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Planning and Implementation of Autonomous Shuttle Buses in Tourism Mobility in the Region Berchtesgaden-Königssee, Germany

Carolin Altena [1] ✉ and Hannes Thees [2]

Abstract
Tourism mobilities are essential in the sustainability (mobility) transition. Thereby, alternative transport systems and mobility innovations need to go hand in hand with a change in mobility behaviour. Autonomous shuttle buses are promising for improving tourists' movements in tourism regions by combining innovative spirit, environmental friendliness, and experiences. As there is only limited research on the implementation of autonomous shuttles in a complex regional context, this study aims to define factors for the planning and implementation of autonomous shuttle buses with investigations from the region of Berchtesgaden-Königssee in Germany. Specifically, the paper answers the question: *How can autonomous shuttle buses be planned and implemented in order to initiate innovative and soft mobility in a tourism destination?* This research question is supported by theories on mobility styles and technical innovations. Considering the complexity of mobility innovation in a region, the methodology includes a multi-method approach by incorporating the viewpoints of various experts to plan appropriate routes and cope with technical factors. The results introduce planning steps and reveal the importance of experience and theme design in addition to several technical challenges. Finally, this article contributes to an emerging research field between tourism, technology, and regional development by demonstrating processes to foster the implementation of innovative and soft mobility.

Keywords: Autonomous Shuttle Buses, Tourism Mobility, Technology Implementation, Future Mobility, Multi-Method Approach

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[1] Fraunhofer Institute for Material Flow and Logistics (IML), Project centre traffic, mobility and environment, Joseph-von-Fraunhofer-Straße 9, 83209 Prien am Chiemsee, Germany; Tel.: +49 151 43807952; email: carolin.altena@iml.fraunhofer.de

[2] German National Competence Centre for Tourism, Hannes.Thees@outlook.de

✉ Corresponding author

1. Introduction

Mobility is essential for travel, both in terms of arrival and departure, as well as mobility "on-site" at the destination (Scuttari, 2014). Since individual motorised transport dominates tourist mobility, a shift towards more flexible and environmentally friendly forms of mobility is necessary (Grèzes Bürcher et al., 2018; Barr, 2018). Such a shift needs to combine mobility solutions and mobility behaviour. Accordingly, changes in mobility behaviour and the use of transportation towards softer forms, are to counter the resulting consequences for the environment and society (Gronau & Groß, 2019), opening up innovation-driven novel concepts for tourism mobility (Verbeek & Mommaas 2008). This is where autonomous shuttle buses come in as an important innovation for public transport in the future (Barillère-Scholz, Büttner & Becker, 2020). In the context of tourism, various applications are already being tested, for example in projects in tourist destinations such as Bad Birnbach and Sylt in Germany or at the Dallas Fort Worth International Airport in the USA (EasyMile SAS, n.d.A; Verband Deutscher Verkehrsunternehmen e.V., n.d.)

However, these vehicles currently have some limitations, so not all potential fields of application can be realised yet. Therefore, the introduction of autonomous shuttle buses sees challenges between technical limitations, environmental conditions and financial issues (Grèzes Bürcher et al., 2018; Grote & Röntgen, 2021). In the research on the topic of highly automated driving, the focus has been on technical and legal aspects mostly (Fraedrich et al., 2015). However, due to the fact that highly automated driving is expected to be of enormous importance in the future, the perspective should be widened (Schreurs & Steuwer, 2015). In the tourism context, Grèzes Bürcher et al. (2018) call to provide concrete scenarios for the use of autonomous shuttle buses as an environmentally friendly and attractive solution in an alpine region.

The objective of this study is to identify suitable implementation strategies for autonomous shuttle buses and the aspects and procedures of planning. Thereby, the general challenges of tourism mobility described above shall be met and the first step towards innovative and soft mobility shall be achieved. In this paper, the term "soft mobility" is understood as environmentally friendly public transport. Therefore, the overarching research question is: *How can autonomous shuttle buses be planned and implemented in order to initiate innovative and soft mobility in a tourism destination?*

This research question contributes to technology implementation in a complex local context, which is so far seldom explored. As a case study, this paper analyses the existing initiatives for autonomous shuttle buses in the Tourism Region Berchtesgaden-Königssee (TRBK), Germany. In addition to aspects of feasibility and routing, tourist interests and stakeholders' perspectives contribute to sketching the implementation.

The research design is based on qualitative semi-structured interviews with experts in the fields of mobility and tourism as well as with tourists. Furthermore, additional data (e.g. regarding street characteristics) was collected and compared respectively completed by observations and self-collected data (e.g. road characteristics).

Ultimately, this paper introduces key steps and procedures in the process of implementing autonomous shuttle buses in a destination. The following sections, therefore, offer a theoretical background in innovation (Section 2), methodology (Section 3) and concrete recommendations for practice (Section 4).

2. Theoretical Background

Due to the involvement of different actors in regional technology implementation, both the demand-side (tourist mobility behaviour and explanatory theoretical approaches) and the supply-oriented side (transport planning and implementation) are considered with regard to mobility styles towards technical considerations of autonomous shuttle buses.

2.1. Mobility Styles and Behaviour

In general, different attitudes and motives shape mobility behaviour (Schlaffer & Hunecke, 2002). The mobility styles approach combines psychological findings on transport use with social theory approaches and other aspects of mobility research and serves to close the gap between these approaches (Götz, 2007). The concept of mobility styles assumes that different views on mobility and means of transport as well as their characteristics exist within society. These views shape mobility behaviour and the understanding of any restrictions (Rosenbaum, 2007; Ramos et al., 2020). In the context of this target group-related approach, a categorisation is made based on these individual attitudes, in which symbolic aspects of transport are also important (Scheiner, 2007; Prillwitz & Barr, 2011).

Meanwhile, countries show different approaches to handling or supporting mobility transformation. For example, the 2015 travel analysis in Germany generally found that the choice of transport depends above all on the destination and distance, as well as the travel companion, since, for example, 60% of family vacations take place by car (Schmücker et al., 2015). A high car share exists especially for domestic trips (71%) and trips to the Alps (76%). The chosen means of transport for arrival has a great influence on the use of transport on-site in the vacation destination, as only 14% of the people who use a car for arrival travel by public transport on-site (Groß & Grimm, 2019). Thus, the study (multiple answers possible) shows that the passenger car is also the most used means of transport at the vacation destination (38%), followed by public transport (24%), cab (17%), rented cars (16%), bicycles (14%), and other means of transport (Schmücker et al., 2015).

Holistic analyses on mobility styles in Germany were conducted by Götz (2007). Based on a cluster analysis of similar mobility attitudes, different mobility styles could be categorised. With 24% affiliation each, the styles *"the traditionally domestic"* and *"the traditionally nature-oriented"* are most frequently represented. For the latter grouping, where females are somewhat more common, public transport is important in principle but with a limited sense of security during evening trips. Also important for public transport is the grouping of the "ecologically determined", mainly characterised by young and technology-savvy people. This group strives for the most environmentally friendly (everyday) mobility behaviour possible without using a private car (Götz, 2007). The *leisure mobility styles* approach represents an extension of mobility styles with regard to leisure mobility, including *"Disadvantaged," "Modern-Exclusive," "Fun-Oriented," "Burdened-Family-Oriented,"* and *"Traditional-Domestic" (*Götz et al., 2002).

In the study by Zukunftsinstitut (2017), a categorisation of the future mobility society was undertaken (including Mobile Lifestyles 2040). First of all, the driving forces of future mobility were identified based on needs and motives, of which "travel" in the sense of tourism is considered a driving force alongside the "individualisation" megatrend. In the context of the driving force "travel", for instance, a change in travel needs is emphasised due to frequent travel (especially by young people) (Zukunftsinstitut, 2017). According to the authors, future mobility shapes not only the moment-in-time experience but also the accumulation of experiences in the long run and the role of emotions. Therefore "…tourism becomes the most creative way of mobility" (Zukunftsinstitut, 2017: 9, 14). The study sees lifestyles and the respective phases in life, as well as individual needs and attitudes as shaping mobility behaviour and future mobility patterns (Zukunftsinstitut, 2017). Based on this basic understanding, the study defines nine mobility style: "Mobile Innovators", "Forever Youngsters", "Silver Mover", "Mobile Families", "High-frequency Commuters", "Global Jetsetters", "Low-Cost Drivers", and "Urban Good Citizens" (Zukunftsinstitut, 2017). The "Mobile Innovators" are considered one of the most important mobility styles, demanding individualised intelligent mobility that is also as environmentally friendly as possible (public transport, car sharing, bicycles or emission-free or autonomous private transport). Intelligent and connected mobility (including highly automated shuttle buses) is also a key issue for the group "public travellers" or "low-cost drivers," which goes hand in hand with demands for a low cost (both groups), simplicity ("public travellers") and a high (service) quality and an innovative design of the means of transport or the service ("low-cost drivers") (Zukunftsinstitut, 2017).

2.2. Requirements for an environmentally friendly tourism mobility

All of these categorisations and styles provide insights for the development of mobility offers in close relation to the customer needs, but also to the requirements concerning sustainability. With regards to the vision of more innovative tourist mobility, approaches based upon value-based behaviour are of interest, since there is a change in values towards an increasing orientation concerning environmental aspects (Schindler, 1999). At the same time, e.g. rationally based approaches and those of life and mobility styles are important to understand mobility behaviour holistically and to be able to derive implementation scenarios. Besides the described mobility styles (Section 2.1), technical considerations impact this shift in tourism mobility. If it is possible to achieve an increase in the attractiveness of environmentally friendly mobility, for example, through innovations such as autonomous shuttle buses, this will have a positive effect on changes in mobility patterns and possibly initiate a new mobility culture.

2.3. Innovation in Mobility

According to Aregger (1976), innovation can be described as a significant change in the actual social system and the introduction of new knowledge, behaviour, or machines. Technological innovation describes the introduction or alteration of technologies into the organisation and is often linked to the commercialisation of a technical idea into a product, service or process with the target of addressing customer needs (Weerakoon & McMurray, 2021).

With the rising complexity of technological innovation, the diffusion of innovations in the social system becomes evident. Rogers (1995) has structured the diffusion of innovations based on communication and various channels, including *Knowledge*, *Persuasion, Decision, Implementation* and the *Confirmation Stage*. Robertson (2017) describes the diffusion of technologies as a situation in which an existing product or concept is used by other people or institutions, in a different place or for a different purpose. For example, the number of pilot projects of autonomous shuttle buses has grown steadily in recent years (Ainsalu et al., 2018). Ultimately, the diffusion process of automobility and related innovations is not straightforward and can bring unexpected consequences and developments (Kanger et al., 2019).

In view of the implementation of mobility innovations or autonomous shuttle buses, it is crucial to create acceptance for the product. User acceptance is of central importance with regard to the success of a system (Davis, 1993). A study of the project of the autonomous shuttle bus on the island of Sylt shows that 89% of the people surveyed trust the technology of the bus and that the bus is seen as safe by 97% of the people (Kühl, n.d.).

Past and ongoing projects of autonomous shuttle buses show that they are mostly tested in mixed traffic (Braun et al., 2020). Regarding the implementation of autonomous shuttle buses, it can be stated that introducing autonomous vehicles in public transport can be challenging due to the free operation in road traffic (Lenz & Fraedrich, 2015). The introduction thus requires consideration of economic aspects, social acceptance, and technological and technical feasibility (Derer & Geis, 2020). In this context, the potential field of application is of particular importance.

Figure 1. *Autonomous shuttle buses in Bad Birnbach, Germany (Source: © DB Regio Bus/Patrick Kuschfeld)*

2.4. Technical Considerations

Bringing technological innovation in mobility to life requires a holistic view that includes also technical considerations. For example, there are various innovations regarding the car or shuttle engine, may it be electric or hydrogen power. Moreover, autonomous driving builds upon specific prerequisites. Current vehicle models of autonomous shuttle buses (e.g. EasyMile or Navya) first require the manufacturer to capture a "virtual track" (recording the exact course of the track) and its spatial features to implement the identified route (Beiker, 2015). With all those developments, the subsequent levels of autonomous driving evolve:

- Level 0: No Driving Automation
- Level 1: Driver Assistance
- Level 2: Partial Driving Automation
- Level 3: Conditional Driving Automation
- Level 4: High Driving Automation
- Level 5: Full Driving Automation (SAE International, 2021)

In the context of autonomous shuttle buses, it can generally be said that the manufacturers Navya and EasyMile are market leaders at the moment. The shuttle buses are electrically driven and have eleven (Navya) or six (EasyMile) seats. They do not have a steering wheel but do have a control element that can be used for manual intervention at any time (Kolb et al., 2020). In principle, the vehicles can reach a speed of 25 km/h (Navya) and up to 40 km/h (EasyMile) (NAVYA SA n.d.; Kolb et al., 2020). The shuttle buses move along a fixed "virtual track" based on a map of the environment, which has been installed manually in advance by the vehicle manufacturer. The vehicle locates itself with centimetre precision through the support of the installed sensor technology (LIDAR, GPS and odometer) and thus travels the pre-recorded route mostly autonomously. LIDAR sensors and cameras are used to perceive the surroundings and obstacles. Local conditions such as the weather or the road surface can have an influence on the function of the sensor system (Rentschler et al., 2020). In general, the vehicles currently have some limits in their performance capabilities, which is why the presence of a safety driver has been mandatory so far. This driver can intervene at any time and take over the control in order to be able to intervene in unforeseen situations or if the vehicle misbehaves. Therefore, autonomously driving shuttle buses have so far been classified in category 2 ("partially automated driving") of the automation levels (Rentschler et al., 2020). However, classifications in higher levels of autonomous driving occurred in the meantime. For instance, EasyMile EZ 10 is classified up to level 4 in demarcated areas (EasyMile, n.d.B).

3. Methodology

To answer the research question, a mixed-methods approach was adopted (see Figure 2). There is a focus on interviews with experts and tourists. In addition, spatial aspects and publicly available data on the traffic situation were considered, some of which (e.g. route widths, gradients, etc.) are also quantitative in nature. Ideas for future shuttle routes were sampled and discussed with experts for autonomous public transport. Afterwards, the utility value for the potential route ideas was defined. Overall, the process can be described as an iterative process.

Figure 2. *Overview of methodical process. Source: Own figure.*

3.1. Study region

The present study refers to the southern subregion of the Berchtesgadener Land. It comprises the municipalities of Berchtesgaden, Schönau am Königssee, Ramsau, Bischofswiesen, and Marktschellenberg and is managed and promoted by the Zweckverband Bergerlebnis Berchtesgaden (Zweckverband Bergerlebnis Berchtesgaden, n.d.A). The district is located in the extreme southeast of Upper Bavaria and has a partly high alpine landscape. The region, whose main tourist attractions are the Berchtesgaden National Park, Lake Königssee, and the peak of the Watzmann, has a high tourism intensity with 2.4 million overnight stays in 2019 in relation to the approximately 24,000 inhabitants (Tourismus Oberbayern München e.V., n.d.; DWIF 2020; Landkreis Berchtesgadener Land, n.d.). In general, the TRBK recommends environmentally friendly travel without the car in the course of participation in the cooperations "Alpine Pearls" and "Fahrtziel Natur" (Zweckverband Bergerlebnis Berchtesgaden, n.d.B). Nevertheless, the destination has identified a need for action regarding the optimisation of arrival and on-site mobility, also with regard to new technologies and future aspects (Berchtesgadener Land Tourismus GmbH, n.d.).

Concerning the mobility aspects in the destination, a mapping of the attractions was necessary (e.g. city centres, hiking possibilities, parking lots, etc.) and shows various highly demanded spots (e.g. Lake Königssee and Lake Hintersee). Overall, there is still potential to increase the share of public transport. Overnight guests can use it free of charge with the guest card they receive from the local accommodation provider (Zweckverband Bergerlebnis Berchtesgaden, n.d.C).

3.2. Interviews

The introduction of innovative mobility solutions in a destination requires a multi-stakeholder approach. In this light, the study conducted six expert interviews. In total, nine experts participated in this study (see Table 1). The experts were either regional stakeholders (e.g. from the field of tourism or mobility) or worked in the cross-regional mobility sector. Interviews with experts took place between August and October 2020. The main questions of the interview relate to challenges in tourism and mobility as well as to specific questions regarding autonomous shuttles (e.g. potential and operational feasibility). Deductive-inductive coding was used to analyse the qualitative data. A total of 700 text passages were coded within the program MAXQDA, 562 of which were attributable to the expert interviews. The findings from the expert interviews are essential to define the implementation processes and reflect the route development.

Table 1. *Overview of qualitative interviews with experts*

Expert number	Industry
E1	Mobility (local level)
E2	Mobility (local level)
E3	Mobility (local level)
E4	Tourism (local level)
E5	Other local stakeholder
E6	Other local stakeholder
E7	Mobility (cross-regional level)
E8	Mobility (cross-regional level)
E9	Mobility (cross-regional level)

In addition, ten explorative interviews were conducted with tourists at Lake Königssee in October 2020. The aim of the interviews with the tourists was to understand the underlying attitudes regarding mobility behaviour and autonomous shuttle buses, for example, in terms of the propensity to use the shuttle buses. The interviews were analysed with MAXQDA as well. Findings from these interviews are of situational importance for this paper (e.g. to demonstrate implementation aspects with regard to operating mode and demand from the demand side, see Section 4.3).

3.3. Additional Data

In addition to the data collected on the routes from the expert interviews, knowledge about the respective route characteristics and the traffic situation is also necessary for identifying and considering the implementation scenarios. Thus, traffic data were researched in advance, for example, using the geoporta1 BayernAtlas, other publicly available data via OpenStreetMap or the local mobility concept (Schlothauer & Wauer Ingenieurgesellschaft für Straßenverkehr MbH et al., 2018). These data were related in advance to possible routes of tourist interest. The existing data were supplemented during a stay in the field (August 25 and 26, 2020) by applying the method of observation (documented with photo and video material) as well as selectively collected data, e.g., on road width, and compiled for the analysis of possible operational scenarios.

3.4. Evaluation of the routes

A rating matrix was assessed with experts for cross-regional and innovative mobility to determine the best route options for the current technical possibilities. This includes an overview of the routes and associated characteristics of traffic situations, obstacles, and any challenges to autonomous operation. Each route has been classified in this rating matrix regarding various aspects of feasibility. The matrix was subsequently supplemented by a points-based evaluation system in the second step. In line with the lowest possible effort, points were initially allocated: one point for "probably feasible" and two for "to be clarified". The classification in this scheme was done for each route individually. The assigned effort points were weighted within the matrix with a factor of the complexity of the situations and, if the situation exists more than once, multiplied accordingly. In addition, feasible situations were counted. Ultimately, to match these results with strategic and touristic aspects, a value-in-use analysis followed. The following categories were defined as criteria in the context of this work:

- "Tourism benefits" (weighting: 30%)
- "Implementation/effort aspects" (weighting: 45%)
- "Strategic aspects / degree of innovation" (weighting: 25%)

According to this pattern, the route ideas have been classified and evaluated. A distinction was made between what is currently feasible (knockout criterion not achieved) and currently not feasible (knockout criterion achieved).

4. Results

This section introduces the main results of the iterative research process. Interviewees are coded as E for the experts and T for the tourists.

4.1. Challenges for operation and implementation in the local context

Due to the current state of technology of the vehicles, not all potential can be realised. This has implications for the feasibility of a wide range of deployment scenarios (E7). The possible limits depend on the particular vehicle and local conditions (E7). Overall, however, challenges lie especially in the area of gradients, difficult weather conditions, and localisation problems (E7 & E8). The results show some scope for enabling deployment scenarios based on current vehicle technology (e.g. through infrastructure upgrades or posted landmarks) (E7 & E8).

Another challenge is the small size of the vehicles (E9), especially in the case of high passenger volumes. Therefore, several autonomous buses with the appropriate frequency are needed. However, this fact calls into question the transport's cost-effectiveness, in combination with the lack of personnel savings so far (E6). Moreover, a large number of buses would lead to increased traffic and resulting burdens (land consumption and obstacle effect in traffic) (E6).

Due to the topographical conditions, potential relations often have inclines (E2) and narrow conditions (E3). In addition, these may be too long for currently reasonable vehicle circulation (E2). Significant challenges may arise from winter weather conditions. Furthermore, local weather conditions must be considered in the context of gradients (E7). Since difficult weather conditions such as heavy rain or heavy snowfall make autonomous operation difficult (E7), this can lead to some challenging operating days in the alpine region (E7). Covering all fields of application also includes optimised processing of more difficult weather conditions in the future (E7). Important areas for improvement in the future include increasing speed (E2), vehicle size (E6) and covering all fields of application (E1). These are the starting points for the indicated future vehicle developments. In principle, this could result in different vessel sizes in the future (E9). In a period of about five years, it is assumed that the vehicles will also be able to cope with steeper and more sustained gradients (E9).

4.2. Identified routes

Experts generally see autonomous shuttle buses on frequently used routes to the main tourist attractions (E4 & E5). During the expert interviews, the following routes (see also Figure 3) were addressed by the experts:

1. *Jennerbahn - Seelände Königssee*
2. *Berchtesgaden train station – Königssee (bus stop)*
3. *Rathaus Unterstein - Königssee (bus stop)*
4. *Part of the Schönau circle line*
5. *Supplementary connection to Berchtesgaden town centre*
6. *Train station - town centre*
7. *Ramsau - Hintersee*
8. *Kehlstein bus stop - Kehlsteinhaus*

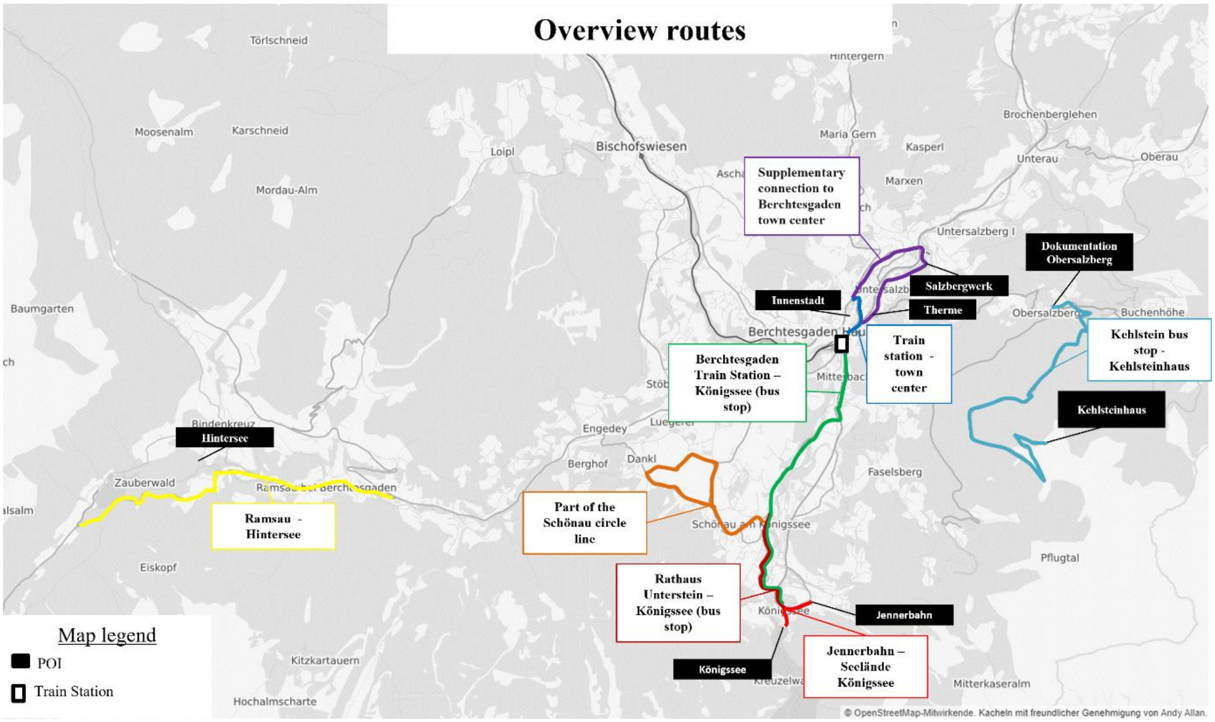

Figure 3. *Overview of identified routes. Source: Own figure based on OpenStreetMap (modified with PowerPoint).*

Feasibility Aspects: Based on the results of the feasibility analysis, the possible routes were ranked. For each route idea, effort points were assigned, among other things, which determine the classification of feasibility (see Section 3.4). The route *Rathaus Unterstein - Königssee (bus* stop) has the fewest effort points (0), and the *supplementary connection to Berchtesgaden town centre* has the highest number of effort points (22). Overall, considering the feasibility aspects results in six routes for which the technical knockout criterion has not yet been reached and two routes that are currently not feasible (knockout criterion reached) according to our investigation.

Based on this classification (knockout criterion achieved and not achieved), a value-in-use analysis was performed separately (see Section 3.4). The consideration of currently implementable route ideas shows that the route *Rathaus Unterstein – Königssee (bus stop)* has the highest utility value, followed by the extended route *Bahnhof Berchtesgaden – Königssee (bus stop)*. The results of the routes likely to be feasible or more reasonable in the future show the highest value for the *Kehlstein-Kehlsteinhaus bus departure* variant.

However, the following routes with the highest utility value currently offer the best possible potential: The route with the highest utility value, *Rathaus Unterstein – Königssee* (bus stop), represents a route in demand with an expandable frequency for existing bus connections, which can be supplemented as needed (E1). In the context of the mode of operation, a classic line according to a timetable could meet the expandable frequency. Of closer interest in this context, however, would be how the tourist demand mentioned by E1 is distributed over the course of the day.

The route *Berchtesgaden train station - Königssee bus stop* represents the main transport axis in high demand by tourists (E4, E2 & E6) and is identified by almost all local experts as a conceivable route for an autonomous shuttle bus. The passenger volume could be equalised by a shuttle bus on a direct route between the regular travel times of the regular buses or permanently operating shuttle buses (E2 & E4). However, this is probably not the best option in terms of the economic use of resources, the high passenger volume, and the current vessel size. However, based on the recommendation of successive development of this route as a second step in the future, larger vessels might already be available at that time, meaning that the fleet would not need as many vehicles.

After considering all route ideas together, a route with a connection to Lake Königssee (e.g. *Berchtesgaden train station – Königssee bus stop*) seems to be useful and obtains potential for step-by-step implementation.

4.3. Implementation aspects with regard to operating mode and demand

Coming from the sustainability transition and the demand pattern, the results show that despite the predominant use of private transport, there is a positive attitude towards environmentally- friendly mobility in tourism. When tourists are asked about the influence of autonomous shuttle buses on future tourist mobility, a predominant picture emerges for a rather higher influence (T2, T3, T5, T6 & T10). T5 sees the level of the influence in "[...] dependence on environment and concept" (T5). According to T2, environmental reasons, for example, could have an influence (T2). The assessment of a low influence is justified by the lack of familiarity with the technology and correspondingly low acceptance, for which educational work must be done (T9). Furthermore, the need for changes in tourism and general mobility is emphasised (T8).

In general, an adapted offer is necessary, consisting of classic scheduled services and on-demand services according to demand (E1). Rigidly scheduled services sometimes have the disadvantage that passengers have to wait for a certain time when there is a high traffic volume. Autonomous shuttle buses can operate as a supplementary service during high passenger volumes, e.g., on the *Ramsau-Hintersee* route (E2). In general, however, according to the expert on bus operation, it depends on the respective area. At Lake Königssee, for example, a fixed timetable is necessary, whereas flexible operation may be appropriate in areas with lower demand. The expert emphasises the need for pre-booking an on-demand service as a potential obstacle (E1). From the tourists' point of view, a change in mobility behaviour through autonomous shuttle buses requires a simple, flexible and demand-driven service with an intuitive digital booking option (T5) or a high frequency of a maximum of 15 minutes (T8). In addition, "[...] a connection from the pick-up point to the sight and back or a route between sights [...]" (T5) is mentioned. This would go hand in hand with a lower need for information, for example, on parking facilities (T5).

Furthermore, the constant linking of measures and offers with digital services is essential. Digital services can generally also contribute to the design of a mobility experience, e.g. by bringing vehicle characteristics closer to the passengers. Götz (2007) describes a similar conflict in the context of mobility styles in rural areas, where a supposedly flexible offer of public transport does not meet the actual flexible needs (due to the obligatory booking). Therefore, it is important to enable booking at short notice and without contact, e.g., digitally. The expert for innovative and autonomous mobility concepts emphasises, for instance, that a digital option for calling up current vehicle characteristics can be provided for technology-savvy passengers (E7). The information could also be communicated via screen, which could possibly increase familiarity with the innovative technology.

4.4. Experience and Theme Design

Another aspect of the implementation is the potential for shaping the ride in terms of specific themes and experiences. The approach of mapping themes and attractions would be a new approach for the operation of autonomous buses and finds approval (E1).

With regard to the interests of the protected area, one option would be to digitally communicate rules of conduct for a visit to the national park (E5). In general, it would be a strategic approach to design the journey with an autonomous bus as an experience. This can counteract any mistrust of the innovation. At the same time, acceptance and possibly even environmental awareness can be increased (E5). This can also turn out to be an approach to counter any traffic restrictions with an attractive alternative and to introduce people to the restrictions with the experience (E5). The shuttle buses have a screen, allowing visual and audio information (E9). For future scenarios, the routes *Kehlstein bus stop - Kehlsteinhaus* and *Ramsau - Hintersee* were identified. Both have the potential to design the trip based on a theme. For example, the route from *Ramsau to Hintersee* can focus on the landscape (E4) and the *route to Kehlsteinhaus* can focus on the historical past (E4). The autonomous shuttle bus itself can also have an attractive character in tourism (E9) and represents a mobility experience (E7).

4.5. Procedure for the Implementation

Based on the discussions with the experts in the case study, important steps for implementing autonomous shuttle buses are identified and necessary. First, the project participants agree on an area of operation, which is then planned in more detail. The local conditions, the capabilities of the vehicles and, for example, the desired operating times play a role here. Afterwards, it is important to take a closer look at the possibilities in the context of the existing local public transport system (E7). At this point, contact is often made with the vehicle manufacturer, who will analyse the usefulness and feasibility of the route suggestions in detail (E9). In the context of implementation, political support and possible subsidies are also important (E7). In the further implementation process, the concretised and planned route is programmed in the system of the autonomous shuttle bus and leads the shuttle on a "virtual rail track" from now on. External analyses and test drives also follow in cooperation with the testing institute and the vehicle manufacturer (E9). Finally, the vehicles are approved by traffic law (E6 & E7). The entire process ideally takes 9-12 months. An overarching theme is also raising awareness and creating acceptance among passengers, especially in alpine regions (E2).

5. Discussion: Factors for the Implementation of Autonomous Shuttle Buses

The introduction of autonomous vehicles in public transport can be a challenging task due to limited autonomous ability to react in case of traffic obstacles or unpredictable situations (see Section 2.4). The introduction thus requires consideration of economic aspects, social acceptance, and technological and technical feasibility (Derer & Geis, 2020). In this context, the potential field of application is of particular importance. In addition to the aspects above and user needs, aspects such as the vehicle's performance and the legal situation are important for the selection of the area (Beiker, 2015). It is recommended to pay attention to diverse scenarios with regard to users and application or operating situations in the implementation phase, taking into account realistic feasibility (Beiker, 2015).

Therefore, the authors worked on the answers to the research question: *How can autonomous shuttle buses be planned and implemented in order to initiate innovative and soft mobility in a tourism destination?* Based on our investigation, the methodical diversity in a mixed-method approach is important to accompany the implementation of autonomous shuttle buses. This includes considering the spatial data and existing infrastructures for identifying possible routes and scenarios. Accordingly, the on-site spatial inspection is crucial, especially to document the traffic situations and thus to have a starting point for considering aspects of feasibility. In addition, it becomes clear that for some routes, the cooperation of various project participants or destination stakeholders is necessary for potential implementation. The qualitative interviews with the experts were of great importance for this overall process. It is also advisable to talk to different local stakeholders for route identifications that are not always part of such elaborations.

Further factors should be discussed to support the implementation of autonomous shuttle buses:

1) **Tourists' attitudes:** Out of the tourists' interviews, a positive attitude towards environmentally friendly mobility is visible. However, the typical use of means of transport on-site shows a focus on the private car. This divergence between expressed and associated actions is called the "attitude behaviour gap" in the academic context of behaviour explanation (Blake, 1999). This attitude-behaviour gap and the necessity for a mobility transformation shed light upon autonomous shuttle buses and their potential in tourism

destinations. The fact that tourists would use the autonomous shuttle buses at Lake Königssee, even though some of them typically use cars as a means of transportation, shows the potential impact of this mode of transportation. This is significant for strengthening innovative tourism mobility and sustainability transition, especially because mobility patterns and symbolic values are part of the sociotechnical system and can impact transition developments at the landscape level (Geels, 2002, 2004). This transition can be achieved either by intrinsically motivated (voluntary) behavioural changes or changed mobility patterns, or by extrinsically motivated coercive situations such as access restrictions. Overall, an interplay of different measures will likely be necessary. The implementation approaches defined in this paper can provide impulses for this. The recorded positive attitude and high propensity to use autonomous shuttle buses support that tourists on vacation are more open to trying innovative means of transport, such as autonomous shuttle buses and thus increasingly use more sustainable forms of mobility. Attracting users on a regular basis is considered a long-term task.

2) **Objectives:** The implementation of autonomous shuttle buses must be well thought out in terms of tourist usability. Above all, this usability should be a major objective as acceptance by tourists is a critical success factor. Mobility needs must be considered when designing the transport system in order to minimise the use of time and environmental resources (Beckmann, 2016).
3) **Possible areas**: Autonomous shuttle buses can be used in different application fields. For example, to connect train stations with bus stops or to connect certain neighbourhoods or areas by means of flexible on-demand operation (Canzler et al., 2019). Against the background of different user needs and application fields, different scenarios arise (e.g. for tourists in a tourist setting or employees on a demarcated company site). These are also driven by the different sizes of the vehicles and the predicted demand. For instance, larger vehicles in urban areas or small vehicles in rural areas (E9). Autonomous shuttle buses will not replace conventional public transport but will go hand in hand with it and contribute to complementing it (E8). Over time, their importance in public transport will increase, which can be attributed primarily to the advantage of flexibility (E7).
4) **Traffic solution:** In the spatially limited Berchtesgaden valley, however, motorised mobility is accompanied by negative side effects such as traffic jams, full parking lots, or resulting tensions with the local population (E5). In some cases, public transport is in high demand (E4) since the guest card allows free use. At this point, it is also worth noting an expert's argument that passenger cars with more environmentally friendly drives do not change the parking or congestion problem. Hence, public services with high capacity and frequent departures help to cope with these challenges. Autonomous shuttle buses can support here. They can also address the less economical operation of routes with larger vehicles (Kolb et al., 2020). With regard to economic traffic operation in less demanded districts, an on-demand operation would presumably offer the connection of the main and the side tracks in order to connect the accommodation businesses existing there also at off-peak times.
5) **Vehicle features**: Not all implementation scenarios are feasible yet due to current vehicle features, as Rentschler et al. (2020) stated. In the local context, challenges arise primarily due to topography or the high volume of visitors. Depending on the route, this would either mean a high number of vehicles or the shuttle buses could only be used as a line reinforcement. With regard to the economical use of resources for transport system design, this is an important issue to be resolved. Ultimately, developments are always dependent on the state of vehicle technology, which is why comprehensive use of autonomous shuttle buses will only be possible in the future.
6) **Mode of operation:** Autonomous shuttle buses are so far often assigned as suitable vehicles to serve the first and last mile or to operate during off-peak hours with little demand due to their small size (Jürgens, 2020). During peak times autonomous shuttle buses can serve as supplementary transport, to cope with the high demand. However, future vehicle generations could meet current requirements in terms of capacity and speed and thus replace currently scheduled buses, if necessary. If the current vessel sizes remain, however, the exclusive use of autonomous shuttle buses should only be considered for less busy seasonal periods in order to avoid having to provide a large fleet size that makes little economic sense. In

terms of further planning of the operational service, a decision needs to be made, also in the context of current capabilities, as to whether operations in the local context will be based on a fixed-line principle or a more flexible on-demand operation.

In summary, those factors need to be considered for implementing autonomous shuttle buses in tourism destinations. However, it is crucial to notice that the presented processes here are case-specific and need local adoption, e.g. with regard to spatial characteristics, local stakeholders, the structure of the destination and existing public transport, as well as the adaption to current technical possibilities.

6. Conclusion

This article focused on tourism mobilities with the sustainability (mobility) transition. Taking into account the mobility patterns and challenges in local tourism development, the study elaborates on the potential and barriers of implementing autonomous shuttle buses in destinations.

6.1. Contribution

Reflecting the innovative capacities of destinations, the implementation of autonomous shuttle buses could change tourism mobility inside a destination to a great extent. Autonomous shuttle buses are promising for improving tourists' movements in tourism regions by combining innovative spirit, environmental friendliness and experiences. As there is limited research on the implementation of autonomous shuttles in complex regional contexts like those of destinations, this study shows the uniqueness of the holistic planning and implementation of autonomous shuttle buses. Therefore, the case study with investigations from the region Berchtesgaden-Königssee, Germany, contributes to the practical discussion on technology implementation in a regional context, but also to combining mobility research with tourism and innovation. For conducting practice-oriented research, this study is a blueprint for analysing such complex issues in a multi-method approach by considering various experts to plan appropriate routes and cope with technical factors. The results introduce planning steps and reveal the importance of experience and theme design in addition to several technical challenges.

6.2. Theoretical implications

The research question on planning and implementing innovative and soft mobility implementation reveals underlying theoretical discussions at the interface of mobility in tourism destinations and the implementation of technological innovations. The user acceptance of such an innovation has been a topic for several research projects, particularly with references from autonomous driving (see Section 2.3). Then there is also the tourism component with the strive for unique experiences and mobility needs, where studies aim to understand the customers' reactions to current and future technologies (Ivanov & Webster, 2020). However, autonomous shuttle buses are influenced not only by the technical side, but also by a social component, which refers to studies on the peoples' requirements for public transport (see Section 2.1). Besides analysing user perceptions and requirements, the development of such applications often goes hand in hand with the rearrangement of the underlying operations and the customer touchpoints - calling to include the service and infrastructure providers in this discussion (Spencer et al. 2012). Therefore, a research field opens at the interface of autonomous mobility, public transport and tourism experiences that is highly relevant for practice.

6.3. Practical implications

The implementation of autonomous shuttle buses depends on route-related as well as general aspects. In terms of routes, there are individual aspects, such as the more complex traffic situations on the route from *Berchtesgaden station to the Königssee bus stop* or explicit weather-related challenges on the *route to the Kehlsteinhaus*. In the context of general aspects, a further differentiation can be made between aspects concerning the design of the final product for the passenger and those concerning the implementation of the operation. The final product for the passenger is characterised by topics such as user-friendly access to innovative soft mobility, in which digital services or the design with regard to certain topics and experiences, such as soft travel, are of great importance. In the context of implementation, the influence of aspects of current vehicle characteristics and limitations of these to meet locally existing challenges become clear. These are important because they directly influence the feasibility of deployment scenarios. With regard to further design, it has to be decided, also in connection with the current possibilities, whether the operation should be based on a fixed line principle or a more flexible design.

A total of eight route ideas were identified during the study. Autonomous shuttle buses can address various mobility needs of tourists, for example with regard to a barrier-free last mile to Königssee or more frequent connections (e.g. *Rathaus Unterstein-Königssee bus stop*). In principle, all routes for which the knockout criterion is not currently reached are (probably) feasible according to our investigation. However, the routes with the highest utility values, as defined in the value-in-use analysis and mentioned in the previous section 4.2, offer the potential for a strategic integration and use. Based on all these aspects, implementation scenarios that offer the potential for the best possible integration as a soft-innovative mode of transport today and in the future can ultimately be developed.

Nevertheless, besides these mentioned aspects, it is important to take into account the local demand and the willingness to use the service. Therefore, conversations with potential users as well as with local stakeholders are of high importance. All things considered, a useful shuttle service with an important role in future (tourism) mobility can be created. The service will have the potential to obtain valuable effects both for the users as well as on a local level (e.g. in terms of environmental effects, tourism acceptance, and the tourism industry itself).

6.4. Limitations and future research directions

In summary, this paper created insights from various perspectives on the introduction and usability of autonomous shuttle buses in tourism mobility. Therefore, it contributes to understanding complex processes in implementing technological innovations in a multi-stakeholder setting. The results highlight the connectedness of the demand needs and the technological possibilities. With the upcoming progress in electric vehicles and autonomous mobility, the implementation of autonomous shuttle buses may be supported further and contribute to overcoming existing technical barriers. As this study is a concrete analysis in the region Berchtesgaden-Königssee, Germany, it is limited to the specific context and the state of technology in 2020. However, it could serve as a blueprint for future implementation studies. Therefore, future research should proceed to define the local requirements for environmentally friendly tourism mobility. This includes the mobility patterns of the locals and the tourists, as well as the capacities of service and infrastructure providers. Especially the mobility needs are changing towards more environmentally friendly modes of transport, which could be a chance for mobility innovations. Consequently, future research needs are rooted in the practical implementation gap at the interface of social acceptance, touristic experience, and technical considerations.

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