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A multi-agent approach

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Chapter 1

Large scale use of collective taxis: a multi-agent approach

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Abstract This paper reports on ongoing work aimed to estimate the potential use of collective taxis at large scale in urban areas as a mean to mitigate congestion and social exclusion. The methodology used to assess the potential of the system is agent based modeling. An existing open source software project, called MAT-Sim-T (Multi-Agent Transport Simulation Toolkit, http://matsim.org), has been enhanced within this project in order to allow the modeling of the taxi mode. Currently the way in which the taxi mode has been added is quite simple. A cost structure reflecting the implementation scheme of the taxi system has been defined. The simulated individuals (agents) will have this additional option and will choose it, or not, according to the generalized cost it generate for their schedules (plans). Even in this simple form the model allows for a preliminary estimation of the collective taxi potential. The results of a test case for the city of Zurich, a scenario with about 160'000 agents, are reported and discussed.

1. Introduction

In metropolitan areas the current transportation system, based on private car use, imposes a heavy burden on society in terms of energy consumption and external costs. Social exclusion is also an issue, as the system is inaccessible to various categories of people. All this calls for new solutions which would bring a more efficient use of the vehicle fleet. This paper reports on ongoing work aimed to explore the use of on-call collective taxi service as a mean to mitigate urban traffic problems. The concept of shared taxi is not new; however, its application has always encountered size barriers which are yet to be overcome. Collective taxis—or more in general—demand responsive transport, have been, and still are, sporadically implemented in Western countries; but their application is usually intended to answer to some special needs or to be used in some limited area. However, Demand Responsive Transports (DTR) are of on-going interest to the scien-
tific and policy making community since the widespread diffusion of some technologies, such as GPS devices and mobile phones, has opened new perspectives for DRT systems, and might help to extend their use to new categories of customers. Most of the recent literature on this subject goes in this direction (Khattak and Yim, 2004; Brake et al., 2007). However, none of these studies, maybe with one exception (Cortes and Jayakrisnan, 2001), is really trying to enhance the concept of DRT envisaging large scale use of the system. In contrast, the main claim of this paper is that the potential is there for the use of such services at a large scale in Western countries and that the implementation of such a system could help to reduce the use of private cars. In order to deliver such conclusions we needed to find, or to create, a suitable modelling framework for the assessment of the large scale collective taxi system. Traditional transport modeling does not seem to be well placed for this, having known limits assessing the potential of new transport modes in general and of innovative transport systems in particular (Shaheen and Rodier, 2004). Here, an agent-based micro-simulation approach is proposed. This allows to model the system at high spatial resolution, but also to consider the behaviour of single individuals. Agent based modelling is a suitable tool to implement direct interaction between demand (individuals) and supply (collective taxis) and therefore, predict the potential of the large scale collective taxi system and evaluate its operational feasibility. This approach is modular, thus flexible, and other analyses can be performed in the future, like the evaluation of policy impacts or the evaluation of societal costs and benefits of different scenarios.

An already existing simulation tool, MATSim-T (Multi-Agent Transport Simulation Toolkit, Balmer, 2007) is the basis for the work presented here. MATSim is an agent based activity-based traffic microsimulation tool, which produces individual daily transport demand as output. However, collective taxi was not considered as an option in the mode choice process of MATSim-T and has been introduced in the framework. The claim of this paper, thus, is to deliver two main scientific results. A preliminary analysis of the possibility to extend the use of collective taxi far beyond its current size limits and the effects that such a system would have in term of traffic mitigation; but also an improved evaluating tool, able to simulate different transport modes and assess their capacity to attract customers according to their characteristics.

This paper is organized in six sections. Motivations lying behind the idea of the implementation of a collective taxi system at large scale are related to environmental and social issues. This is discussed in Section 2. In Section 3 the description of MATSim-T is followed by a discussion on the possible approaches in which the toolkit can be enhanced in order to model shared taxis. Section 4 reports on a test case, a simulation for the city of Zurich in Switzerland. Details on the different implementations of the shared taxi system which have been tested are provided together with a description of the large scale simulation scenario. In this same section the results of the simulation are presented and discussed. Conclusions and an outlook on the future work are the subjects of Section 6.
2. Motivations

It is well known that the current transportation system imposes a heavy burden on society in terms of energy consumption and external costs such as accidents, noise emissions, pollution, space consumption, etc. But it is often neglected that this system also entails social exclusion, and that it is for different reasons inaccessible to various categories of people. The idea of collective taxi at large scale should be seen as a part of an effort to rethink urban travel and try to mitigate both problems. In particular, the goal is to find ways to substitute private car travel in a way which is more environmentally friendly and more democratic. The taxi system would be part of a global system where also other services, like car-sharing, car-pooling, bike sharing, etc., are also deployed at large scale. The integration of such systems should be a contribution to a major shift from private oriented, individually driven, urban transport; to more sustainable multi-modal shared transport.

2.1 Pollution reduction

The current discussion on car pollution mainly focuses on car emissions, in particular on carbon dioxide emissions. This is sound with many of the current studies on the topic since road transport is one of the major causes of this kind of pollution. According to the United Nations Framework Convention on Climate Change (http://unfccc.int/2860.php), the transport sector in western countries accounts for about 40% of CO$_2$ emissions. By far, the largest part of these emissions is related to road transport (in the USA for example 84%). However, if one looks to a broader definition of pollution and speaks more in general of environmental costs (other pollutants, the waste of materials, etc.), it has been assessed that a large part of the costs related to the use of the car are coming from its production, and not depending on travel. In fact according to some researchers (Umwelt und Prognose Institut Heidelberg, 1993), the largest part of the pollution related to a car life cycle is coming from its manufacturing, while a smaller, but not negligible, contribution comes from car disposal at the end of its life cycle. This is a good reason to focus not only on emissions reduction (either directly producing cleaner car engines or indirectly reducing car travel), but also on the reduction of the number of cars overall.

2.2 Social exclusion mitigation

Social exclusion means that people or areas are suffering from a combination of linked problems such as unemployment, poor skills, low incomes, poor housing, etc. (Pickup and Giuliano, 2005). In our societies mobility is perceived as a fundamental personal freedom and considered one indicator of the quality of life we experience. But transport is also a tool for living and working; it provides a level
of mobility and accessibility to meet activity requirements. The lack of mobility is recognized as one of the possible factors of social exclusion. Links between transport and social exclusion has been extensively discussed, among others, by Hine and Mitchell (2003). Such problems are much stronger in North America, due to a development style implying private car mobility and, consequently, weak public transport system. However such problems are not unknown to European societies either (see for example: Pickup and Giuliano, 2005, Church et al., 2000) and could be addressed by a system like the one proposed in this paper.

3. The modeling Framework

The modelling of a large scale collective taxi system is challenging. A crucial step to overcome limits usually encountered with traditional modelling frameworks in the forecasting of new transport options is to have a more precise representation of the service (Shaheen and Rodier, 2004). An explicit representation of trip chaining of individuals, for example, allows detecting who could meaningfully use the taxi service in his/her out-of-home tour. For this, a representation of travel at the individual level with explicit modelling of modal choice is necessary. The representation of individual travel needs increases the precision of the model (shopping, work, leisure, etc.). High spatial and temporal resolution would be also important, since access time to the service is a fundamental parameter in customer choice. Here, an agent-based micro-simulation approach is proposed. This technique allows to model the system at high spatial resolution, but also to consider the behaviour of single individuals. An already existing simulation tool, MATSim-T (Multi-Agent Transport Simulation Toolkit, http://matsim.org) is the basis for this work. MATSim is an agent based and activity-based travel microsimulation tool, which produces individual daily transport demand as output.

3.1 The MATSim toolkit

MATSim-T is a fast, dynamic microscopic transport model. Results are completely disaggregated and analysis can be performed at any level of resolution in space and time, and for any individual agent. Transport is assumed to be a derived necessity for individuals, in relation to the primary need of individuals to perform certain activities during the day. Therefore a plan (daily schedule) is generated for each agent (a synthetic person). A plan contains information on the activities planned by an agent for a certain time span, typically one day, assigned according to its socio-demographic profile. Not only are activities listed, it is also specified where and when those activities will be performed, and which mode of transport will be used to reach the different locations. The plans are executed simultaneously during the traffic flow simulation. Several plans for each agent are retained, given a score, and compared. The plans with the highest scores are kept, and used
to create new plans based on their previous experiences. Trying to improve their score, the agents can choose when to leave home, and the transport mode and the route to concatenate all activities. The system iterates between plan generation and traffic flow simulation until a relaxed state is reached (Fig. 1). MATSim’s most prominent application is a simulation of the travel behaviour of the entire Swiss population, where 7.5 millions of agents are simulated, and about 2.3 million individuals are travelling by car on a network with 882,000 links. More information on the data needed to set up and run the simulation can be found in Ciari et al. (2007) and in Meister (2008), while in Meister et al. (2008) and Balmer et al. (2009) it is demonstrated that the toolkit is able to deal with large-scale scenarios, producing results that are consistent with observed traffic data. In the current version, each traveller of the real system is modelled as an individual agent, while the supply side is modelled as fixed constraints of the system. However, in MATSim-T, each single actor of the transport system can be simulated according to the agent paradigm on both the supply and demand sides.

![Diagram of MATSim simulation framework](image)

**Fig. 1.** Graphic representation of the MATSim simulation framework (adapted from …)

### 3.2 Modeling options

In the most recent version of the MATSim toolkit the available modes were Car, Public transport, Bike and walk; taxi was not considered as an option. The optimization process, described above, is based on the evaluation of the plans using a specific scoring function. The MATSim scoring function (Charypar and Nagel, 2005) is currently based on two ideas: logarithmically decreasing marginal utility of the activity duration and a Vickrey (1969) inspired valuation of the timing of the activities. Its general form is

\[
U_{plan} = \sum_{i=1}^{n} (U_{act,i} + U_{travel,i}).
\]  

(1)
Travel produces a negative score, and the value of this score depends on the length of the trip, both in terms of time and distance, and the type of transport mode used. The elements included in the second term of equation (1), which is basically the utility function of traveling, are access/egress time, traveling time and the cost of the trip with a given mode.

$$U_{\text{travel,mode}_{i}} = \alpha_{\text{mode}_{i}} + \beta_{1}^{\text{mode}} \times TT + \beta_{2}^{\text{mode}} \times Cost_{\text{mode}} \times Dist \quad (2)$$

Access and egress time are not calculated but assigned for each mode in the form of a negative constant $\alpha$. Other kinds of out-of-pocket expenses (like parking costs) can be added in this same way. Travel time (TT) is calculated knowing the distance (which is calculated in turn with different methods according to the mode) and the speed of the mode (it is assumed a specific average speed for each of the modes, based on mobility census data). With Cost is intended the kilometric cost for the considered mode, Dist is the distance for the trip. The constant $\alpha$ and the parameters $\beta_1$ and $\beta_2$ are different for each mode, meaning different attractiveness of travel, and have been estimated with a stated preferences survey (for more details on this topic see Balmer et al., 2009; Kickhöfer, 2009; and Vrtic et al., 2008). Within this approach it is possible to vary the characteristic of different modes and observe the reaction of agents to such variations. For example it is possible to vary the cost of a given mode and see what happens to this mode’s share of global trips. Note, however, that currently the only mode which is properly simulated, the only which is “physically” represented in the model, is the car option. Through the use of this mode agents are interacting, in the sense that the real cost (intended as generalized costs) of one car trip will depend also on the congestion of the network, and thus on the mobility behavior of other agents. In other words, for one agent, travel with car mode from point A to point B has not a constant cost, but depends on other agents’ decisions (if they are traveling with the car or not, when they are traveling, along which route, etc.) For all other modes currently simulated (public transport, bicycle, walk) the utility of travel is independent of other agents’ behavior, the route followed and the travel time are fixed for any two points of the network, and the trip is not “executed” in the simulation. According to what explained above, it is possible to introduce a new mode, the shared taxi mode in this case, in various forms and with a different level of accuracy. The first possibility is to simply define a cost structure for the new mode. The agents will get this new option, which mean that in the re-planning part of the simulation agents can get a plan where the shared taxi mode is used. The plan is evaluated as usual and, within this process, the trip with the new mode is evaluated according to the introduced cost structure. According to the type of service that we want to introduce we can give to the relevant variables different values. Parameters can be estimated with the help of an appropriate SP survey, or more simply, imputed with the help of parameters of existing modes; for example in the case of shared taxi it seems reasonable that the attractiveness of travel (the parameters of the travel time variable) will be between the one of car and the one of public transport. This modeling option is not only the simplest possible in order to introduce a new mode, but
also a necessary premise for any more sophisticated approach. If no new cost structure is defined, no new mode will be available to the agents.

3.2.1 Simulated collective taxi

The simple solution presented above does not include yet the simulation of the taxi mode. In particular in this way, it is implicitly assumed that the taxi service is always available at any time and in any point of the network. It is a system with infinite capacity, and all the demand for this mode can be always satisfied. Of course this assumption is not very realistic and, indeed, an important advantage of the agent based approach versus other methodologies relies on the possibility to simulate the access to the vehicle for each passenger, and to put in relation the number of car assigned to the service and the effective number of customers. The route can be assigned with the same router as for the car mode, this allow having a dynamic assignment to the network also for the taxi mode. Note that a large scale shared taxi system will have an impact on traffic, reducing the overall number of circulating cars during the simulated day, and reducing congestion at some times at some points of the network. But taxi travel, as mentioned above, will be not simulated, creating a bias on the system. The solution to all these issues is the explicit simulation of the taxi mode. In some parallel work (Rieser et al., 2009) the tools to introduce new types of vehicle in the simulation have been created. This allows for the representation of the vehicle capacity, and creates a direct interaction between car and taxi mode, putting taxis in the simulation if the taxi system is adopted by agents. This approach raises new issues, since currently the problem of the coordination of the schedule of different agents which need to catch the same vehicle does not exist. This is probably the most problematic part of explicitly simulating shared taxi travel.

3.2.2 Agent based supply side

A further refinement step for the model, and an attractive option for the modelling of collective taxi, is the introduction of a taxi operator agent. Every actor of the transport system, both on the supply and the demand side, can be simulated in MATSim-T according to the agent paradigm. In the current version each traveller of the real system is modelled as an individual agent while the supply side is modelled through fixed constraints. A first effort introducing an agent modelling for supply side actors of the system is Ciari et al. (2008). The operator agent is the decision maker having the control of the whole collective taxi system and is able to modify its characteristics. It can be provided with attributes, knowledge, objectives, a strategy to pursue, a methodology to implement this strategy and a group of allowed choices. The operator agent’s objective function can be assumed to be more or less complex. In the simplest case the agent would seek to maximize the number of customers, but other possibility could be the maximization of profit or
of social welfare. The knowledge of the agent - similar to those of individuals - is the memory of some previous score and the corresponding configuration of the service. In the case that costs are not part of the objective function of the operator a posterior evaluation of the financial feasibility could be performed. The dimensions on which the agent could operate are for example the fleet (number of cars, dimensions) and the price scheme (price level, distance and time dependency). The whole system can be optimized with an evolutionary approach. The operator would change some of the characteristics of the collective taxi scheme in order to try to obtain a better score. It would be possible to isolate also the effect of a single decision dimension, blocking the possibility to modify the others. This way the characteristics of the service would be not fixed anymore, but would emerge as equilibrium depending on the behaviour of the operator and those of individual agents. This approach is much more sophisticated than the other proposed above and also really challenging. One of the greater difficulties is the right interpretation of the results (Ciari and Loechl, 2008). If the price of the service and its extension are not an input anymore but become a result of the simulation, these results are dependent on the number of agents using collective taxis which depends on the characteristics of the system in turn, and so on. With only one type of agents the relaxed state of MATSim is considered to be reached as soon as the average score of agents is not changing anymore (or changes observed between two successive iterations are less than a given threshold value). Of course this get more complicated if two types of agents are there, and little is know about the type of equilibriums that can be obtained. This approach can be seen as a development of the model further than the explicit simulation of the taxi mode. Theoretically, this approach can be used even coupled with the simplest representation of the taxi system, since the existence of the taxi mode with its cost structure is a sufficient condition to implement it. However, it would probably make the interpretation of the results even more difficult, since the characteristics which could be varied by the operator agent would not be directly something like the number of taxis of the scheme, but the variable and/or the parameters of equation (2). If with such values a description of the model is definitely possible, the level of approximation implicit in this description make this more suitable to a qualitative discussion than to an optimization process.

4. A test case: the city of Zurich

The work presented in this paper is part of an ongoing project which final goal is to assess the potential of a large scale taxi system for the city of Zurich and the area around it. The project is not yet finished, and the taxi mode has been introduced only in its simpler variation, which means defining a cost structure for the taxi mode. Nevertheless, many test simulations have already been conducted and from the available output, even preliminary, some interesting results have already emerged.
4.1 The implemented taxi system

The cost structure should reflect the type of service that the taxi operator wants to offer. Practically, this means to assume values for the access/egress time, for the distance, and for the cost (expressed in Chf/km) and see how the agents react to this. The travel time, which is also a variable in equation (2), is calculated knowing the distance and assuming an average speed for the mode, thus an assumption on the speed need to be done as well. However, to give a score to the trip it would be necessary to know the values of parameters corresponding to these variables, for example estimating them on the basis of an SP survey, as it has been the case for the other modes. This instrument might be used at a later stage of this project but, for the time being, these parameters have been imputed making assumptions on the attractiveness of the service compared to car and pt modes, of which the collective taxi mode can be considered a kind of hybridization. In fact it is possible to play with such variables and parameters in order to configure different shared taxi options. Two possible implementations of the taxi scheme are here proposed, which for simplicity are identified with the names of “Budget” and “Executive”.

4.1.1 Collective taxi Budget

In this implementation it is supposed that the service is more similar to public transport in terms of comfort, costs and access time. It might be the case for example of a service working on given “corridors” and not providing a point-to-point service, but also working on demand in the sense that no fixed schedule or stops exist. In this case it is supposed that the access/egress time is relatively high (nearer to the one of public transport than to the one of car). An intermediate value between car and public transport is assigned to the travel time parameter as well as to the cost parameter. The distance is supposed to be 1.2 the distance with car (which is calculated with a specific router) because of the multiple stops, and the speed to be the same as car. The cost is slightly higher than the cost for public transport without owning some kind of reduction card.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Constant</th>
<th>α</th>
<th>β</th>
<th>Cost</th>
<th>Distance</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>-0.48</td>
<td>0</td>
<td>-0.2</td>
<td>0.12 Chf/km</td>
<td>Dist. car</td>
<td>50km/h</td>
</tr>
<tr>
<td>PT</td>
<td>-2</td>
<td>-0.1</td>
<td>-0.05</td>
<td>0.14/0.28 Chf/km</td>
<td>Dist. Pt 33km/h</td>
<td></td>
</tr>
<tr>
<td>Taxi</td>
<td>-1.5</td>
<td>-0.05</td>
<td>-0.05</td>
<td>0.30 Chf/km</td>
<td>Dist. Car + 20% 50km/h</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Parameters used for simulating the “Budget” service.
4.1.2 Collective taxi Executive

This implementation assumes a more comfortable service and most of all a point-to-point service, which means a very limited access/egress time. Conversely the cost will be higher than for the Budget version. For the time and cost parameters a value nearer to the one of car is assumed. Assumptions on trip length and speed are the same as before.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Constant</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>Cost</th>
<th>Distance</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>-0.48</td>
<td>0</td>
<td>-0.2</td>
<td>0.12</td>
<td>Dist. car</td>
<td>50km/h</td>
</tr>
<tr>
<td>PT</td>
<td>-2</td>
<td>-0.1</td>
<td>-0.05</td>
<td>0.14/0.28</td>
<td>Dist. Pt</td>
<td>33km/h</td>
</tr>
<tr>
<td>Taxi</td>
<td>-0.2</td>
<td>-0.01</td>
<td>-0.2</td>
<td>1.0</td>
<td>Dist. Car + 20%</td>
<td>50km/h</td>
</tr>
</tbody>
</table>

4.2 The simulation scenario

The set up of a simulation scenario is a complex task, involving the integration of different data sets. The description of this process is beyond the scope of this paper, more information on it can be found in Ciari et al. (2007). The scenario used here is a “Greater Zürich” scenario. The scenario is a subset of the Swiss scenario, and covers an area of about 2800 km$^2$, obtained drawing a 30 km circle around the “Bellevue” place in the centre of Zurich. This scenario is built with geo-coded data from the year 2000 census of population (agents, households, commuting matrices), the year 2000 census of workplaces (facilities by type and capacity) and the national travel survey for the year 2005 (477 types of activity chains / 9429 types of activity chains with duration classes; eight classes of agents by age and work status are distinguished). This area has approximately 1.5 M inhabitants, note, however, that in the scenario are included also all agents having plans where an activity within the area is scheduled or agents simply crossing the area. Also transit traffic through the country is included; it was generated with the relevant border survey data. Those crossing the study area or entering/leaving it are represented by agents with a plan including either the single observed trip (for transit traffic) or two trips (for e.g. commuters from outside Switzerland). A map of the scenario is presented in Fig. 2.
The road network model has more than 236,000 directed links and more than 73,000 nodes; it is obtained from the data of the Teleatlas navigation network. The number of facilities for out-of-home facilities is 373,155. A MATSim specific subdivision of activities, including 17 different types is used. Those activities are basically all the activities which are possible entries in one agent’s plan, and they are: work_sector2, work_sector3; kindergarten; primary school; secondary school; higher education; other education; retail_lt100sqm; retail_get100sqm; retail_get400sqm, retail_get1000sqm, retail_gt2500sqm, other retails; culture; restaurant et al.; sports. The transport modes allowed are: car driver, public transport, bicycle, walk, and shared taxi.

For computational reasons the simulation is run on a 10% sample of this scenario, which means that for this scenario 161,810 agents are simulated. All of the described dimensions stay the same, except the network capacity which is also scaled (each link’s capacity is set to 10% of the original capacity) in order to have realistic traffic flows on the network’s links. In this sample the number of agents crossing the study area while transiting Switzerland is 5’791, linked to 880 home facilities outside Switzerland.

With the computer used for the simulation (3 cores, 40G Ram) the 10% sample scenario takes about 10 hours of computing time for a simulation of 50 iterations.

4.3 Results and discussion
The results reported here are preliminary and moving on to analyzing them it is necessary to pay attention not to perform an “over-interpreting” the model. The implementation of the taxi mode is currently still very simple but, on the contrary, many parts of the model are much more refined and would invite to more advanced analysis exercises. In this case a cautionary approach is to expect that the level of accuracy of the model’s results depend on the less accurate of these. For this reason here only the global shares of the modes, the shares for different distance groups and comparisons with a No-taxi scenario (a simulation run on a scenario which is exactly the same as the one described above, but where the taxi mode is not available) are presented. Microcensus data is also used for comparisons. When an improved implementation of the taxi mode will be available other analysis, better exploiting the potential of the MATSim toolkit, like spatial analysis, will be also provided. The results have been obtained simulating the two service schemes Budget and Executive implemented in the 10% sample of the Greater Zurich scenario. In Fig. 3 the shares of the transport modes for the three alternatives Budget, Executive and No taxi are showed together with the shares extracted from the Microcensus.

Fig. 3. Shares of the transportation modes for the simulation scenario “Greater Zurich” using three different alternatives for the taxi scheme and real shares from the Microcensus

The first thing that is worth to observe is if the agents effectively abandon one of the modes used so far in order to travel with the new taxi mode. It is definitely the case, the taxi mode is accredited by the simulation of an encouraging 13% in the case of the Budget implementation and of an almost incredible 33% in the case of the Executive. The second thing to observe is which modes have been abandoned for the new taxi modes. In the case of the Budget implementation it seems that the mode is able to capture customers most of all from public transport. The mode car, which users are in principle the target of the system is loosing only 1.3% of its users. One possible reason for this is that such a taxi scheme is too
similar to the public transport mode, which is in fact largely penalized by the presence of the taxis. The bike mode has only a small negative variation, as well as the walk mode. The small loss for these two modes can be explained with the high constant term (access/egress time), making the taxi option not competitive with bike and walk for shorter distances. A more precise idea of what is happening can be obtained comparing the alternative No-taxi with the alternative Budget, plotting the differences of share against distances for each of the mode once (Fig. 4).

From this further analysis it is even clearer that the taxi mode is gaining its customers from pt and mostly from longer trips (from 5 km trips and longer) which is the range of distances where public transport is stronger. The few car travelers gained by the taxi mode are also coming from these same categories of trips. Walk is loosing some points at very short distances (up to 0.2 km) despite the high value for the constant term. In the case of the Executive implementation of the taxi scheme the situation is different. The car mode is loosing about 11% of its users to the taxi mode. Interestingly also the walk mode is loosing a big share of its customers (more than 6%), probably because of the small constant term which make the taxi mode attractive also for very short trips. Bike is also loosing more customers than with the Budget implementation. Public transport is also loosing a bit more. In Fig. 5 the differences in shares for the alternatives No-taxi and Executive are reported against distance ranges.
For this alternative it is clear that the competitiveness with the car mode is much higher, many agents who were traveling between 2 km and 10 km are now using the taxi. However, the system is capturing also many customers from other modes, and in particular from walk and bike for trips up to 5 km and from pt for trips longer than 5 km. It is also worth to notice that the taxi scheme seems to be especially suitable for trips in the range 2-10 km where it has a share up to more than 40%. Globally it seems that this alternative is much more attractive than the Budget one, even if the cost per km is much higher. The Executive alternative is also able to put many private cars off the road but is also substituting many of the trips made with the other modes. As explained above the system is assumed to have unlimited capacity and no assumptions are made on the number of persons transported with each taxi vehicle. However, assuming that 3 persons are transported in each trip the introduction of the taxi mode would be a zero-sum game in terms of number of trips, since the traffic taking customers from the other modes would exactly compensate the reduction of private cars (because its global share is 33% and car is losing 11%). In other words, if so many agents are gained from public transport and non-motorized modes, the system would effectively help to mitigate the traffic (in terms of reducing the global number of trips) only if in average more than 4 people are on board during the same trip. Moreover, even this count is very approximate since it is made in terms of number of trips, regardless to the length of the trip. To which extent such a taxi system could reduce the overall number of traveled kilometer (car + taxi) depends also on the ability of the system optimizing the path when putting together more travelers on the same vehicle. Obviously with this modeling approach this important aspect cannot be yet taken into account. The fact that so many agents are switching from non-car modes to the taxi is not only negative. Indeed, it is also an indicator that the mobility of the
persons has improved and might be a suggestion that the problem of social exclu-
sion could be mitigated by such a large scale taxi system.

5. Conclusions and Outlook

This paper reported on ongoing work on the possibility of implementing a collective taxi system at large scale in an urban area. The main motivations for the implementations of such a system are of environmental and of social nature. The work is still on an early stage; however, two important achievements can already be claimed. First, from a methodological point of view; the introduction of the taxi mode in the agent based simulation toolkit MATSim, even if in a very simple way, is a necessary premise for any kind of more sophisticated modeling approach, and gives the precious opportunity to test the behavior of the system under different implementations of the taxi scheme. Second, the results shown are preliminary, but quite strongly suggest that such a system would have the potential to be implemented at large scale in an urban area like the one of Zurich in Switzerland. The way in which the taxi mode has been introduced in MATSim is really simple and thus results are not completely reliable. In particular it seems clear that the model assuming infinite capacity has a strong tendency to overestimate the potential of the taxi mode. Still the high number of agents which would use the taxi system (13% for one alternative scheme, and 33% for the other) can be hardly only the fruit of an optimistic model. In fact the idea that many persons could have an interest, in an economic sense, in adopting this transport mode, if available, seems quite reasonable also if compared with forecasting of the potential of other innovative systems (for example see the case of car-sharing, Millard-Ball et al., 2005). What it is hard to understand is how far this potential, which could be called theoretical potential, can be effectively being exploited in a real life situation. In this sense the results presented in this paper—they could appear too good to be true—confirm again that a crucial point to assess the potential of new transport options is the modeling methodology. It is extremely important to understand to which extent the modeling methodology used is appropriate and how potentially accurate.

The simulation approach proposed has the potential to represent the system at the microscopic level, even when simulating a large scale scenario, permitting an accurate study of the feasibility of the system, both in technical and in economical terms. Thinking to the current implementation of the taxi mode, it is expected that the explicit simulation of the vehicles, the computation of access and egress time (instead of their imputation), and the computation of the traveling distance (instead of using the one for car and assume a multiplicative coefficient) will give much more realism to the model. These will be the most important steps to undertake in the near future within this project. The improved method will allow also for much more sophisticated analysis of the simulation’s results. For example it will be possible to perform many kinds of spatial analysis, to investigate if the system is able to induce multimodality and most of all, to directly see if and how
much car travel is reduced. In a long term perspective the modeling of the operator as an agent will be also attempted. This is expected to help in finding new solutions for the large scale taxi system, including counterintuitive ones, allowing for a better understanding of the interactions of the different modes in the transportation system. But it will be also an important step to have an always more complete and flexible modeling framework, enhancing the palette of scenarios which can be modeled with the MATSim toolkit.

6. References


