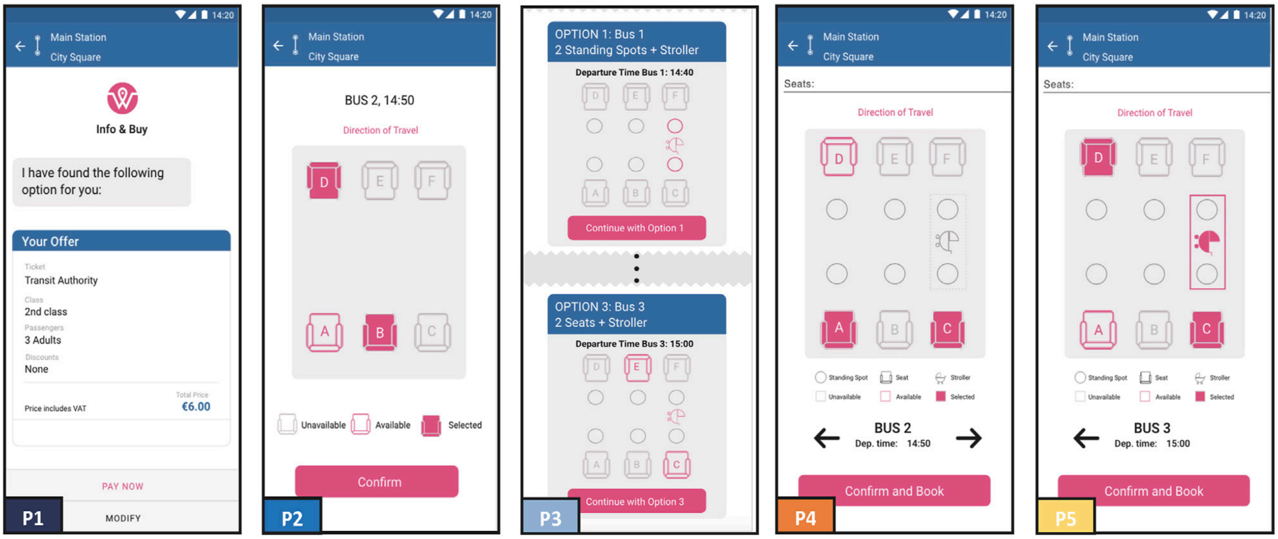

FIGURE 6 | Study 2: The interaction flow for all five booking prototypes.

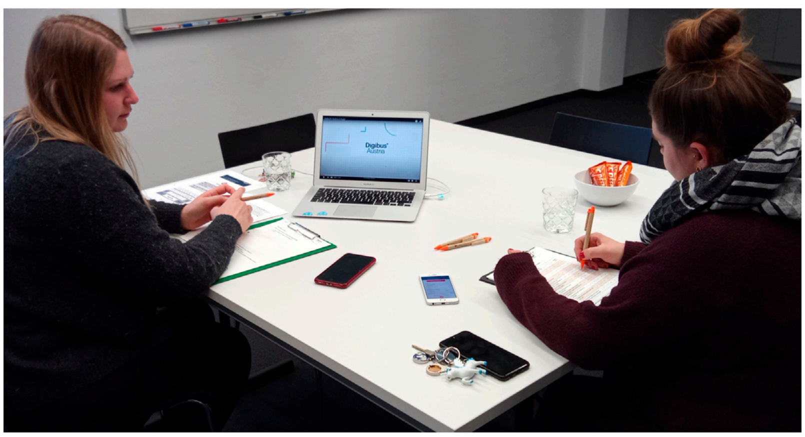

FIGURE 7 | Study 2: Participant interacting with booking app on the right, observer on the left.

standard in booking applications. P2 and P4 allowed free choice of seating among the three remaining seats (three were set to be occupied). For P3 and P5, seats and/or standing spots in combination with stroller spots were pre-assigned but could be re-assigned by the user *via* a simple tap-and-choose interface modeled after existing applications Mindinventory (2020); Theatres (2020); Santos (2020); Delta Air Lines (2020). These choices were made in order to keep the interaction complexity low. The possibility to choose seats had not been part of the Wegfinder application at that time and was designed additionally for all prototypes. A simulated payment screen, loading animation and booking confirmation screen marked the end of the booking process for each path.

The study was conducted in a single setting with one participant and one researcher, who served as both the study conductor and observer. The participants were asked to interact with the different variants of the booking app (P1-P5) across the three different conditions (A-C). The click dummy was loaded onto a smartphone [Apple iPhone 6 (4.7in)], which the participants interacted with during the study (**Figure 7**). Participants were recruited externally *via* several channels (mailing lists, social media posts, bulletin boards) and received a compensation of EUR 20,- for participating in the study.

After being introduced to the goals of the study and agenda, each participant was shown a video of the automated shuttle in real traffic for familiarization with the context. The participant then signed the informed consent form and filled in the *pre-*

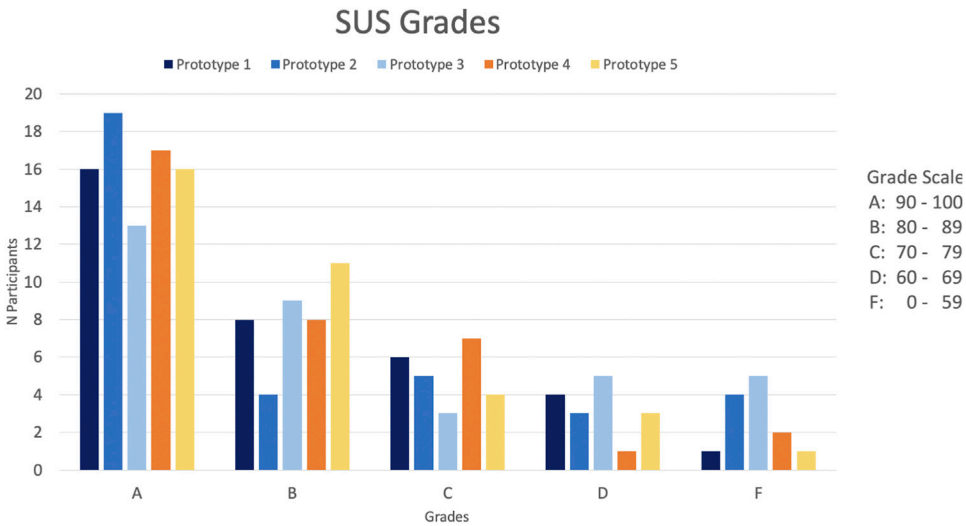

FIGURE 8 | Study 2: The SUS scores on the grade scale for each of the five prototypes.

questionnaire were filled in by the participant. Then the participant was handed a scenario descriptions to read through, while the conductor loaded the appropriate prototype and condition before handing the smartphone to the participants. The interaction was screen- and audio-recorded. Each participant had to interact with each prototype across all three conditions each, which resulted in a total 15 ticket booking processes per participant. The order of prototypes and conditions within each prototype were permutated in order to avoid bias. After each interaction, the participant filled in the SUS-questionnaire for that prototype. After all interactions had been concluded, After all interactions with the prototypes were done, the *interview* followed, which concluded the session. Each session took between 45 and 60 min.

5.3 Sample Description

The 35 participants (20f, 15 m) were between 19 and 72 years old, with 80% being below the age of 39 (M = 30,8 years, SD = 14,8 years). None of them had disabilities or were otherwise part of vulnerable populations. All participants were experienced smartphone owners. About half of the participants 17) used public transit at least once per week; 77% 26) stated Google Maps as their most frequently used app for route planning. Half of all participants indicated to at least sometimes purchase tickets for public transport on their smartphone.

6 RESULTS

In the following, we summarize both the quantitative and the qualitative results from this study. For a more thorough explanation of the analysis and detailed results, please refer to the original publication [Mirnig et al. (2020b)]. In the following sections, we will only highlight the results in as far as they are relevant for this paper and the follow-up study.

6.1 Quantitative Results: SUS Scores and Grades

For the quantitative analysis, we calculated the average of each individual SUS-score per prototype (35 participants = 35 SUS-scores for each of P1-P5; **Figure 8**) to arrive at one overall SUS-score for each of the five prototypes. All prototypes received an overall score in the upper range of the spectrum (⩾ 79), with a B for all prototypes except for P3, which received a close C (off by 1 point) on the grade scale by Bangor et al. Bangor et al. (2009). We also ran a Friedman test followed by pairwise comparisons in order to identify significant differences for individual SUS-items between the prototypes.

While all five prototypes performed close to each other on the B-C spectrum, we found P3 to have the most weaknesses in terms of usability. For comparisons between P3 and the other prototypes, we excluded all items with significant differences between P3 to P5, since these two prototypes had the same capacity management capabilities, and thus the usability differences were likely induced by the design of P3. Items that did not have to be excluded were 3 (*ease-of-use*), 4 (*support needed*), 7 (*learnability*), 9 (*confidence*), and 10 (*effort*). For these, we were only able to find a significant difference between P1 and P3 for *confidence* (item 9). There were also significant differences between P1 and P5 for *use frequency* (item 1) and *integration* (item 5).

We interpreted these results as the streamlined interaction flow in P1, which has the lowest amount of options, to have a slight positive influence on usability, as well as a positive influence of the additional capacity management capabilities in P5 (seat, standing spot, stroller). Apart from a negative influence of the implementation regarding seating options caused by the chat-interface in P3, no other effects caused by the design were identified.

6.2 Qualitative Results

As with the quantitative results, we will highlight and summarize some of the qualitative results in relevance to the research scope of this paper. For more detailed results, please refer to the original publication.

The importance of choice of seat and driving direction: The results regarding choice of seat were interestingly mixed. While half 18) out of all 35 participants indicated to prefer free over fixed seating, 11 stated a preference for the inverse, with 6 participants stating no preference in either direction. Only 5 participants stated choice of seat with regard to driving direction to be a relevant factor. However, almost half 14) mentioned to either imagine or know others for whom this would be relevant, mentioning older or impaired relatives and acquaintances. Both length of trip and size of shuttle were stated to influence the necessity for capacity management: the longer the trip, the higher the preference for choosing a spot in the driving direction; the smaller the bus, the higher the need for reserving a spot in advance.

Splitting, high vs. low capacities, and preferences of use: Splitting groups was received rather favourably, with approximately 60% finding it to be acceptable if there was no other alternative. Participants mentioned that the urgency of the trip would influence the likelihood of them splitting up instead of waiting for the next shuttle or using a different means of transport altogether. The same was said for times between arrivals/departures: the less time it takes for another shuttle to arrive, the more willing participants were to split up.

Many participants found last-mile low capacity shuttles to be particularly useful for older adults or smaller children and saw distant rural areas as a sensible use case for such shuttles. At the same time, participants expressed a desire for high frequencies (a maximum of 10 min between shuttles was mentioned frequently) in order to regularly use such medium to lower capacity shuttles. According to participants' statements, lower capacities can be compensated *via* higher frequencies, although low capacity shuttles were also considered generally less suitable in some situations ("rush hours" e.g., after school). In general, participants' expectations appeared to be influenced by what they were used from urban traffic (high frequencies, flexibility), which was reflected in their capacity management requirements regarding booking and shuttle use.

7 STUDY 3: DEPLOYMENT IN REAL TRAFFIC

In the first study, we found that capacity management is a challenge that is not to be underestimated and that employing capacity management strategies once the passengers have boarded *via* conventionally available means (audio in our case) works but is not ideal. Capacity management should begin—and ideally be mostly done—before the passengers have boarded. Thus, we looked at the most logical and straightforward way to do so: a ticket booking application. In study 2, we compared several levels of interaction and booking freedom as well as two interaction styles for such an app, resulting in a good idea of what a satisfactory booking application would look like. What remained was a deployment of said application and integrate it within the shuttle, in order to assess whether or in how far such a solution consisting of a booking application and in-shuttle auxiliary information can address capacity management needs in an automated shuttle. This is the focus of this final study.

FIGURE 9 | Study 3: After boarding and before departure. Not visible: capacity management information screen behind operator on the right.

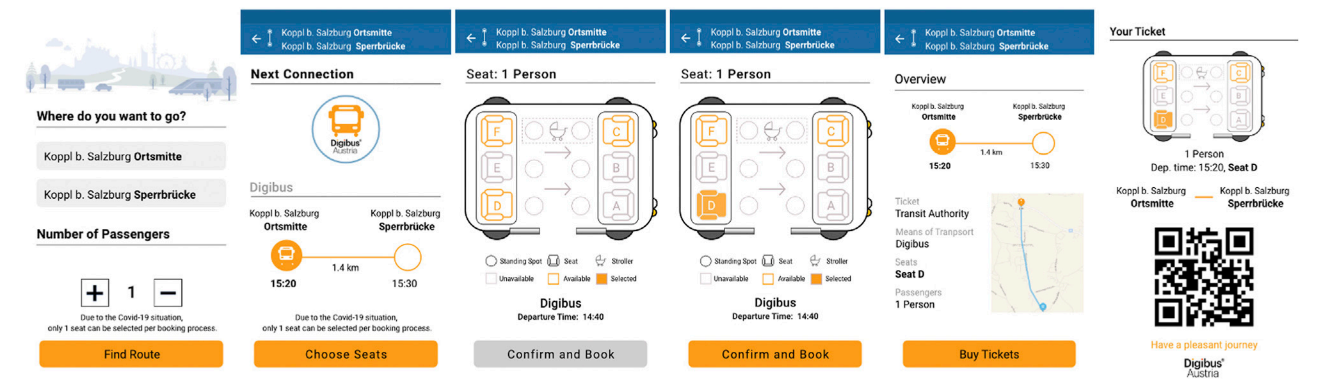

FIGURE 10 | Study 3: Interaction overview of the iterated app.

7.1 Study Setup

This study was integrated into the project's final public demonstration phase (**Figure 9**). During this phase, the shuttle was circulating between the two bus stops (city center and edge of city) on a regular itinerary and could be freely used by the public. For the duration of this particular study, public use was suspended and the shuttle was exclusively used by the participants recruited for this study. This was done in order to be able to control the bus' capacity, since only the recruited participants would interact with the booking application.

In addition, the Covid-19-pandemic had already arrived in Austria by this point, so the possible number of participants in the vehicle at the same time had to be limited and strictly controlled. This was another reason why the study was not integrated with the public demonstrator traffic and why we also opted to not have capacity conflicts (booking over capacity) like we had done for study 1.

The technical setup consisted of a smartphone with an iterated version of the booking app (a visually overhauled version of P5) and an in-shuttle information monitor. Similar to how it worked in Study 2, the app allowed to choose and book a seat in the shuttle in the specified direction and ended at a confirmation and e-ticket screen. Due to the setup and Covid-19, the app only allowed choosing the two destinations the shuttle was actually servicing, the number of individuals to book a ticket for was limited to 1, and seats were limited to 3 (4 in case all participants came from the same household—in conformity with the regulations at the time). An overview of the interaction in this iterated version of the app can be seen in **Figure 10**. The monitor inside the shuttle showed time, date, and connections to other public transport in the top part (**Figure 11**). The middle part contained infos and a link (*via* QR-code) for those who wanted to book a ticket for their connecting journey online. The lower part was the most relevant one for this study, as it contained information regarding the Covid-19-related seating restrictions and requirements, as well as a top-down view with seat labels, which was intended to help passengers find the seat they had booked once inside the shuttle.

7.2 Study Setup

The used methods consisted again in two questionnaires—a pre-ride and a post-ride questionnaire, and a group interview at the end. The two questionnaires contained questions on the participants' stance regarding seven criteria (reliability, safety, comfort, modernity, sustainability, costs, necessity) on a 4-point Likert scale for comparison before and after interacting with the shuttle and the associated capacity management capabilities. The pre-ride questionnaire contained additional demographics information as well as questions regarding participants' prior experience with automated vehicles (and shuttles in particular).

The group interviews were conducted in a semi-structured manner and contained the following guiding questions:

1. Would you be worried on getting a seat in a fully automated shuttle?
2. Do you find a seat reservation option to be important or mandatory (why/why not)?
3. How was your booking experience (what went well, what not so well)?
4. Was being able to book a seat in relation to the direction of travel an important criterion for you?
5. Do you think you would be able to book an automated shuttle in real life with an app like the one you used today?
6. What would you want to see improved in the booking application?
7. How did you feel about the information provided to you *via* the app as well as in- and outside the shuttle (what was helpful, what was superfluous, what was missing)?
8. How helpful were the Covid-19-related infos for you (what was helpful, what was superfluous, what was missing)?

For questions 4 and 5, we prepared labeled printouts of every single step in the interaction with the app, so that participants could refer to them more easily in the discussion. Question 8 was tangentially related to the study goals, since the seating information in the shuttle was influenced by Covid-19 and its resulting restrictions. The primary purpose of question 8, however, was to inform future study setups within the pandemic to ensure the safety of participants.

FIGURE 11 | Study 3: The in-shuttle information screen.

7.3 Procedure

The shuttle was again deployed in the Austrian town *Koppl bei Salzburg* with the same two stops as during the first study. The study was conducted on-site and the participants had to get there on their own. Participants were recruited in groups of 3-4 in accordance with the Covid-19-related restrictions.

After arriving, the participants were briefed, signed the informed consent form and filled in the pre-ride questionnaire. After that, they were led to the bus station, where the shuttle would eventually arrive. While waiting, the participants were handed a smartphone with the booking app and were asked to book a ticket for the next shuttle. The participants received the smartphone one after another and the app was set up such so that seats booked by one participant would no longer show as available for the other participants. The decision to have the booking happen individually and in sequence was made largely in order to avoid direct contact between the participants (social distancing). Since the app "remembered"

FIGURE 12 | Study 3: The physical ticket that was handed out to the participants after completing the booking process in the app.

already made bookings, we assumed that this would still result in a sufficiently realistic booking experience in the end. The smartphone was disinfected before and after each use.

Once a participant had booked a seat, the participant in question was handed a physical ticket from the accompanying researcher. This ticket was made to resemble a regular ticket and contained the connection information as well as the seat the participant had booked (see **Figure 12**). While the booking app would have logically resulted in an e-ticket, we opted for physical substitutes, as they have largely the same function and we did not need to supply the participants with multiple smartphones this way.

Once everyone had booked their ticket, the participants waited for the shuttle to arrived and boarded, once it had. The participants then rode on the shuttle until they arrived back where they had started. On their way back from the first stop, they were asked to start filling in the post-ride questionnaire. Once the participants had arrived back and had completed the questionnaire. After that, the group moved to a separate area and the group interview began, moderated by the researcher. After the interview, the participants were thanked, received their compensation, and the session ended.

7.4 Sample Description

The 27 participants (13f, 11m, missing = 3), we recruited for the study, were between 14 and 84 years old, with 50% being younger than 30, and 80% being younger than 52 years (M = 38,2 years, SD = 18,3 years). One third of them (N = 9) reported to suffer from a visual or hearing impairment. Of these, three people indicated to be short-sighted, one person reported to be short-sighted and suffer from one-sided hearing loss, three persons were long-sighted, one person stated to have presbyopia, and one did not specify their impairment. Two thirds (N = 18) stated to have no visual or hearing impairment. Four (18%, N = 22, missing = 5) of the participants indicated to have previous experience with autonomous vehicles, while 18 persons (82%) never experienced an autonomous ride before, so the majority was not biased towards self-driving vehicles before the ride.

Public transportation was by far not the main means of transportation in this sample. Only two people (N = 26, 7.7%) indicated to use public transport on a daily basis, while eleven participants (42,3%), the largest subgroup, indicated to go by public transport less often than once a month. With the Covid-19 crisis overshadowing everyday life massively at the time the study was conducted, it can be assumed, though, that the frequency of public transportation use might have been reported differently by the participants before the outbreak, as many people started to avoid public transportation due to the crisis or at some times were even forbidden by governmental restrictions to use public transport at all but for commuting to work.

In comparison to the samples of study 1 and 2, these participants were also not that used to using their mobile phones for purchasing tickets or public transportation as a means to travel from A to B. In line with them not travelling publicly very often, a third of the participants (N = 9) indicated to never have purchased tickets for public transport on their smartphone, while about 41% (N = 11) at least sometimes use their mobile phones for that purpose. In this context, participants were also asked if they were familiar with or had ever used the "Wegfinder" application. Of 24 participants, who answered this questions (missing = 3), 21 were not familiar with the app, 2 had heard about but never used it, and 1 person had used it for planning a travel route but not for purchasing tickets.

7.5 Quantitative Results

As described in the study set-up section, participants were asked to rate their autonomous ride on a four-point scale with respect to joy and safety. 23 of 27 participants (missing = 4) stated they enjoyed (N = 9) or very much enjoyed (N = 14) the ride with the autonomous shuttle bus. No one rated the ride to be not enjoyable (at all). Participants also had felt to be safe while on the bus, with 23 of 24 participants (95,8%, missing = 3) reporting the either felt safe (N = 11) or very safe (N = 12) during the ride. Only 1 person felt not so safe. No one felt not safe at all. Furthermore, participants (N = 22, missing = 5) also rated their comfort level on the same scale, with twelve persons being very

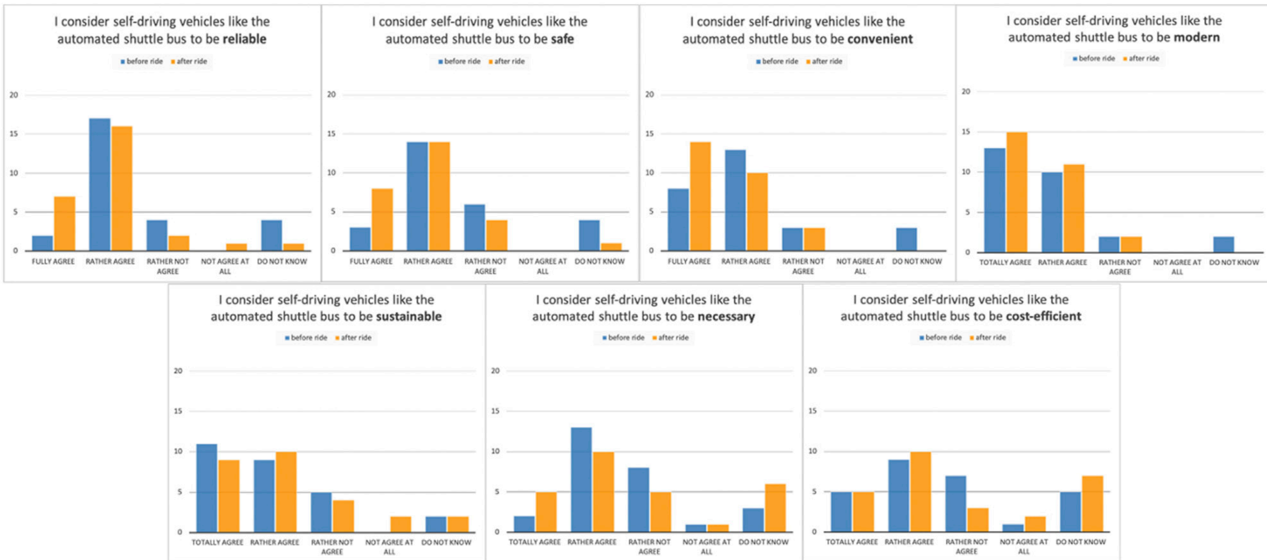

FIGURE 13 | Study 3: participants' assessments before and after using the shuttle.

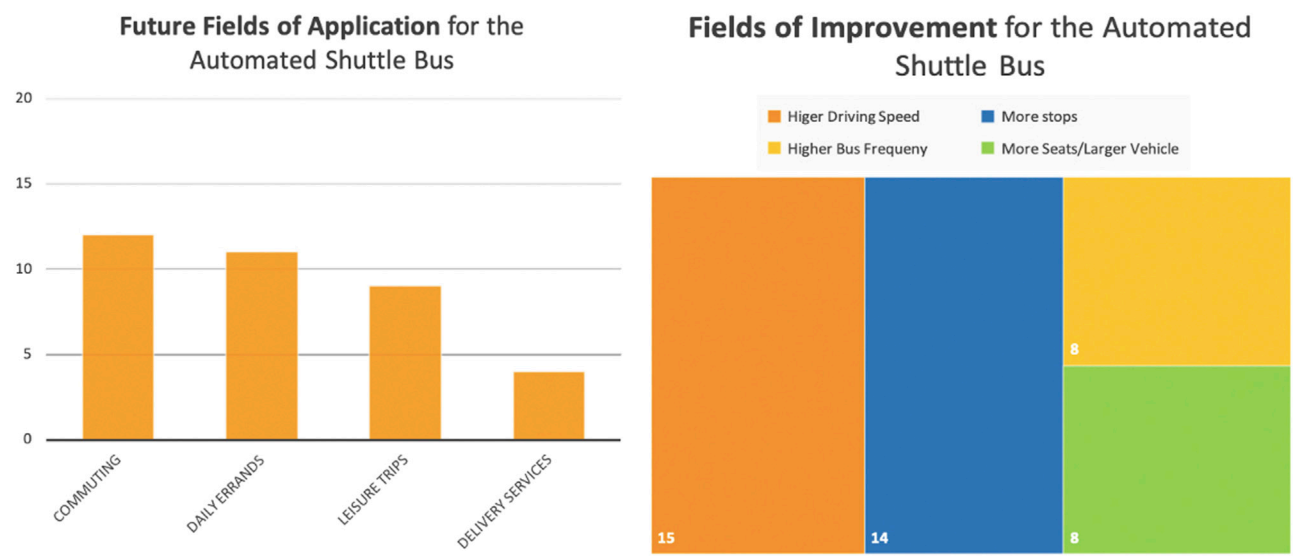

FIGURE 14 | Study 3: Responses regarding future fields of application for the automated shuttle bus.

comfortable, eight persons being comfortable, and two being not so much in comfort while in the shuttle bus. No one felt not comfortable at all.

Participants were also asked to rate how understandable they thought the Covid-19-related safety and seating instructions to be on a four-point scale, which ranged from "very understandable" to "not understandable at all". There was also a "Have not seen"-option provided. Out of 24 participants, 20 rated the instructions to be understandable ($N = 13$) or even very understandable ($N = 7$). Only two people could rather not understand the information, while another two people indicated to have not seen the instructions at all. Again, participants were asked about their opinion on seven criteria (reliability, safety, convenience, modernity, sustainability, cost-efficiency, and necessity) related to the autonomous shuttle bus before and after the ride. **Figure 13** illustrates how participants' opinion changed as a consequence of their ride with the shuttle bus.

As in study 1, the comparisons of pre-and post-ride data show that participants chose the "don't know" option noticeably less often after than before the ride, indicating that the participants formed an opinion on the automated shuttle bus during their ride. Again, for sustainability and cost-efficiency this was not the case, though, but as already argued in the according results section of study 1, one can hardly form an opinion on these criteria by experiencing a one-time trip. Interestingly, although, they felt safe and thought the shuttle to be reliable, more people were unsure whether or not there's a necessity for automated shuttle busses on the streets after ($N = 6$) than before ($N = 3$) the ride. This decreasing level of recognising a need for an automated shuttle bus, was also observed in study 1. In general, the shuttle was experienced to be quite reliable and safe, though. There was no noticeable decrease in these ratings after the ride, in contrast to the decrease in reliability, which the participants experienced in study 1. Participants' expectations seem to have been met with respect to these two criteria. More people fully agreed to the bus being reliable and safe after ($N = 7$, $N = 8$) than before ($N = 2$, $N = 3$) the ride. Again, Modernity and this time also convenience were rated highest, with 15 respectively 14 people fully agreeing to the respective statement after the ride.

When asked, what they would use the bus for, participants stated commuting ($N = 12$), daily errands ($N = 11$), leisure trips ($N = 9$), and delivery services ($N = 4$) as adequate application fields for the automated shuttle bus (**Figure 14**).

Finally, participants were asked, what they would improve about the automated shuttle bus so that they would use it regularly. They could choose between four pre-defined categories (higher driving speed, more stops, higher bus frequency, and more seats/larger vehicle). Multiple answers were possible. Of 22 participants, who gave an answer to this question, 15 (68,2%) opted for a higher driving speed, 14 (63,4%) for more bus stops, and eight (36,4%) each for a higher bus frequency and more seats (**Figure 14**).

7.6 Qualitative Results

The majority of participants indicated that they would use this app in everyday life and feel able to use it in order to book a seat on an autonomous bus shuttle.

Concerns about getting a seat: Regarding the question if they had concerns getting a seat in the bus, participants gave quite differentiated answers: Many of them noticed the limited number of six seats in the Bus and mentioned that there are situations in which they would have concerns getting a seat in such a bus. Four participants mentioned the difference between cities and rural areas. While in a rural area like Koppl six seats may be enough, they would have had concerns getting a seat if such a bus drove in a city. In the words of one participant:*"It has comparatively few seats. But for how often it drives here it is appropriate for the operation. Because in Koppl probably not so many people will ride. In larger cities, that would be problematic again."*. Other concerns were how to get a seat during rush hour, high number of passengers and when the courses frequency in the timetable is low. Still, participants often mentioned that they found a smaller shuttle more suitable for a suburban area such as Koppl bei Salzburg, with frequent reasoning being that of sustainability as well (as one participant expressed it: *"I really don't need to see these large buses with two or three people in it every day. It's not good for the environment either."*). However, there was also a general consensus that, since the shuttle was rather small, that it could become crowded very quickly. Thus, while participants expressed to find a small capacity shuttle generally more suitable for a low-volume suburban environment, they also expressed concerns about times or spots with higher traffic volumes, which would require increased frequency or higher maximum capacities.

Reservations—Obligatory vs. Mandatory: Nearly all participants agreed that the possibility to make reservations would decrease their concerns of getting a seat, particularly in a small bus and when certain routes are overcrowded. Two participants expressed their opinion that the operation of such a bus without the possibility to reserve a seat would be impossible. One of them stated *"But without a reservation it will not work out, because if there are seven people standing there, or if a school class is off and wants to get in there ...* " However, participants also expressed concerns and limitations of seat reservations: Most participants agreed that seat reservations should not be mandatory. They argued that it might be hard for elderly persons to reserve a seat for the bus, especially through a smartphone application. It was suggested that vending machines might be necessary to enable everyone to make reservations. In general, Internet access being necessary to be able to book a ticket was met with concern and participants expressed to still wanting to be able to book *via* more traditional means (vending machines, kiosks, phone call to a ticket office, etc.,.). Another argument against mandatory reservations was that it should still be possible to board a bus spontaneously. One participant stated: *"No reservation obligation for everyday life. With ÖBB (Austrian Federal Railways) it makes sense, but if I really only want to go to the city, that's borderline."*. While some participants expected that reservations can solve the question of who is allowed to enter the bus, one participant expressed concerns that through reservations conflicts may arise, for example between commuters and tourists as well as people that made and did not make reservations: "It could be problematic if someone always uses the app and makes a reservation in advance and arrives and there are a lot of people at the stop and he says, 'But I've already made a reservation, I can get on now,' I imagine that would be problematic because some people haven't made a reservation in advance. That could lead to conflicts." Two participants noted that in the case that reservations can be made, a screen at the bus stop should display the number of seats that are available and reserved.

Direction of travel: When asked whether the direction of travel was a relevant factor for their choice of seat, four participants stated that it was relevant for them and another four felt indifferent about it. However, three of the latter mentioned that they know persons for which it is a relevant criteria. Reasons for the relevance of direction were motion sickness, nausea and the wish to have a view out of the front window.

Interaction with the app: In general the booking app was considered as easy to use, self-explanatory, fast, clear and as having precise instructions. The participants felt confident in using the app and for most of them all relevant information was included in the app. One person put it like this: "Totally simple. Worked great. Four clicks and done.". Participants saw the app as consistent to the standards of other seat-booking applications, for example cinemas, and therefore had a fast understanding of the app and could easily detect the common theme that such apps deploy.

However, there were several minor suggestions for improvements, mainly regarding the design (for example regarding the spelling and the coloration). Participants suggested a pre-selection of the person and the seat as in other booking apps that could be changed if wanted to. The selection of the number of passengers led to minor confusions amongst the participants, the majority preferred a change of position of the plus and the minus button (minus to the left and plus to the right). Some of the participants were not fond of the colors used in the app interface, especially the grey and red color shades during the selection of the seats. It was suggested to use stronger and more signalling colors to indicate if a seat has been selected or a reservation has been made. Some participants reported that they first were unsure which seats were already selected or occupied. Different participants also stated that there was an overload of information on the seat-selection screen causing confusion. For example the circles indicating standing places, the arrows indicating the direction of travel, and the legend. Especially the direction of travel was not easy to detect for some participants. As one participant states: "What I notice now is that the arrows represent the direction of travel. This was not clear to me when I used the cell phone earlier. It would be better if the direction of travel is written next to it explicitly. The arrows are totally lost." Since travel of direction is an important booking criteria for some of the participants it is important that its display is simple and unambiguous. Some participants were irritated by the fact that it was not possible to choose other bus connections. They wanted to look at other connections and book seats for the next day.

Most of the participants perceived the local map on one of the screens as useful. It was described as a help to orientate in a surrounding one is not familiar with. However, many participants did not recognize the possibility to see an enlarged version of the map. They suggested to clearly label the map as an interactive and scalable tool and to use plus and minus signs or a link to Google Maps to show that possibility. Some participants suggested alternative wording of specific buttons or headings. For example the use of simpler words on buttons like "Next" or "Okay" instead of "Book Seat". Also, instead of using the phrase "Where to?" when choosing a connection, participants suggested using a simple "From" and "To".

Accessibility: Accessibility was a major theme in the interviews with participants. As mentioned earlier, many participants pointed out that elderly, too, must be able to do a booking for a bus and that the booking process must be adapted to their needs and capabilities. One example was that elder persons might not be as experienced in the use of smartphones as to book a seat in a bus or might not even possess a smartphone. One participant also noted that there should be a possibility to inform somebody if there is a passenger with physical, vision, hearing or any other impairment requiring special assistance or attention.

"What about accessibility? Is there a function in the app that you can indicate that you need help or that a ramp has to roll out that you can get in? You should be able to indicate that you need a ramp or other assistance. At the moment, people with walking disabilities who rely on wheelchairs can't ride." Another participant noted that the app should be adjusted to the needs of people with a vision impairment while another suggested that the app needs a stronger contrast of color.

Integration of the in-shuttle monitor: Most participants were satisfied with the information they received from the screen in the bus. None indicated having had trouble finding their seat or notice the Covid-19-regulations. It has to be noted that with only six seats (and a maximum of four due to Covid-19), finding the right one is not as challenging as if there are 30 or 50 seats instead. Further remarks and suggestions for improvement were made mainly in regard to the top part and the itinerary information, e.g.: "I liked the top display (on the bus), you always know where you are". A frequently made suggestion here was to add more information about connecting services, as well as arrival times and stops.

On-vs. offline, additional features: Many of the participants could see themselves using solely an online ticket *via* smartphone to board the bus. They also felt that the information on the ticket is completely sufficient to use the shuttle, although there were minor suggestions such as adding the arrival time, price, date, and validity. Yet again concerns emerged about people who don't own smartphones or might feel uneasy about digital tickets. Therefore, the option to purchase printed tickets should be given and thereby add further assurance. One participant wished for the possibility to save the ticket as a pdf file or receive it per mail in order to print it out. Another suggestion was to purchase the ticket *via* a computer for people who don't have a smartphone.

Several participants expressed the wish for additional features or information in the app. One participant wished for more information on the bus stop, the stopovers, and additional travel information. One participant asked for information about the occupancy rate, especially in times of Covid-19.

Overall: The results showed again that the participants are concerned about getting seats on busses where the number of seats is limited. They see seat reservations as a solution to the problem of capacity management that would also mitigate their concerns. However, there was also consensus that reservations should not be mandatory due to short-term and spontaneous travel plans. The participants agreed that a booking app is a practical way to make reservations and would use them in everyday life. The app used throughout this study was perceived as appropriate to serve this purpose and participants had only minor suggestions. Amongst the participants there was a high awareness of the needs of people with impairments and the ensuing requirements towards an automated shuttle. The integration of the display on the bus was seen as a good approach.

The additional pre-ride capacity management, such as the booking app and the information on the displays, also enhanced participants' assessment of the shuttle's reliability, and had a positive impact on the post-ride safety ratings.

8 DISCUSSION

After presenting all three studies and their results, we will now discuss these and the implications for designing capacity management systems in and for automated shuttles.

8.1 A Need for More

Ticketing is mostly an automated process nowadays, which largely occurs before the vehicle of choice—be it manually operated or automated—is being boarded. Ticket machines at stations and booking apps address this very well. The presence of a driver in a manually operated vehicle (or a conductor in an automated one) presents an additional element to either compensate for issues with the booking process prior boarding or it simply provides a convenient way of booking a ticket on board - an option which is common in public transit, especially useful for those without smartphones. If there is no driver or conductor physically present, there is also no (human) point of contact for potential questions, requests or answers in problematic situations. Without human factor on the premises these functionalities and services cannot be catered for but, instead, need to be substituted in a different manner.

Another factor that renders capacity management challenging are the different *behavioral patterns* exhibited by passengers when resolving capacity conflicts. It appears that many negotiation and behavioral strategies favor those in need; however, diffusion of responsibility in particular can bring the boarding process and even the shuttle operation to a halt if no external intervention is available. Thus, while it is true that even in manually operated vehicles negotiations between passengers occur and can help to resolve capacity conflicts, obviously, it cannot serve as the sole compensation mechanism for this kind of conflicts.

8.2 Before and after, Inside and Outside

In order to address these challenges, effective capacity management must encompass pre- and post-boarding processes. Using standard booking applications for public transport for automated shuttles can work well, although users need to be able to choose a seat and have the necessary information to make that choice (driving direction, proximity to parking place for stroller, wheelchair, etc.,.). In addition, users need to know in advance the maximum capacity as well as the capacity at the time of booking. This is more relevant, the closer the number of passengers is to the shuttle's maximum capacity. Thus, it is generally relevant for shuttles with very small capacities but also for those with larger capacities that are operated in areas with high passenger volumes.

The information about the shuttle's current and maximum capacity should be visible not only in every booking application, but also at station monitors, online itineraries, and perhaps even on the shuttle itself. This renders the shuttle more suitable for unplanned trips as well as hop-on-hop-off-use. This is an important role of last mile shuttles, so capacity management (and information related to it) should not be all hidden away in a booking app.

Finally, information in the shuttle should provide further assistance to complete the boarding process. This encompasses clearly visible seat labels and seating instructions for those, who have booked earlier. It also includes booking instructions for those who continue their journey with a different means of transport (if this service is not a part of the common payment scheme offered by independent mobility provider—this is not uncommon in low-density areas or for last-mile operations). After the first study we focused exclusively on visual interaction, in the study 3 we decided that an audio-visual interaction would provide the preferred solution and improve accessibility. Here, the visual component is the primary channel while the audio information provides assistance during the boarding process.

8.3 Old Is New

While it might seem counter intuitive at first, more effective and flexible capacity management can also be achieved by offering instruments that would seem outdated in the age of automation—not only but in particular considering the automation technology—to do so. Enabling the purchase of tickets at kiosks, vending machines, or even *via* telephone pre-boarding is one way to use existing offline means of booking to add flexibility to the booking process for those with limited smartphone or Internet access. Another strategy would be to enable optional physical ticket printing on the shuttle while boarding. This way, the booking itself can be completed on the device of choice (or even at a standard ticket machine at a station) and neither booking nor boarding require access to a compatible smartphone, thereby increasing accessibility.

The take-away here is that, despite the relatively futuristic character of automated shuttle, the demographic using the shuttle is not so much driven by the technological nature of it, rather by infrastructural constraints and the transportation needs. Therefore, it would be wrong to expect users of an automated shuttle to approve of technological solutions if they entail less flexibility. For older demographics in particular, it might be wise to offer seemingly archaic yet well known and established means to provide not only flexibility but also adequate compensation for the now absent human element in the shuttle.

8.4 Flexibility vs. Predictability

The need for being able to reserve a specific seat also varied with the intended use context, with rural areas bearing a higher need for such reservation capabilities as opposed to urban ones. Urban vs. rural also played an interesting role in the question of maximum capacity and frequencies. The participants found smaller shuttles to be more suitable for rural contexts with less traffic density and lower transportation demands (in terms of quantity), not just in terms of comfort but also regarding sustainability, where large traditional buses were typically regarded as “too much”. However, to contrast these smaller capacities, participants also expressed the demand for shuttle frequencies and intervals better suited for urban operation (i.e., intervals of no more than 10 min between shuttles).

This means that shuttles might either need to be operated at higher intervals or under capacity in order to satisfy demands. Ideally, such measures (more or larger shuttles) should be tailored towards the factors that necessitate them, e.g., send out larger sized shuttles or decrease intervals only before school begins and school ends, around noon, and similar. Naturally, this needs to be reflected in the itinerary and related capacity management information—users need to know when to expect which availabilities—both in terms of times as well as available spots.

Another related factor here is that, as discussed in the previous section, capacity management cannot be entirely pre-planned or it might exclude a significant part of the population from using such services effectively. In addition, study 3 also suggests that even with reservation capabilities, the possibility for conflicts over reserved seats cannot be excluded. Therefore, apart from balancing the maximum capacities of shuttles in accordance with external constraints or requirements, it will also be inevitable to balance the available capacity into at least two *contingents*: one rigid/reservable and one flexible/non-reservable contingent. The rigid contingent can be booked *via* standard booking tools and guarantees seating for those who booked in advance. It can ensure that those who need to take the means in question at the specific time (e.g., for a doctor’s appointment) can do so, just as they would with current public means of transport. The flexible contingent is intended for hop-on-hop-off-travelling; it cannot be booked prior to boarding and ensures that passengers, who did not book previously nor have no intention to do so, are not continually confronted by one fully booked shuttle after another arriving while they are waiting at the station. While offering contingents is easier with higher maximum capacities, they can be used with very small capacities as well (e.g., 2 + 4, 4 + 4, 8 + 2, etc.,.). This way, booking can be rendered reliable to ensure availability for important journeys, while keeping everything sufficiently flexible and increasing accessibility that way.

9 LIMITATIONS

Studies 1 and 3 were conducted in shuttles with very low capacities. While both EZ10 models used would have allowed for 6 standing spots in addition to the 6 seats, regulatory restrictions only allowed for the 6 seats to be used. We argue that capacity management issues arise when there is a stark mismatch between the shuttle’s maximum capacity and the number of passengers intending to use it. Thus, a 6-seater that 7 people are trying to board is just as over capacity as a 30-seater that is being boarded by 31. What cannot be denied, however, is that the proportions are different: A larger shuttle has more room for compensating overcapacities (e.g., squeezing in 2 more standing passengers in a 30-seater is easier than in a 6-seater) and group dynamics of higher passenger amounts in larger shuttles might lead to different experiences and interactions.

Both field studies were conducted in the same suburban area, whereas study 2 was conducted in the laboratory. While the participants answered the questions asked to them during the interviews often with reference to both urban and non-urban environments (and explaining different needs or preferences for each), the only actual experience they had as a basis for their statements were those from using the shuttle in the suburban area. Thus, it stands to reasons that the results presented in this publication hold higher validity for suburban than for urban contexts and that results from studies conducted in urban areas might highlight additional or different insights. In addition, all studies were conducted in Austria, Europe. Cultural effects on the results can not be excluded, nor could potential cross-cultural differences be examined in the studies presented. Furthermore, there were no participants with impairments or disabilities involved. Effects of capacity management can expected to be stronger for those demographics, depending on the type and/or degree of the impairment. Any statements regarding these demographics from study participants should be interpreted with appropriate caution.

Studies 1 and 3 were conduced in the field but the participants were recruited specifically for these studies (and in quantities that would cause capacity conflicts). Thus the setup was not entirely natural. While the setting and the shuttle’s environment certainly were and additional measures (e.g., the printed tickets) were taken to make it as realistic as possible, the participants arrived with the specific goal to participate in a study, with going from A to B as a secondary goal and part of their instructions. In addition, regulations at the time required the presence of an on-board operator at all times. While this operator was instructed to interact as little as possible with the participants, it still created a context different from a shuttle without any human point of reference at all, which is the expected future scenario. Due to the COVID19-related restrictions on the maximum number of passenger during study 3, it was not possible to have a visibly crowded shuttle during that study (as it had been the case for study 1). Since the number of passengers per group was larger than the shuttle’s maximum allowed capacity, capacity conflicts still arose but since no physical overcrowding of the shuttle could happen, possible differences in behavior or responses due to group dynamics could not be observed.

10 CONCLUSION

In this paper, we presented the results from three different studies on capacity management in automated small-capacity shuttle, which were conducted within the Austrian flagship project Digibus®Austria. Departing from the assumption that the absence of a human factor combined with the smaller overall capacity of shuttles might introduce additional challenges for capacity management in such shuttles. In the series of studies, we first employed auditory announcements for capacity management in-shuttle, then used a booking application for capacity management pre-boarding, to finally use an integrated solution consisting of a booking application and in-shuttle information monitor to handle capacity management.

Throughout the studies, we were able to confirm that additional challenges do exist and that existing means (booking applications, in-shuttle and station information) with appropriate extensions or modifications can be used for effective capacity management in automated shuttles. We compiled our findings into recommendations on how such extensions or modifications might look like, so that future work can extend the investigation or draw upon the findings for implementation.

Successful capacity management begins before the ride but must also have enough flexibility to enable use without prior reservation. Separation of spots into contingents is an effective way to do this. Similarly, if booking and ticketing is not limited to smartphones or on-line booking only, this further increases flexibility. Offering more traditional means (e.g., physical tickets) might seem like a regress in the technical sense but can be considered a progress in terms of accessibility. The technology may be new but the interaction with it should be familiar.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available as they are joint property of several involved research partners. Requests to access the datasets should be directed to alexander.mirnig@sbg.ac.at.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

AGM led the research efforts presented in the paper (both in planning and on-site) and contributed to all parts of the submission. MG supported the research planning and conduction and primarily contributed the quantitative analyses. VW was in charge of the booking application and in-shuttle monitor design and contributed parts accordingly, EF, KA, and JR supported the research planning and conduction. They also provided the initial versions of the qualitative results parts. AM assisted with related literature research.

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REFERENCES

Araldo, A., Di Maria, A., Di Stefano, A., and Morana, G. (2019). "On the Importance of Demand Consolidation in Mobility on Demand," in Proceedings of the 23rd IEEE/ACM International Symposium on Distributed Simulation and Real Time Applications, Cosenza, Italy (DS-RT '19: IEEE Press)), 51–58.

Ayoub, J., Mason, B., Morse, K., Kirchner, A., Tumanyan, N., and Zhou, F. (2020). "Otto: An Autonomous School Bus System for Parents and Children," in CHI EA '20: Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA (New York, NY, USA: Association for Computing Machinery), 1–7. doi:10.1145/3334480.3382926

Bangor, A., Kortum, P., and Miller, J. (2009). Determining what Individual sus Scores Mean: Adding an Adjective Rating Scale. *J. Usability Stud.* 4, 114–123. doi:10.5555/2835587.2835589

Bernhard, C., Oberfeld, D., Hoffmann, C., Weismüller, D., and Hecht, H. (2020). User Acceptance of Automated Public Transport. *Transportation Res. F: Traffic Psychol. Behav.* 70, 109–123. doi:10.1016/j.trf.2020.02.008

Brooke, J. (1996). "Sus-a Quick and Dirty Usability Scale," in *Usability Evaluation in Industry* (London: CRC Press), 189–194.

Chen, C.-F. (2019). Factors Affecting the Decision to Use Autonomous Shuttle Services: Evidence from a Scooter-Dominant Urban Context. *Transportation Res. Part F: Traffic Psychol. Behav.* 67, 195–204. doi:10.1016/j.trf.2019.10.016

Dahlbäck, N., Jönsson, A., and Ahrenberg, L. (1993). Wizard of Oz Studies - Why and How. *Knowledge-based Syst.* 6, 258–266. doi:10.1016/0950-7051(93)90017-n

Delta Air Lines, I. (2020). Flydelta App. Available at: https://apps.apple.com/de/app/fly-delta/id388491656 (Accessed May, 2021).

Distler, V., Lallemand, C., and Bellet, T. (2018). "Acceptability and Acceptance of Autonomous Mobility on Demand," in CHI '18: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal, QC, Canada (New York, NY, USA: Association for Computing Machinery)). doi:10.1145/3173574.3174186

Fröhlich, P., Millonig, A., Frison, A.-K., Trösterer, S., and Baldauf, M. (2018). "User Interfaces for Public Transport Vehicles," in AutomotiveUI '18: Adjunct Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Toronto, ON, Canada (New York, NY, USA: ACM), 50–55. doi:10.1145/3239092.3239101

iMobility GmbH (2018). Wegfinder Company Website. Available at: https://wegfinder.at (Accessed May, 2021).

Kumsila, T., and Phithakkitnukoon, S. (2018). "Jerney," in UbiComp '18: Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers, Singapore (New York, NY, USA: Association for Computing Machinery)), 1060–1068. doi:10.1145/3267305.3274161

Lamotte, R., de Palma, A., and Geroliminis, N. (2017). On the Use of Reservation-Based Autonomous Vehicles for Demand Management. *Transportation Res. B: Methodological* 99, 205–227. doi:10.1016/j.trb.2017.01.003

Liang, X., Correia, G. H. D. A., and van Arem, B. (2016). Optimizing the Service Area and Trip Selection of an Electric Automated Taxi System Used for the Last Mile of Train Trips. *Transportation Res. E: Logistics Transportation Rev.* 93, 115–129. doi:10.1016/j.tre.2016.05.006

Ma, L. V., Azam, S., Munir, F., Jeon, M., and Choi, J. (2019). "Automated Taxi Booking Operations for Autonomous Vehicles," in 2019 13th International Conference on Signal Processing and Communication Systems, Gold Coast, QLD, Australia (IEEE), 1–5. doi:10.1109/ICSPCS47537.2019.9008449

Merlin, L. (2017). Comparing Automated Shared Taxis and Conventional Bus Transit for a Small City. *Jpt* 20, 19–39. doi:10.5038/2375-0901.20.2.2

Mindinventory (2020). Mybus Booking App. Available at: https://www.mindinventory.com/mobile-portfolio/bus-ticket-booking-app.php (Accessed May, 2021).

Mirnig, A. G., Gärtner, M., Füssl, E., Ausserer, K., Meschtscherjakov, A., Wallner, V., et al. (2020a). Suppose Your Bus Broke Down and Nobody Came. *Pers Ubiquit Comput.* 24, 797–812. doi:10.1007/s00779-020-01454-8

Mirnig, A. G., Gärtner, M., Wallner, V., Trösterer, S., Meschtscherjakov, A., and Tscheligi, M. (2019). "Where Does it Go? A Study on Visual on-Screen Designs for Exit Management in an Automated Shuttle975 Bus," in AutomotiveUI '19: Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Utrecht, Netherlands (New York, NY, USA: Association for Computing Machinery)), 233–243. doi:10.1145/3342197.3344541

Mirnig, A. G., Wallner, V., Gärtner, M., Meschtscherjakov, A., and Tscheligi, M. (2020b). "Capacity Management in an Automated Shuttle Bus: Findings from a Lab Study," in AutomotiveUI '20: 12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Virtual Event, DC, USA (New York, NY, USA: Association for Computing Machinery), 270–279. doi:10.1145/3409120.3410665

Nordhoff, S., de Winter, J., Kyriakidis, M., van Arem, B., and Happee, R. (2018a). Acceptance of Driverless Vehicles: Results from a Large Cross-National Questionnaire Study. *J. Adv. Transportation* 2018, 1–22. doi:10.1155/2018/5382192

Nordhoff, S., de Winter, J., Madigan, R., Merat, N., van Arem, B., and Happee, R. (2018b). User Acceptance of Automated Shuttles in Berlin-Schöneberg: A Questionnaire Study. *Transportation Res. Part F: Traffic Psychol. Behav.* 58, 843–854. doi:10.1016/j.trf.2018.06.024

Nordhoff, S., de Winter, J., Payre, W., van Arem, B., and Happee, R. (2019). What Impressions Do Users Have after a Ride in an Automated Shuttle? an Interview Study. *Transportation Res. Part F: Traffic Psychol. Behav.* 63, 252–269. doi:10.1016/j.trf.2019.04.009

Reddy, A., Lu, A., Kumar, S., Bashmakov, V., and Rudenko, S. (2009). Entry-only Automated Fare-Collection System Data Used to Infer Ridership, Rider Destinations, Unlinked Trips, and Passenger miles. *Transportation Res. Rec.* 2110, 128–136. doi:10.3141/2110-16

Santos, A. D. (2020). Intrcity Smartbus App. Available at: https://apkpure.com/intrcity-smartbus-app-book-intercity-bus-tickets/bus.tickets.intrcity (Accessed May, 2021).

Shen, Y., Zhang, H., and Zhao, J. (2018). Integrating Shared Autonomous Vehicle in Public Transportation System: A Supply-Side Simulation of the First-Mile Service in singapore. *Transportation Res. A: Pol. Pract.* 113, 125–136. doi:10.1016/j.tra.2018.04.004

Theatres, A. (2020). Amc Stubs. Available at: https://apps.apple.com/de/app/fly-delta/id388491656 (Accessed May, 2021).

Verma, H., Pythoud, G., Eden, G., Lalanne, D., and Evéquoz, F. (2019). Pedestrians and Visual Signs of Intent. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 3, 1–31. doi:10.1145/3351265

Wintersberger, P., Frison, A.-K., and Riener, A. (2018). "Man vs. Machine: Comparing a Fully Automated Bus Shuttle with a Manually Driven Group Taxi in a Field Study," in AutomotiveUI '18: Adjunct Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Toronto, ON, Canada (New York, NY, USA: Association for Computing Machinery)), 215–220. doi:10.1145/3239092.3265969

Yap, M. D., Correia, G., and van Arem, B. (2016). Preferences of Travellers for Using Automated Vehicles as Last Mile Public Transport of Multimodal Train Trips. *Transportation Res. Part A: Pol. Pract.* 94, 1–16. doi:10.1016/j.tra.2016.09.003

Zhang, D., Zhao, J., Zhang, F., Jiang, R., and He, T. (2015). "Feeder: Supporting Last-Mile Transit with Extreme-Scale Urban Infrastructure Data," in IPSN '15: Proceedings of the 14th International Conference on Information Processing in Sensor Networks, Seattle, Washington (New York, NY, USA: Association for Computing Machinery), 226–237. doi:10.1145/2737095.2737121

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