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Why closing an airport may not matter – The impact of the relocation of TXL airport on the bus network of Berlin

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Abstract

This paper investigates the closure of TXL airport and its impact on the bus network of Berlin. The results of the scenario are based on a co-evolutionary algorithm for public transit network design. The algorithm is integrated in a multi-modal multi-agent simulation. In the simulation, competing minibus operators start exploring the public transport market offering their services. With more successful operators expanding and less successful operators going bankrupt, a sustainable network of minibus services evolves. In the TXL scenario, the impact of the massive change in demand is found to be locally confined. Only transit lines serving TXL airport directly are affected. Furthermore, transit lines are found to have a higher probability of surviving if connecting two different activity centers, e.g. transit hubs. Following a hub-and-spoke approach by letting the line end in low-demand areas renders a line less attractive because of a reduced connectivity, e.g. to one train station only.

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Keywords: Demand Responsive; Evolutionary Algorithm; MATSim; Multi-Agent Simulation; Public Transport; Transit Network Design

1. Introduction

Major changes in travel demand such as are expected with the opening of the new international airport of Berlin and Brandenburg (BER, Germany) are difficult to overcome with traditional expert knowledge. The state-of-practice approach of the stepwise local optimization will not be sufficient to restructure the current transit network that is grown over decades. Especially, the existing airport Tegel will cease operations. Thus, transport planners face a completely new situation. Overcoming old habits, they need to recreate the bus network serving the area around the former airport from scratch. The only information available to them is the travel demand forecast and the road infrastructure that is already in place.

Analytic approaches to solve the transit network design problem include e.g. [1,2,3,4,5], and more recently [6]. However, most analytic approaches lack the ability of being applied to large-scale scenarios which is why heuristics are often used to solve real-world planning problems e.g. [7].

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The minibus model applied in this paper follows[8], [9], and[10] in the application of bio-inspired algorithms and metaheuristics[11]. But rather than solving one system-wide instance, the approach looks at a number of competing elements, each of them evolving according to its own optimization procedure. This is not the same as swarm behavior, where multiple instances cooperate to solve a problem e.g.[12], but rather related to co-evolution and evolutionary game theory e.g.[13,14,15,16].

In the model, transit line operators compete each other and evolve by applying the genetic operators of mutation and selection to their lines. Mutations include changing the line's route profile, its time of operation, and its service frequency. Selection is represented by each individual line's fitness. Vehicles are removed gradually from unprofitable lines and when no vehicle is left, the line dies out. With more successful operators expanding and less successful operators going bankrupt, a sustainable network of minibus services evolves.

At the end of each day, each operator calculates the revenue generated by each of its lines and the expenses related to these lines. Revenue is generated by collecting fares. The fare system allows for lump sums, distance-based fares, and combinations of both. Expenses consist of fixed costs and distance-based costs. Fixed costs cover expenses related to the vehicle, e.g. official operating license and driver. Distance-based costs, e.g. fuel, are summed up for each kilometer traveled by the operator's vehicles. Each operator provides as much services as it can afford. Operators thus transfer some of their profit to the passenger side. However, this is still far away from social cost pricing[17].

The algorithm is set up as a Stackelberg game[18], with the operators as the leading player and the passengers as the followers. The operators state their quantities in form of the provided capacity. The passengers choose their best response in form of the least cost path. Opposing the schedule by e.g. going the long way on purpose, will usually yield a lower utility for the passenger compared to the least cost path. Thus, this is not a valid option for the passenger side. The leading side of the operators can then proclaim the new quantities of the their schedule well knowing that the passengers have to follow.

The minibus model has been integrated in the multi-modal multi-agent simulation of MATSim[19,20]. The model has been verified through multiple illustrative scenarios that analyze the model's sensitivity towards different demand patterns, transfers, and the interactions of minibuses and a formal operator's fixed train line[21,22,23,20]. The minibus model's first application to a real world scenario in[24] focused on the creation and simulation of real minibus networks in South Africa.

This paper features the application of the model to a real world planning problem of a public transport company in Berlin, Germany. Instead of reconstructing a bus network from scratch as in the South African case, a major change in the demand and its effects on the bus transit network are analyzed. The relocation of the airport Tegel (TXL) to the new airport of Berlin and Brandenburg (BER) provides a background for this scenario.

2. Application

The Berliner Verkehrsbetriebe (BVG) is Berlin's main public transport company and runs all kind of services with the exception of the S-Bahn urban rail system. This includes bus services, the subway network, the largest tram network of Germany as well as ferry services.

2.1. Scenario description

As depicted in Figure 1, the scenario area is situated close to the center of Berlin. The detail shows the bus network for the scenario area and the location of TXL. Note that TXL is exclusively served by buses operated by BVG.

In this paper, the BVG-MATSim model for the year 2008 is used[25]. In brief, the model contains about 115,000 links, about 15,000 directed stops, 6.0 million agents, and 539 public transport lines operated by BVG and other companies of the city of Berlin and the state of Brandenburg.

To keep the running time of the simulation in bounds, the scenario is reduced to a 25 % sample of the population. In addition, all agents not passing through the scenario area are removed from the population. The remaining population consists of 306,842 agents. Since each of these agents actually represents four agents of the full population (100 % sample) the public transport supply is also altered: The capacity of each vehicle type is reduced to one quarter. The fare, the boarding and alighting delays for each vehicle type are increased by a factor of 4 accordingly. For a more detailed configuration of MATSim and the model itself, the interested reader is referred to[20] and[25].

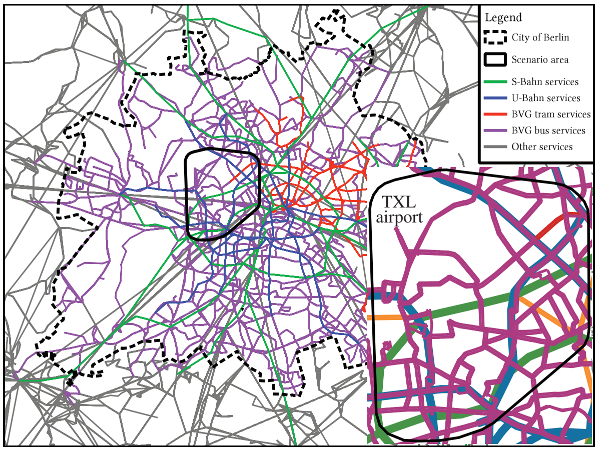


Fig. 1: Location and close-up of the TXL scenario area showing the public transport network — The category “other services” includes bus and tram services not operated by BVG as well as ferry services and non-commuter rail services.

In the base scenario, TXL is still operational. For further reference, this is called the *TXL* case. In the altered scenario, TXL is supposed to be closed. All activities located at TXL are relocated to BER. This assumes that travelers as well as employees will simply move to the new airport. This furthermore ignores changes in demand that are induced by e.g. a higher projected attractiveness of BER[26]. The altered scenario is referred to as the *BER* case. Figure 2 depicts all activities for the *BER* case. A total of 7,672 activities are relocated from TXL to the new airport of BER and are therefore not shown in the figure. In the *TXL* case, these activities form a singular source of demand which would by far dominate in Figure 2. Note that large parts of the scenario area surrounding the airport feature only a low density of activity. Thus, the high density spot at TXL is isolated from the rest of the city, e.g. the City West around the transit hub of Zoologischer Garten (Zoo).

Setups

The same input data and configuration is used with two different setups of the scenario called *Corridor* and *Area*.

The *Corridor* setup removes all four lines serving TXL from the transit supply. Namely these are 109, 128, the express bus X9, and the airport express TXL, see Figure 3a. Note that 109 and X9 both connect the transit hub at Zoo to TXL. Minibuses can only serve passengers within a 100 m wide buffer around the removed lines. That is, they can serve all formal transit stops within that buffer. They are not restricted otherwise. A minibus operator can decide to ply outside the buffer. In this case, its vehicles are not allowed to pick up or drop off any passengers as long as the vehicle is outside the buffer. In order to test for stability, the four removed bus lines serve as seeds for the initial minibus operators. That is, for each bus line one operator is initialized with approximately the same *route*, operating time, frequency, and capacity. Note that the all operators founded in later iterations are created from scratch.

The *Area* setup removes all bus lines operated by BVG from the scenario area. That is, lines operating only within the scenario area are removed completely. Lines starting or ending within the area are truncated so that they start and end at the first stop of the scenario area. The departures of the remaining parts of the lines are modified in such a way that the transit supply outside the scenario area isn’t altered compared to the original transit schedule. The final transit network of the *Area* setup is shown in Figure 3b. Again, the four removed bus lines function as seeds.

An *ensemble run* is performed for the *Corridor* and the *Area* setup. Each ensemble run consists of ten runs with identical configuration and input data. Only the initial random seed is varied. The heuristic of the minibus model is then able to produce different results with the same initialization. The results of the ten runs of one ensemble run are fused to allow for a more reliable analysis and to identify stable and repeating solutions.

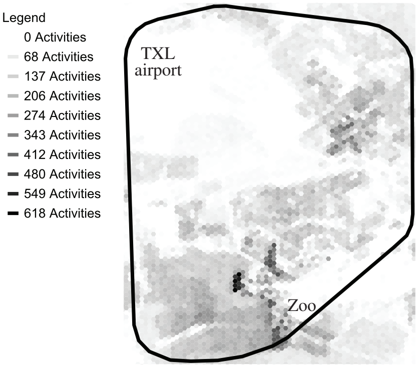
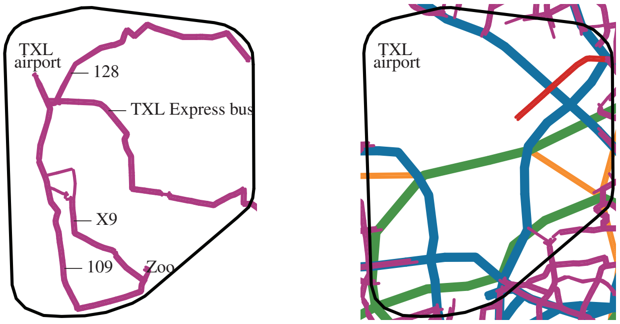


Fig. 2: Distribution of activities within the scenario area — *BER* case. A total of 7,672 activities are relocated from TXL to the new airport BER.



(a) All bus lines serving TXL are removed in the *Corridor* setup. These lines serve as seeds for the initial minibus operators.

(b) Public transport services in the *Area* setup. All bus lines operated by BVG within the scenario area are removed.

Fig. 3: Comparison of public transport service of the *Corridor* setup and the *Area* setup. Scenario area (black), U-Bahn services (blue), S-Bahn services (green), BVG bus services (purple) and other services (orange).

2.2. Results of the Corridor setup

The results of the *Corridor* setup are depicted in Figure 4. For the *TXL* case, all four transformed bus lines serving TXL prevail. In addition, there is a non-stop connection from the corridor of the TXL Express bus to the X9, denoted (a). This implies that from the point of view of the model, the formal service on this corridor, the bus line 245, could be improved. While this is not done, it is vulnerable to competition by minibuses. In the *BER* case, this non-stop connection is operated as well. However, the bus stop at TXL is not served anymore. The terminus of 109 and X9 is relocated to the U-Bahn station of Jakob-Kaiser-Platz (b), compare Figure 3b. The bus line 128 is reduced to the part between the U-Bahn station of Kurt-Schumacher-Platz (c) and its eastern terminus. The airport express is shortened to the S-Bahn station of Beusselstrasse (d) and only about half the capacity is offered onwards to the light industrial park (e). Apart from TXL, the rest of the network is unaffected by the closure of the airport. That is, in both cases, the same demand is served on the same corridors.

Since the opening of BER has been postponed only a few days before the planned opening date, information on the planned bus lines and routes is available. With the closure of TXL on 3 June 2012, BVG had scheduled the following changes for bus lines serving TXL[27]:

109 The terminus is relocated from TXL to the S-Bahn and U-Bahn station of Jungfernheide, denoted (j) in Figure 4b.

128 The terminus is relocated from TXL to the U-Bahn station of Kurt-Schumacher-Platz (c).

X9 This line is canceled.

TXL The TXL Express bus is substituted by a regular bus line. The terminus is relocated from TXL to the S-Bahn station of Beusselstrasse (d).

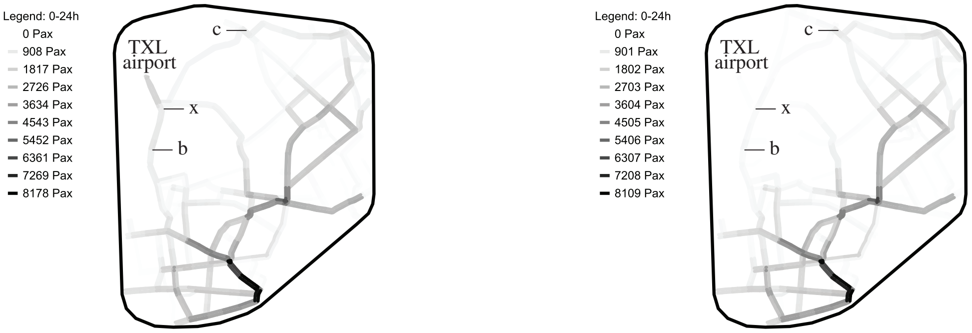
Overall, the scheduled changes of BVG match the outcome of the minibus model. However, the minibus model indicates that there is enough demand for maintaining X9.

2.3. Results of the Area setup

For the *Area* setup, the results, depicted in Figure 5, are basically the same. Although the minibus operators are allowed to search freely in the complete scenario area, the resulting networks look similar. Again, with the exception of TXL itself, the same demand is served on the same corridors. Differences occur on the branches from TXL to the nearest train station. While the TXL Express bus shows the same pattern as in the *Corridor* setup, the other bus lines

(a) *TXL* case (b) *BER* case

Fig. 4: Comparison of the average number of passengers served per street section of all ten runs — *Corridor* setup



(a) *TXL* case (b) *BER* case

Fig. 5: Comparison of the average number of passengers served per street section of all ten runs — *Area* setup

do not cease service completely. Recall that in the *Corridor* setup some formal bus lines are still present. These lines provide a direct connection from Jakob-Kaiser-Platz (b) to Kurt-Schumacher-Platz (c). In the *Area* setup, these lines are missing and their demand is served by the minibus.

3. Discussion and summary

The *Corridor* setup demonstrates that the closure of TXL does not affect the remaining bus network. Only the branches from TXL to the nearest train station are affected. Essentially, the *Area* setup provides similar results. The remaining network is unchanged showing very stable results with reoccurring solutions throughout the individual runs of the ensemble run. The impact of TXL on the public transport network is thus locally confined. The comparison with the projected changes of BVG reveal a close match with the minibus model's solution. However, information on the planning instruments and data used by BVG is not available.

Furthermore, the results of the *BER* case indicate that effective bus lines should connect centers of activity. A bus line may pass through low-demand areas, but still be profitable by offering more transfers to the rest of the transit network. Furthermore, this may provide a direct connection, e.g. between otherwise unconnected train stations as in the example of the corridor from (b) to (c). This further increases the connectivity of the network. In contrast, a hub-and-spoke pattern more likely looses this connectivity because of each bus serving only as a feeder. For example, the TXL Express bus terminates in the light industrial park and functions as a one-sided feeder to the train station of Beusselstrasse. It would attract more passengers if the terminus was relocated to a train station in the northwestern part of the scenario area.

4. Outlook

Current research focuses on a) the possibility of further reducing the population sample to 10 %, b) using standard buses with an enlarged capacity instead of the minibuses, and c) the application of the minibus model to the whole city of Berlin.

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