Low-emission Commuting with Micro Public Transport: Investigation of Travel Times and CO_2 Emissions

Marcel Ciesla[1], Victoria Oberascher[1], Sven Eder[1], Stefan Kirchweger[2], Wolfgang E. Baaske[2]
and Gerald Ostermayer[1]
[1]*Research Group Networks and Mobility, University of Applied Sciences Upper Austria, Austria*
[2]*Studienzentrum für internationale Analysen (STUDIA), Schlierbach, Austria*
https://nemo.fh-hagenberg.at/,
https://www.studia-austria.com/

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Abstract: The omnipresent trend towards sustainable mobility is a major challenge, especially for commuters in rural areas. The use of micro public transport systems is expected to significantly reduce pollutant emissions, as several commuters travel the first mile together with a single pick-up bus instead of their own car. In this paper, different aspects of such a micro public transport system are analyzed. The main findings of the investigations should be how the travel times of commuters change and how many CO_2 emissions can be saved if some of the commuters use public transport instead of their own vehicle.

1 INTRODUCTION

Mobility in rural areas is strongly influenced by individual traffic. Public transport is usually insufficient to meet commuter demands. The disadvantages for commuters are that public transport is mostly based on fixed stops, which means that they have to cover a way to a bus stop first. In addition, schedules of buses and trains are usually predefined, which means that individual commuters' needs may not be met. There are two different options for commuters to get to work. On the one hand, they can cover the entire route by public transport. Since stops such as bus stops are in many cases too far away to be reached on foot or by bike, the first distance to a train station can be covered with an own vehicle. This creates the so-called **first-and-last-mile problem**. However, since this is still too much of a hassle for many commuters, they drive the entire distance to work with their own vehicle. For the region, this means very heavy traffic at peak times on the commuter routes. This ultimately leads to traffic jams, time delays and increased carbon dioxide emissions. These problems can be counteracted by using a suitable micro public transport system for the commuters' first mile. People who want to get to work are collected by one or multiple buses and brought to a train station. Afterwards, they can use a train to get to their place of work. It is expected that with such a micro public transport system emissions can be reduced and fewer traffic jams occur due to the reduced commuter routes.

This paper deals with an approach to investigate the travel times and carbon dioxide emissions of a micro public transport system mentioned before. The remainder of this paper is organized as follows. At the beginning it is explained how the examinations were carried out. Afterwards, existing literature is reviewed which serves as the basis for our work. The next section describes the simulation setup which was used to perform simulations for different scenarios. The results of these simulations are presented in the following section. This section points out whether a micro public transport system is suitable for sparsely populated areas. In addition, a comparison between individual transport and micro public transport is made, which shows how much CO_2 can be saved when commuters use a micro public transport system.

2 METHODS

Existing micro public transport systems cannot satisfy the dynamic requirements of commuters and are therefore only hardly accepted. Therefore, the main objective of the project EBIM-ÖV (”Low-emission commuting with intelligent micro public transport”) was to investigate a micro public transport system for

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a sparsely populated area. An important aspect of this project was to figure out the benefits of micro public transport, where commuters share a bus with other commuters to overcome the first mile to a train station. Another focus was to find out to what extent commuters' travel times change using micro public transport, which has a strong influence on user acceptance. The base goals of the project can be divided into following sub-goals:

- **Mathematical Modelling of the Optimization Problem:** A sub-goal of the project was the realistic mathematical modelling of the optimization problem for the control of a ride service. The problem is to pick up customers from any location and bring them to a given destination, which is a train station. The optimization task consists in falling below a travel time that is acceptable for the user under very dynamic conditions. These conditions include different traffic situations and a varying number of customers with different pick-up points who are to be served by the system. The departure times of the desired train line play a particularly important role, as these times are decisive for when the commuters should arrive at the station.
- **Route Control:** With the help of mathematical modelling of the problem, an algorithm was developed that dynamically controls a vehicle fleet. This vehicle fleet consists of several buses with predefined capacities that are intended to satisfy the various pick-up requests. The task of the algorithm is to choose optimal routes and departure times of the buses so that the optimization criteria are met as good as possible.
- **Traffic Simulation:** Microscopic traffic simulations are used to validate the developed control algorithm. The focus is on determining the potential for saving carbon dioxide emissions and comparing travel times between individual transport and a micro public transport system for different scenarios.

Through the above-mentioned sub-goals, a system was created with the goal of simulating an intelligent micro public transport system. With the help of microscopic traffic simulations, scenarios were examined in which commuters get to their workplaces individually with their own vehicle and with the micro public transport system. The mathematical modelling of the optimization problem ensures that the routes of the pick-up buses are optimally chosen so that their total travel time is minimized and commuters' individual time constraints are satisfied. This has the effect of increasing commuter acceptance of a micro public transport system. When designing the simulations, the focus was placed on one train line per scenario. This means that only those commuters who want to catch the same train will be considered. It is not possible for a pick-up bus to serve commuters with different preferred train lines, as the different train lines are usually quite far apart in relation to the departure times and the commuters' travel times would therefore suffer as a result.

3 RELATED WORK

The ideal chemical reaction of fuel combustion chamber produces carbon dioxide and water and, as a result of the transient combustion process, additional combustion products. Consequently, fuel design holds a big potential for further improvements in reduction of unwanted combustion products (Überall et al., 2015). However, as long as one is not willing to completely change the method of transportation using internal combustion engines, carbon dioxide (CO_2) emission is always unavoidable. As a consequence CO_2 takes about 65% of the total greenhouse gas emissions, where the transportation sector currently contributes 20 -25% of global CO_2 emissions with its global share estimated to rise to 30-50% by 2050 (Yang et al., 2019).

At first sight one might think that alternative fuel vehicles such as all-electric and fuel cell vehicles will be the best solution to reduce CO_2 emissions. These fall into the category of cleaner vehicle strategies reducing emission rates per vehicle-kilometre. However, according to (Litman, 2017), efficient and alternative fuel vehicles only provide a few benefits, and by increasing total vehicle travel tend to exacerbate problems such as congestion, accidents and sprawl. Moreover one should be aware of the fact that for such vehicles one has always to take into account the full life time cycle (manufacturing, use of the vehicle, end of life, and recycling) (Marín and De Miguel Perales, 2021). Mobility management, i.e. strategies which reduce total vehicle travel, provides far more benefits.

Eco-driving, a term used for driving assistance techniques that support the driver in optimizing route choice and driving behavior, is a cleaner vehicle strategy which is suggested in (Engelmann et al., 2020). In their study they incorporate a vehicle dynamic based CO_2 emission model and a Pareto-optimal based routing approach and discuss the benefit trade-off between travel time and emission in a simulation study. Similarly (Engelmann et al., 2020) discusses emission optimized routes in terms of NO_x using the GraphHopper API and OpenStreetMap. In all evaluated cases (Engelmann et al., 2020) there was no NO_x-optimized route found for which the estimated travel time is less than with a speed-optimized route calculation and this is a general observation in eco-driving.

Shifting travelers' travel mode from the private car to public transport is another effective method of reducing CO_2 emissions and easing traffic congestion (Yoshida and Harata, 1996) belonging to the category of mobility management. This was investigated in (Yang et al., 2019) (Li and Tamura, 2003) for CO_2 emissions produced by commuters. To avoid an increase in commuting CO_2 emissions in Chinese cities, car use restrictions and transit priorities are the most important traffic demand management measures to be considered (Yang et al., 2019). Moreover (Li and Tamura, 2003) describes a CO_2 emission forecasting model for estimating the amount of CO_2 emissions due to urban commute travel and analyses the effect of two policy changes, cutting down public transport fee and decreasing in-vehicle time, to shift commuters' travel mode from private car to public transport.

Another way as is done in this work is to provide additional service feeder buses which operate on demand and try to address as many commuters as possible by using time optimal routes under real traffic conditions respecting the individual in-vehicle time restrictions of the commuters since commuters tend to take time optimal routes and not emission optimal ones from eco-driving.

4 SIMULATION SETUP

The whole simulation process is based on the interaction between two independent simulation entities. On the one hand, a traffic simulator called TraffSim (Backfrieder et al., 2013) (Backfrieder et al., 2014) has been extended and adjusted to the requirements of this project. This traffic simulator is a powerful tool which is able to integrate road networks from OpenStreetMap data and to perform traffic simulations in a microscopic way. For this project, TraffSim has been used to analyze a micro public transport system in a certain region under real traffic conditions.

On the other hand, a linear optimizer has been developed, which deals with a Dynamic Dial-a-Ride Problem. This optimizer receives current state information from TraffSim about routing costs and pick-up requests. The problem solver computes the optimal amount of pick-up buses and their starting times from the bus depot. Furthermore, the order of the pick-up requests is determined in which the requests are to be processed by the respective bus. These results are then used by TraffSim to simulate realistic scenarios for the micro public transport system.

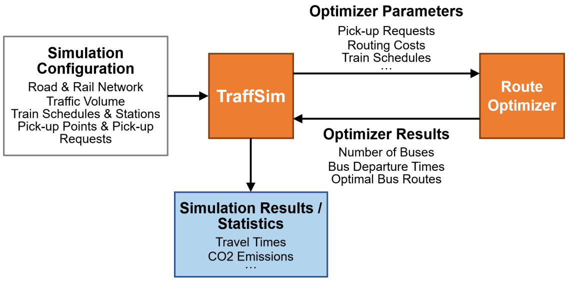

Figure 1: Interaction between TraffSim and Route Optimizer.

As illustrated in Figure 1, these simulation entities interact with each other so that the results of the optimizer are applied to a scenario in the traffic simulator. Data regarding traffic volumes and commuters have been provided by the project partner STUDIA. How this data was collected and processed for TraffSim scenarios is described in the next sections.

4.1 TraffSim

The microscopic traffic simulator project TraffSim has been enhanced to simulate the micro public transport system described in this paper. The following sections show how the different input types of the simulator have been configured.

4.1.1 Study Region

The study region consists of the municipalities Kirchdorf, Micheldorf, Schlierbach and Inzersdorf in the South of Upper Austria. There is one main train line going toward the Upper Austrian capital Linz and a motorway where you can head to Salzburg, Passau and also Linz. The region is rather rural, with the provincial town of Kirchdorf. A lot of people find work within the region but a big punch of people must commute out, in particular to Linz and between. In order to do our analyses we split the region in a raster grid with 250 by 250 meter grid cells. The used data and the analyses of the spatial distribution of roads and railway as well as traffic and commuters is described in the following sections.

4.1.2 Road and Rail Network

To build up a road network which can be used by TraffSim, data from OpenStreetMap (OSM) has been processed. OSM data contains information about roads and rails including their geometries, speed limits and lanes as well as junctions between the road segments. The traffic simulator uses a library called osm2po to create a routable directed graph from this

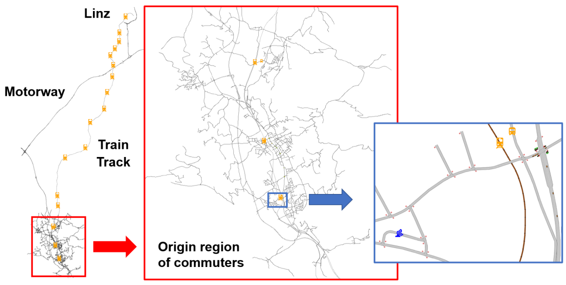

Figure 2: Road and rail network.

data, which can be used afterwards to determine routes and travel costs. Figure 2 shows the processed road and rail network in TraffSim which represents the mentioned study region. In the left part of the figure, the whole region including the commuter routes on the motorway and train rails can be seen. The blue box shows a more detailed section of the road network, where the blue icon represents a pick-up point. From such a point, customers are picked up by a pick-up bus and are delivered to a train station. Furthermore, the blue box contains a train station visualised by a yellow icon on the train tracks and the corresponding bus stop also represented by a yellow icon on the road.

4.1.3 Traffic Situation

In order to obtain meaningful results in terms of travel times and emissions, a realistic mapping of the traffic was an important aspect of the project. Especially in the morning, when commuter routes are heavily used, there can be traffic jams and delays. In order to be able to simulate this morning traffic we identified all geographical points where vehicles can enter (starting or entering point) or leave (stopping or leaving point) the simulation area in TraffSim. For each of these points the number of cars are calculated using rasterized data of principal residence within the study region, provided by Statistik Austria (Austria, 2016), the Upper Austrian traffic census, provided by the provincial government of Upper Austrian (Amt der OOe. Landesregierung, 2012) as well as a rasterized freely accessible land use plan of Upper Austria. Whereas the traffic census data gives us the municipality of origin and destination, the hour of departure as well as the used means of transport, the raster data and a randomization algorithm allows us to distribute the traffic spatially explicit within the region. Afterwards, this data is diluted with the coordinates of the enter and leave points. This results in a source-destination matrices for every departure hour consisting of each enter and leave point. These matrices were then mapped onto vehicles and routes in TraffSim.

With regard to the microscopic modelling of each individual car, the following assumptions were made. The Intelligent Driver Model was used as the longitudinal model. More detailed descriptions of the model and its mathematical basis can be found in (Treiber et al., 2000). In order to calculate the fuel consumption and, as a result, the CO_2 emissions of vehicles, the physics-based consumption model from Treiber and Kesting was used. When using this model, it was assumed that each vehicle has a mass of 1500 kg and is powered by a diesel engine with a power of 90 kW. More detailed information on the consumption model can be found in (Treiber and Kesting, 2013) .

4.1.4 Commuters

We use a rasterized dataset of commuters, provided by Statistik Austria (Austria, 2016) and the Upper Austrian traffic census, provided by the provincial government of Upper Austrian (Amt der OOe. Landesregierung, 2012) in order to identify commuters place of origin (grid cell), their chosen train number and their destination train station. Our investigations focus on commuters who travel by car or train towards the Upper Austrian capital Linz between 4:00 and 10:00 in the morning. A randomization algorithm is used to select those commuters who possibly use a micro public transport. As this information is so far only available on grid cells level, realistic pick-up points are achieved by distributing the commuters uniformly within the grid cells. Then, a set of multiple pick-up points was defined for the entire area, which the bus will use to pick up the commuters. The entire commuter locations were then assigned to the closest pick-up point. The Euclidean distance was used as the metric for the assignment. After the data was grouped according to the desired train line, the result was a **set of pick-up points** with assigned commuters, which are also called **pick-up requests**. If a pick-up point has not any requests assigned, it is simply ignored for this train line and will not be approached by the pick-up bus.

4.1.5 Train Schedule

For the implementation of the EBIM-ÖV scenarios, trains and timetables also had to be implemented. Therefore, we used real timetables from the Austrian Federal Railways (ÖBB) (ÖBB, n.d.). From this train schedule, all relevant train stations from Micheldorf to Linz Central Station have been included in the TraffSim scenarios. By inserting the real train schedule, it is guaranteed that the commuter train times correspond to reality.

4.1.6 Pick-up Buses

The route optimizer (see 4.2) provides the start time for each pick-up bus and the order in which the pick-up requests are to be picked up. All buses start at a bus depot near the train stop in Kirchdorf. As soon as the bus leaves the depot, the micro public transport system calculates expected arrival times at the pick-up points and train stations where the requests are delivered. These times are based on the routing costs of the current bus route, which originate from the graph. These times are updated at regular intervals (e.g. 60 seconds) and communicated to the users. The first promised pick-up time for the requests plays an important role. Since the users of the EBIM-ÖV orient themselves at this point in time, the first promised pick-up time is also used to calculate the travel times. This means that the travel time with the micro public transport system results from the difference between the first promised pick-up time and the arrival time with the train at the respective destination train station. In addition, the first promised pick-up time is also important for the pick-up process itself. If the bus arrives at a pick-up point before the first promised pick-up time has passed, it must wait until then before it is allowed to continue. With the pick-up buses it should be noted that the standing times at a pick-up point or a train station depends on the number of passengers who want to get on or off at this stop. The standing time results from the sum of a constant value (12 seconds) and a factor of 6 seconds per passenger who gets on or off. For example, if 3 people want to board at a pick-up point, the bus will stop for 30 seconds.

As with normal traffic (see 4.1.3), the Intelligent Driver Model was used as a longitudinal model for the buses. As far as fuel consumption is concerned, the physics-based consumption model from Driver and Kesting was chosen again, but with different parameters. A Mercedes-Benz Sprinter Transfer 45 with 22 passenger seats and an engine of 105 kW served as the basis for selecting the parameters (Mercedes-benz Sprinter Transfe, 2022).

4.1.7 Comparison between Micro Public Transport and Individual Traffic

One of the main aims of the project was to find out how much CO_2 emissions can be saved with a micro public transport system and how travel times change compared to individual transport. To achieve this, several simulation scenarios were created in which every commuter drives with his own car to his or her desired destination train station. For this purpose, the places of origin and destination stations from the commuter data (see 4.1.4) were used again to generate an individual vehicle for each commuter.

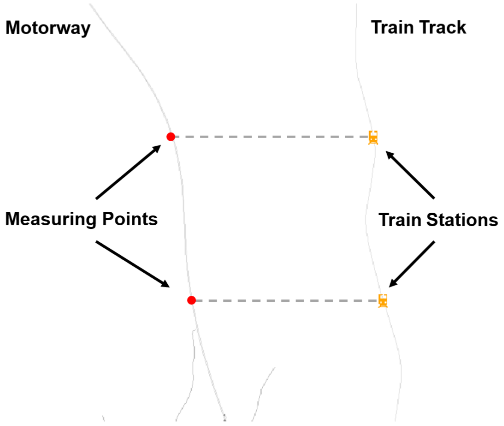

Figure 3: Measuring points for CO_2 evaluation.

In order to make a meaningful comparison between micro public transport and individual transport, certain measures had to be taken. On the one hand, the departure times of the commuters had to be chosen so that they arrive at the desired destination station at around the same time as the train of the respective train line itself. This ensures that the high traffic volume on the commuter routes is realistically reproduced and that the same traffic conditions for the comparison are given. Another aspect was that there was not always a corresponding motorway exit on the tracks for each destination train station. The commuter routes in the road network only consist of the motorway and the train tracks (see 4.1.2). As illustrated in Figure 3, a suitable measuring point on the motorway was defined for each destination train station on the rails. As soon as a commuter who would like to reach a specific station by train crosses this point with his car, the vehicle's statistics are saved at this point in time. These statistics include the time of arrival at the measuring point and vehicle-relevant values such as CO_2 emissions and consumed fuel.

4.2 Route Optimizer

A customer request is defined by a number of persons who want to reach a certain train line in time. Thus the target train station is not fixed at the outset. Moreover, in time means that a person is not only able to reach the train but also his travel time should not differ too much from the travel time experienced with his own car. The task is to find bus routes for a fleet of buses with given capacity which minimize the total travel time of the buses where each bus picks up the customers from predefined locations such that at the end the customers are satisfied. Since the departure times of the busses is determined by the optimizer, the time window for the emergence of the pick-up requests ends with the execution of the optimization.

To solve this problem we mapped it to the Dial a Ride problem (DaRP) using its 2-index formulation as given in (Ropke et al., 2007). Since this is not straightforward to solve by general purpose optimization software we developed a modification of it which used only a subset of the precedence constraints. The route optimizer itself is a Python module able to communicate with TraffSim which solves the DaRP in its mixed integer linear programming problem (MIP) formulation using the Python-MIP Package (Python-MIP, n.d.) together with the MIP solver Gurobi (Gurobi, n.d).

We applied several heuristics to simplify and solve the MIP problem. First we define the train station which can be reached in the shortest time from the pickup location as the target train station, to avoid the solution of several DaRP problems. Only in the case of a small deviation in travel time to another train station, which was about 1.5 minutes in our setting, we checked if better results are obtained by using this train station as target. Here small has to be seen in relation to the acceptance times of the customers. These were modeled by the shortest time needed to reach the target train station plus some customer specific delay, which is at least as large as the time needed to walk from the bus station to the target train station to enter the train. Then the acceptance time constraint is not satisfied if the difference of train arrival time and promised pick-up time is greater than the acceptance time. Observe that this delay has to be increased until the fleet size of the solution is equal to the required fleet size.

Secondly, pick-up requests having the same pickup point and the same target train station are mapped to a virtual customer request where the number of persons equals the sum of persons from each request and the acceptance time is the minimum of acceptance times for each request.

Thirdly, we applied a clustering of requests with respect to the train line and their target train station, because simulations without clustering showed that the solutions get clustered in exactly this way. The main reason for this seems to be the fact that the difference in train arrival times at the train stations are so small that the buses are not able to visit more than one train station without violating some of the constraints. This in turn allows us to use only a subset of precedence constraints as long as the pickup nodes are uniquely mapped to one bus. This was always the case in our simulations. Though it can happen that the delivery train station of the request is mapped to the wrong bus we can correct this by exchanging requests since in the cluster the target train station remains the same.

5 SIMULATION RESULTS

For this project, only outbound trips were considered, i.e. those where commuters travel to their workplace with the micro public transport system. The return trip was not considered in the course of this project. For the comparison between individual transport and EBIM-ÖV, different scenarios were simulated in which the number of requests varied. Several scenarios were taken into account, which consisted of 35, 50, 65 and 80 pick-up requests. Some of these requests could not achieve the desired acceptance due to unacceptable travel times. This is because these requests could not be optimally integrated into the route of a bus because of their geographical location. Pick-up requests with an unacceptable travel time were therefore filtered out from the results of these simulations. For this purpose, two threshold values were defined for the ratio of travel time with micro public transport to travel time with individual transport. The threshold values selected were 1.7 and 1.85, which means that with these limits all pick-up requests are selected for which the travel time with micro public transport is 70% or 85% longer than with one's own car. After the filtering process, further simulations were carried out in which only these pick-up requests were taken into account.

It was found out that the scenario with 80 pick up requests included 50 within the 85% threshold, whereas 37 requests were within the 70% threshold concerning the additional travel time with the micro public transport system. For these two subsets of requests, simulations were performed again and the results of these two simulation scenarios are presented in the next sections. Although the scenario with the 50 requests builds on the other, it should be noted that both are viewed as separate simulations. This means that, despite similar requirements for the pick-up buses, there can be differences in the calculated routes. Due to a random factor in the geographical distribution of commuters, it cannot be guaranteed that the same commuter will be picked up from the same pick-up point in both scenarios.

5.1 Travel Time Differences

The following two histograms in fig. 4 show the difference between commuter travel time with the micro public transport and with the commuter's own vehicle. The illustration on the right shows that 2 of the 50 requests with the micro public transport system were able to reach their destination station faster or almost as quickly as compared to their own car. This is because these two requests were quite a short distance from the train station to which the bus brought them. In addition, the bus picked them up at the end, which brought them straight to the train station without any detours. However, the commuters with the micro public transport system needed on average 14.1 minutes longer for the 37 requests and 14.6 minutes longer for the 50 requests than with the individual vehicle.

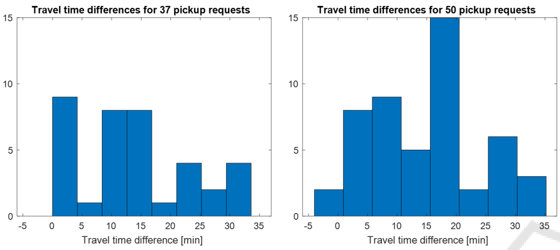

Figure 4: Travel time differences.

Since there is a connection between the travel time differences and the destination train stations, the travel time ratio of micro public transport to individual traffic grouped by the different destination stations is shown in fig. 5. The destination stations that are close to the source region (Schlierbach, Nussbach, Wartberg, Kremsmuenster and Rohr-Bad Hall) are subject to greater fluctuations in a direct comparison. The spatial distribution of commuters within the source region shows a high impact at these destination stations. Since the commuter travel time in their own car is usually very short at these train stations, even small time deviations due to the micro public transport system have a strong impact on the result. At stations that are further away from the source region (Traun and Linz), the spatial distribution of the pick-up requests plays a lesser role. Since the travel time ratios are almost identical for the 37 and 50 requests, it can be concluded that, due to the long total travel time, it does not matter where the commuters come from. Furthermore, it can be assumed that in the case of destination stations near the source area, the comparison is characterized by the longer travel time of the pick-up buses and in the case of more distant stations by the longer travel time of the trains. For the 50 pick-up requests, of which 12 had the destination station Linz, the figure shows a ratio of 1.5. This means that these 12 commuters took an average of 50% longer to get to their work place with the micro public transport system than with their own vehicle.

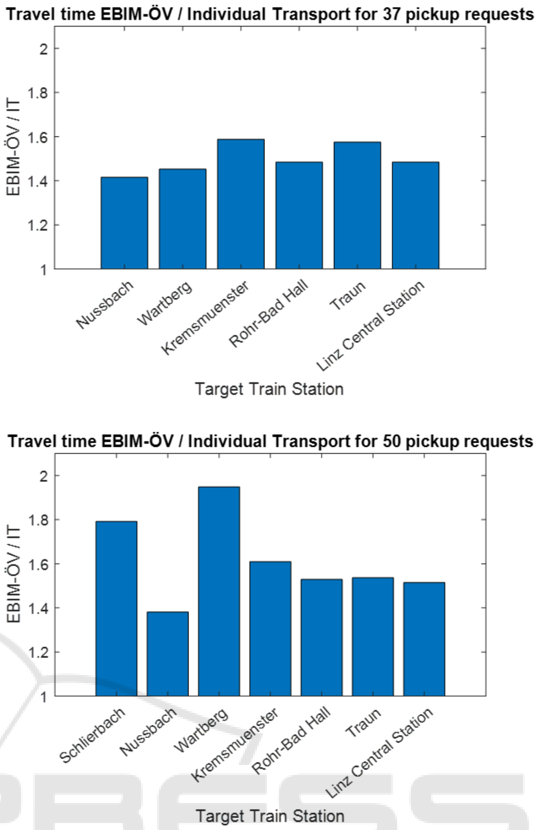

Figure 5: Travel time differences grouped by target train stations.

5.2 Carbon Dioxide Emissions

With the help of the fuel consumption models implemented in TraffSim, it was possible to measure the CO_2 footprint of every commuter when they commute to their workplace in their own vehicle. These values were required in order to be able to set up a CO_2 comparison between individual transport and the micro public transport system. The CO_2 emissions caused by the micro public transport system are made up of the emissions from the pick-up buses and those of the respective train. The CO_2 consumption of the pick-up buses was taken from the statistics of the traffic simulations. However, no model is implemented in TraffSim that can determine the CO_2 consumption of trains. The source for the CO_2 footprint of passenger trains was the sustainability report of the Austrian Federal Railways (ÖBB) from 2019, which defines an emission of 8.2 grams of CO_2 per person and kilometre. This information was used to determine the respective CO_2 emissions by train for each commuter, depending on the source and destination station. As a result, the entire CO_2 footprint of the micro public transport system could be calculated. In the simulation scenario with 37 requests, individual traffic resulted in CO_2 emissions of 154.7 kg. The micro public transport system, which serves the same commuters, causes a total of 18.1 kg of emissions, which results in a saving of 88.3%. In the second scenario with 50 commuters, 219.6 kg of CO_2 were emitted by one's own car and 20.8 kg of CO_2 by the micro public transport system. Here the savings potential is 90.5%.

Table 1: Detailed CO_2 footprint micro public transport system.

	37 Requests	50 Requests
Carbon footprint buses	12.3 kg	12.1 kg
Carbon footprint train	5.8 kg	8.7 kg
Total carbon footprint	**18.1 kg**	**20.8 kg**

5.3 Further Findings

5.3.1 Number of Buses and Their Occupancies

In the scenario with 37 requests and also in the scenario with 50 requests, three pick-up buses were needed. Each of these pick-up buses had a maximum capacity of 22 seats and the occupancies of the individual buses are shown in the following illustration in fig. 6.

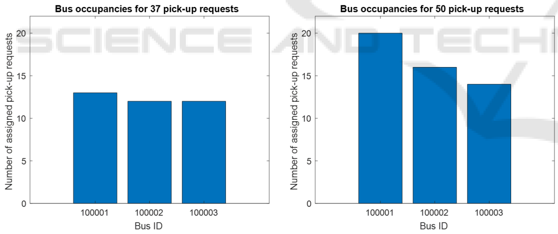

Figure 6: Bus occupancies.

5.3.2 Distances to Pick-up Points

The following histograms in fig. 7 show the distances that commuters have to cover from their place of origin to the assigned pick-up point. On average, the distance in the scenario with 37 requests is 258.4 meters and in the scenario with 50 requests 255.9 meters. As can be seen in both histograms, the commuters contain an outlier with a distance of 1259.9 meters, for whom there was no suitable pick-up point in his vicinity.

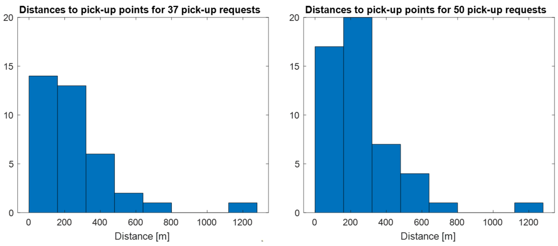

Figure 7: Distances to pick-up points.

6 CONCLUSION

In the course of the "EBIM-ÖV" project, different aspects of a micro public transport system were analyzed using a microscopic traffic simulator. By simulating commuter scenarios, in which commuters commute to work on the one hand with their own vehicle and on the other hand with a micro public transport system consisting of pick-up buses and trains, a comparison between the two types of mobility could be drawn. In summary, it can be said that a micro public transport system consisting of 3 pick-up buses with 22 seats each could find acceptance for the simulated test area. According to the simulations carried out, commuters have to accept that they have to walk about 257 meters to a pick-up point. Depending on the destination train station of the commuter, there is an increase in commuter travel time of 38% to 95% compared to the travel time with one's own car. It should be noted that the comparison for nearby destination stations depends heavily on the places of origin of the commuters. At the destination train station in Linz, which is furthest away from the source area, the travel time increased by 48% to 51%. The geographical distribution of the places of origin is less important here, as the travel time is much longer and is largely determined by the train. Provided that out of 50 commuters all commute with the micro public transport system instead of their own car, it can be said that over 90% of CO_2 emissions can be saved.

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