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Transportation Research Procedia 00 (2024) 000–000

Transportation Research Procedia

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26th Euro Working Group on Transportation Meeting (EWGT 2024)

Tour Bus Traffic Management: Enhancing Sustainability and Reducing Conflicts in Urban Areas

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Abstract

This study addresses the environmental and operational challenges associated with tour bus traffic in urban settings, focusing on Berlin's city center. Through the use of agent-based traffic simulation, various strategies are explored to mitigate pollution, noise, and waiting times while enhancing efficiency and reducing conflicts among stakeholders. Key findings highlight the effectiveness of measures such as designated parking spaces, maximum stopping times, and reservation systems in reducing emissions, optimizing routes, and improving user-friendliness. The study underscores the importance of coordinated efforts to promote sustainable and efficient tour bus transportation systems in urban areas.

Keywords: parking; parking search; transport simulation; MATSim; parking behavior; parking infrastructure; parking slot classification; reservation

1. Introduction

From the standpoint of emissions per passenger-kilometer, the tour bus is considered an environmentally friendly mode of transportation (Lin, 2010). However, the presence of idling engines and extended search times for parking has a detrimental effect on the otherwise eco-friendly profile of this transportation mode. Without a well-coordinated strategy for tour buses, including designated parking spaces and specified routes, unorganized tour bus circulation in Berlin's city center contributes to pollution, noise, and congestion. Consequently, conflicts arise among commuters, residents, and bus tourists.

Hence, the objective of this study is to formulate a cohesive tour bus concept aimed at mitigating pollution, noise, and congestion resulting from tour bus traffic and preventing conflicts among stakeholders, including commuters, residents, and tourists. Throughout the study, a simulation is employed to model various approaches to organizing tour

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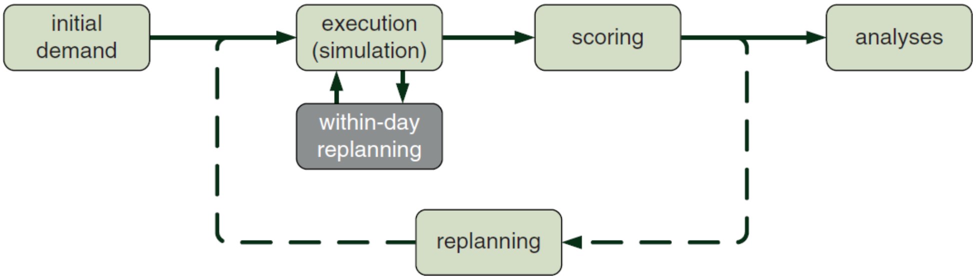

Fig. 1: (Iterative) within-day replanning MATSim loop (Dobler and Nagel, 2016)

bus traffic in Berlin. The simulation helps determine the reduction in emissions (specifically CO_2 and particulate matter emissions) and enhance the efficiency of tourist transportation for bus operators. Additionally, it helps to identify possible routes, parking locations, and drop-off points.

Most of the existing research in this field has either focused on the environmental impact of tourism in general (Russo et al., 2020; Lin, 2010) or on the planning of bus tours (Bagloee et al., 2017; Ko and Ko, 2023). The impact of parking locations for tour buses is only investigated by a few numbers of studies, e.g., in Beijing or Washington D.C. (Lin, 2018; Daniels et al., 2018). In summarize, this research field has some starting points, but still needs some investigations to find a fast transition to a less environmental footprint of this sector.

It is important to note that this work does not solely concentrate on tour bus traffic but also addresses inefficient operational structures, such as unnecessary trips during the search for parking, and explores ways to eliminate them. Therefore, this study investigates the consequences of implementing a bus parking structure by identifying different parking categories. This study only investigates touristic bus traffic which have stops with at least one exit of the passengers while the tour. This means that regular public transport, long-distance bus traffic and tours without stops are not considered in this study.

2. Methodology

This study can be split into different parts. The first part is to extend an agent-based simulation, which represents the touristic bus traffic in Berlin (Ewert and Nagel, 2023). While the study of Ewert and Nagel (2023) deals with various general parking strategies (e.g., centralized or decentralized parking), this study focuses on the classification of parking spaces. This means that the parking infrastructure currently available in Berlin will be adapted in such a way that a significant reduction in unnecessary bus trips to find a bus parking space is achieved. This contains three parts: the classification of the remaining parking spaces, the elimination of uneconomical parking spaces and the creation of new parking spaces. These parts are described in the following sections. The second part is to investigate the existing parking infrastructure in Berlin and to develop a modified parking infrastructure which is more efficient and sustainable. Additionally, the impact of a possible reservation system is investigated. These parts are described in the following sections.

2.1. Traffic simulation

To create this study, the agent-based traffic simulation Multi Agent Transport Simulation (MATSim) (Horni et al., 2016) is used to develop a model which represents the touristic bus traffic in Berlin (Ewert and Nagel, 2023). Therefore, the functionality of within-day replanning (Dobler and Nagel, 2016) (see Figure 1) is combined with the existing of parking search in MATSim (Bischoff and Nagel, 2017). This provides the advantage that the buses react to the current parking situation within one iteration.

2.2. *Modification of the parking infrastructure*

2.2.1. *Parking space classification*

The starting point of the classification of the parking spaces is the existing parking infrastructure for buses in Berlin, which is shown in the latest BusStop plan (Berlin Tourismus & Kongress GmbH, 2016). This infrastructure is shown in Figure 2. It is characterized by a large number of parking spaces, some with small capacities (1–2 spaces) and a small number of parking spaces with a parking time limitation. Due to the decentralized offer with partly low capacity, there is a risk with this design that buses drive to a parking space that is already occupied, so that the bus drivers have to continue searching. This situation was the starting point for the creation of the new parking infrastructure.

The main goal of this study is to reduce the search time for parking spaces and to ensure that the parking spaces are used efficiently. To achieve this, all parking spaces are classified according to their use. This means that parking spaces which are near a tourist attraction should not be used for long-term parking, so that the capacity is available for the drop-off or pick-up of the passengers. Therefore, we introduce three different types of purposes of using a bus parking space which results in these three different categories of parking spaces:

- **Drop-off points:** These parking spaces are used for the drop-off and pick-up of the passengers while they visit an attraction. The maximum parking duration is **30 minutes**.
- **Short-term parking:** These parking spaces are used for the parking of the bus for a maximum of **2 hours**.
- **Long-term parking:** These parking spaces are used for the parking of the bus **without a time limit**.

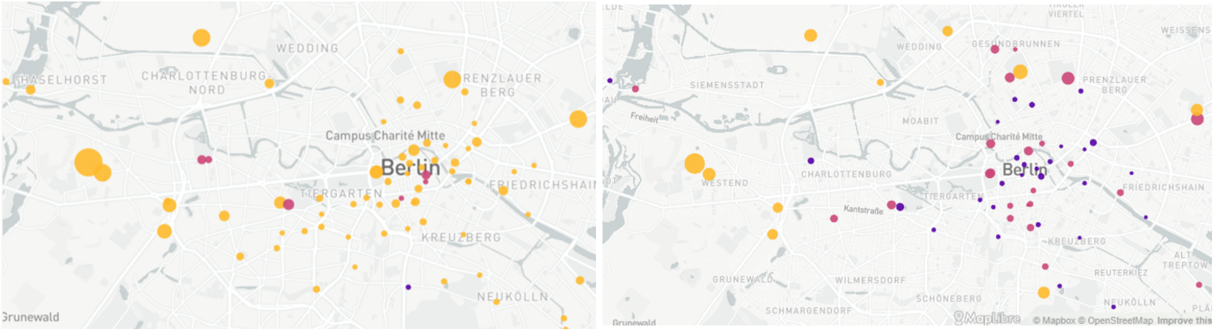

Fig. 2: Comparison of the existing (left) and modified (right) bus parking infrastructure in Berlin. The yellow parking spaces are long-term parking spaces, the red parking spaces are short-term parking spaces, and the violet parking spaces are drop-off points. The circle radius represents the capacity of the parking space. Source: Own plot using simwrapper (Charlton and Sana, 2022) software.

The base of the assignment of the different parking categories is mobile phone data kindly provided by Visit Berlin (2023) (see Figure 3). This data contains the share of the tourism activities for various areas, compared to the complete tourism activities in Berlin. Based on the intensities of tourism activities, the bus parking spaces are assigned to one of the categories. A description of the different classifications of the parking spaces is given in the following.

Drop-off points are parking spaces that are located in the immediate vicinity of a tourist attraction with a high intensity of tourist activities. These bus parking spaces are only used for passengers getting on and off the bus and for short stops of up to 30 minutes. Regarding the implementation in the simulation, it should be noted that 15 minutes are assumed for each boarding and alighting process. Considering that available space is limited in the metropolis of Berlin, especially in the inner-city area, an average distance of 300 m - 400 m walking distance between a drop-off point and an attraction is assumed to be feasible and acceptable for visitors.

Long-term parking spaces are parking spaces that are located outside the city center and are used for long-term parking. The idea is that passengers should leave the coach at attractions, where the drop-off points are generally located. The coach should then aim for a permanent parking space if the time it takes to pick up the passengers again after leaving the coach exceeds 2 hours. An important feature of a long-term parking area is the connection to the public transport network to enable the coach driver to continue the journey easily. Furthermore, it should be noted that the distance between the attraction and the long-term parking space is not relevant for the passengers because they leave the coach at the drop-off.

Short-term parking spaces are parking spaces for a short stay of up to 2 hours. When determining the short-term parking spaces, it is considered that the locations are predominantly in places with a medium tourist intensity and therefore no relevant sights are in the immediate vicinity. Furthermore, all drop-off parking areas have a maximum distance of 4 km from a short-term parking area.

2.2.2. *Elimination of uneconomical parking spaces*

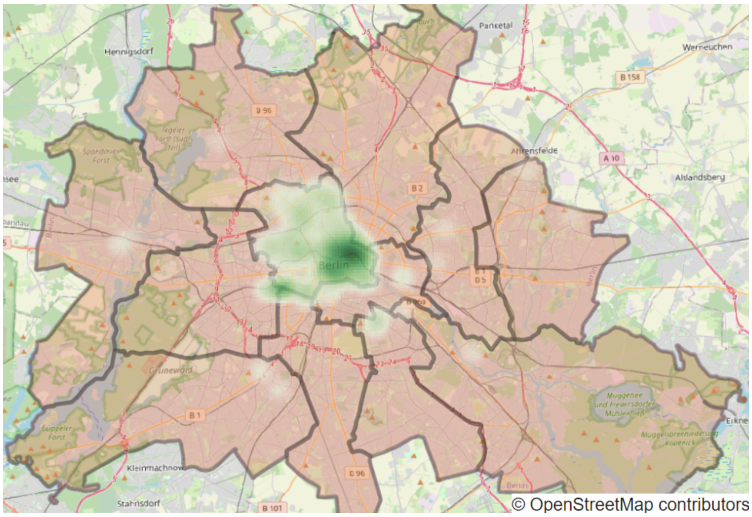

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Fig. 3: Visualization of the located hotspots of touristic activities in Berlin, data source: Visit Berlin (2023)

To assess the economic viability, all existing parking spaces have been evaluated individually according to the BusStop Plan in terms of their proximity to a tourist attraction. It is assumed that parking spaces that are located outside the city and having a capacity for fewer than four buses and are not close to a tourist attraction are generally uneconomical. The background to this is, in particular, that in the context of possible digital parking space booking, the costs for little-used parking spaces are high, and the expected benefit is rather low. In total, 41 parking locations with 103 parking spaces are eliminated in this way.

2.2.3. *Creation of new parking spaces*

New parking spaces are generated to compensate for the parking capacity lost as a result of the restructuring and the elimination of uneconomical parking spaces. Because many of the parking spaces in the city center have been converted to Drop-off points, the newly generated parking spaces are either long-term parking spaces without a time limit or short-term parking spaces for up to 2 hours. The assignment of the parking spaces to the different categories is based on the description in Section 2.2.1. For the newly added permanent parking spaces, it has been ensured that the number of parking spaces at this location is sufficient. Addidionally the accessibility of the new parking spaces has been observed. This ensures that the bus driver easily can take the public transport to travel to the hotel. This increases the attractiveness of the car park and makes it more likely to be used by bus drivers. The capacity of a new parking space has been calculated using the average length of a coach of 15 m and the length of the road along which the new parking space is added. In total, 10 new parking locations with 180 parking spaces have been created.

The result of the classification of the parking spaces is shown in Figure 2 and Table 1. Compared to the existing infrastructure, the number of parking locations has been reduced by 30% from 98 to 69. On the other hand, the total number of parking spaces at these locations has been extended from 607 to 690. The main difference compared to the existing infrastructure is that every parking space is now classified based on its purpose.

2.3. *Implementation of the parking search*

In this section, we explain briefly how bus drivers find parking spots in the simulation. Based on the available parking spaces (as described in Section 2.2), the bus driver can choose a possible parking spot. It is assumed that the bus driver exclusively selects from the available bus parking spaces and does not utilize other parking options (e.g., parking in the second row, violating parking restrictions or circling). Additionally, no personal experiences or preferences of the bus driver are integrated into the simulations (e.g., choosing a parking spot based on experience where they typically find a spot). Because this study also focuses on the reduction of conflicting situations between the bus drivers and other road users, the study does not investigate these possible parking behaviors. That means that only the following described parking behavior is implemented in the simulation.

Table 1: Overview of the current and the developed parking infrastructure in Berlin.

	Current Infrastructure				**Modified Infrastructure**			
	dropOff	short	long	total	dropOff	short	long	total
Parking Locations (existing)	—	7	91	98	33	16	8	57
Parking Spaces (existing)	—	34	573	607	125	189	196	510
new Parking Locations	—	—	—	—	—	6	4	10
new Parking Spaces	—	—	—	—	—	68	112	180
Total Parking Locations	—	7	91	98	33	24	12	69
Total Parking Spaces	—	34	573	607	125	257	308	690

Parking behavior. The basic implemented strategy is that the bus driver chooses the closest available parking space to park. According to the simulation, the closest means the parking space with minimal expected travel time from the current location to the parking space and back to the drop-off-becoming-pick-up location of the passengers. Depending on the configuration of the option for parking space reservation, this may lead to a different parking space. For example, without reservation, the bus driver chooses the nearest parking space from all available spaces, while with the option of reservation, they select the nearest still vacant parking space.

Parking space reservation. If the bus driver can reserve an available parking space, it eliminates the possibility of arriving at occupied parking spots entirely. A reserved parking space will always be free and will not be occupied by other buses. In the simulation, this rule is assumed to mean that once a parking space is reserved, it will stay available for the designated bus and will not be used by other buses.

3. Case study: Berlin

The case study is based on the city of Berlin, which is a popular destination for tourists. With around 14 million overnight guests in 2019, Berlin is one of the most visited cities in Europe (Senatsverwaltung für Wirtschaft, Energie und Betriebe, 2023). In our study, we focus on the bus tours with stops during the tour. Coming from a total number of 4.1 million relevant bus passengers in 2019 (Amt für Statistik Berlin-Brandenburg, 2020), we calculate with 239 bus tours per day in Berlin (Ewert and Nagel, 2023). In this study, we extend the work of Ewert and Nagel (2023) by investigating the impact of the classification of the parking spaces together with a reservation system. Therefore, we compare the simulation results of the base case with the results of the in Section 2.2.1 described classification of the parking spaces.

Additionally, we assume that the reorganization of the parking infrastructure has the consequence that the drop-off or pick-up at stops during the tour will take place only in bus parking spaces. The reason for this is to create a more safe and tidy situation. This is an important difference compared to the base case, which represents the current situation that the buses stop at the side of the road to let the passengers get off. In interviews with bus drivers and companies, we have learned that the drivers try to make the stop as close to the planned activity as possible. This study attempts to prevent this by establishing the drop-off points. Another assumption for the simulation is that the bus will wait at the nearest drop-off point until a space this free. The consequence is that if the drop-off point is occupied for a long time, the bus has to wait and the passengers cannot leave the bus.

To investigate the impact of the different measures, we set up different scenarios. They are split in the base case, single measures, and scenarios. The single measures should help to understand the single impacts being combined in scenario 1.

- **Base case:** Current situation in Berlin.
  - The bus stops at the side of the road to let the passengers get off.
  - The bus driver has no information about the availability of free parking spaces.
  - Current parking infrastructure.

- **Single Measure 1:** Exit and entry exclusively at bus parking spaces.
  - The bus stops only at bus parking spaces to let the passengers get off.
  - The bus driver has no information about the availability of free parking spaces.
  - Current parking infrastructure.
- **Scenario 1:** Exit and entry exclusively at bus parking spaces with new classification of the parking spaces.
  - The bus stops only at bus parking spaces to let the passengers get off.
  - The bus driver has no information about the availability of free parking spaces.
  - New parking infrastructure.
- **Single Measure 2:** New classification of the parking spaces.
  - The bus stops at the side of the road to let the passengers get off.
  - The bus driver has no information about the availability of free parking spaces.
  - New parking infrastructure.
- **Scenario 2 + 3:** Exit and entry exclusively at bus parking spaces, new classification of the parking spaces and reservation system (Scenario 3 with a doubling of the parking capacities)
  - The bus stops only at bus parking spaces to let the passengers get off.
  - The bus driver can reserve a parking space.
  - New parking infrastructure.

4. Results

The main results of the scenarios are shown in Table 2 as average values per tour. More results, visualizations, and analysis can be found on our website (Ewert, 2023).

Table 2: Simulation results of the different scenarios. The results are shown as average values per tour. The percentage values in brackets show the difference to the base scenario. Empty runs are the trips without passengers after a get off. The parking search distance is the distance from the get off until the bus successfully finds a parking space. The waiting time is the time the bus has to wait for an empty parking space for drop off or get in.

		Base Case	Single Measure		Scenario		
			1	2	1	2	3
Driven distance	(km)	36.6	28.6 (-22%)	35.8 (-2%)	32.1 (-12%)	31.4 (-14%)	31.3 (-14%)
Distance empty runs	(km)	9.7	2.0 (-79%)	8.9 (-8%)	4.9 (-49%)	4.3 (-56%)	4.1 (-57%)
Distance parking search	(km)	5.1	1.2 (-76%)	4.1 (-19%)	2.6 (-48%)	2.1 (-59%)	2.0 (-60%)
Duration Waiting time	(hh:mm)	00:00	08:12	00:00	00:29	01:01	00:02
Duration of parking space search per stop	(min)	4.9	160 (+3168%)	4.3 (-12%)	13.6 (+180%)	23.5 (+382%)	4.2 (-14%)
CO2 emissions	(kg)	26.6	20.6 (-23%)	26.0 (-2%)	23.4 (-12%)	22.8 (-14%)	22.8 (-14%)

Summarized, the main key results are:

- **Entry and exit exclusively at bus parking spaces requires mandatory classification of the bus parking spaces**. (Single Measure 1)

  The results show that, assuming that passengers only get off at bus parking spaces, the waiting times for a free parking space are excessively long. The waiting time is a result of the implementation in the simulation. For example, it is assumed that all bus drivers do not break the rules and that passengers are only let off at a free parking space. It is also assumed that the bus does not drive to a more distant parking space as an alternative to keep the walking distance as short as possible. The result is that a bus waits next to a parking lot until a parking space becomes available. In the simulation, this results in an average waiting time of 08:12 hours per trip. Of course, this value would not be observable in reality. However, the consequence would be that bus drivers would still let passengers get off outside bus parking spaces, which in turn would be against the rules and should be avoided. The reason for the long waiting times for arriving buses is that the buses can also park directly in the parking spaces, and it is therefore not possible for other buses to stop at this parking space as long as it is occupied by a parking bus. Accordingly, these results indicate that it is imperative to define the modified parking infrastructure when implementing alighting at parking spaces. For the bus users, this measure results in an increase in distance from the exit from the bus to the attraction (in average from 42m distance to 420m).

- **Implementing the modified parking infrastructure**. (Single Measure 2)

  If the parking spaces are assigned to suitable categories (drop-off, short-term parking, long-term parking), this reduces emissions. The simulation results show that 2% of CO_2 emissions (54.6 tons per year) can be saved in this way. However, the reduction in the distance traveled by empty trips is 7.9%; the discrepancy results from the proportion of the total trip accounted for by empty trips. The implementation of this parking infrastructure can be realized with little effort, as only the signage at the parking spaces would have to be changed, since no technical aids (capacity detection or reservation system) are assumed in this scenario. Especially if the goal is to implement a digital coach strategy, this step could be implemented before the start of an app and thus already save emissions by then.

- **By defining the maximum stopping times at the parking spaces, extreme waiting times at the bus parking spaces for passengers to alight can be avoided**. (Scenario 1)

  The average waiting times could be reduced to approx. 30 minutes per trip if forced drop-off/pick-up at parking locations (Single Measure 1) is combined with classifying the parking spaces, cf. Single Measure 2. This is because the heavily frequented parking spaces are no longer blocked by long-term parkers and are therefore available more frequently. Due to the remaining waiting times, the average duration of one parking search (driving to the parking space and waiting for an empty lot) increases from 4.9 min to 13.6 min compared to the base scenario.

- **A reservation system reduces the number of empty runs.** (Scenario 2)

  The results indicate that the implementation of a reservation system achieves benefits in terms of empty runs. The number of empty trips is reduced by 56% compared to the base scenario. This results in a 14% reduction in CO_2 emissions when a reservation system is included.

- **The capacity of the parking space is sufficient to ensure that stops are user-friendly.** (Scenario 3)

  The results show that if sufficient parking capacity is made available, the waiting time for buses can be reduced to an average of 2 minutes per trip. It is therefore to be expected that bus drivers would no longer need to do the drop-off in violation of the rules. In addition, the distance of empty trips would be reduced by 57% and the average time spent driving to a parking space would be reduced by 14% to 4.2 minutes. Furthermore, almost all parking activities could take place, whereas in the base scenario, 10% of all planned parking activities were canceled because no suitable parking space could be found (effectively buses kept searching for parking until they needed to drive to the pick-up point).

5. Conclusion and outlook

In conclusion, the simulations indicate that these strategies would reduce the traffic, improve air quality, and enhance the overall efficiency of coach operations in Berlin. This comprehensive case study highlights the challenges of managing coach traffic in a major city and provides actionable insights and strategies to address these issues, contributing to more sustainable urban mobility. It is also shown that these measures are only effective if sufficient parking capacity is ensured. If this capacity is not provided, the buses would likely (continue to) stop at unsuitable places to allow passengers to get off.

Continuous collaboration among city planners, transport authorities, and stakeholders will be crucial to adapt and refine these strategies, ensuring they meet the evolving needs of urban transportation. Future research should also explore the integration of these measures with other sustainable transport initiatives, such as electric buses, to further enhance the environmental benefits and establish a comprehensive approach to urban mobility management, primarily driven by the objective of achieving zero net greenhouse gas emissions.

In addition, future work could investigate different parking behaviours. For example, the effect of different proportions of different parking behaviours could be analysed. Based on the developed simulation, it is also possible to set a proportion of buses that can reserve a parking space, compared to the base case where no reservation is possible.

Acknowledgement. This work is part of the project “Reisebusstrategie für Berlin” in the Berlin Program for Sustainable Development (BENE) funded by the European Regional Development Fund and the State of Berlin (project number 1317-B5-O).

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