Activity-based travel demand modelling including freight and cross-border traffic with transit simulation

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Activity-based Travel Demand Modelling including Freight and Cross-border traffic with transit simulation

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Abstract

This paper presents results of an activity-based multi-agent transport simulation using MAT-Sim (http://www.matsim.org) for a Greater Zurich scenario. So far the scenario consisted of private motorized traffic only hence freight and cross-border traffic are added in attempt to improve the travel demand produced by the simulation. New agents and facilities are created from O-D matrices and information on workplaces and shopping locations. Furthermore, agent-based public transit simulation has been used for the execution of agent plans using transit network and timetables of Zurich. Apart from that, the paper uses a new replanning strategy PlanomatX, which is a new scheduling algorithm based on Tabu Search that generates comprehensively optimized all-day schedules. The schedules are evaluated using a new utility function that unlike the current scoring system of MATSim copes with a flexible number of activities in a schedule. The results are then compared to Swiss Microcensus data and tests conducted on the scenario prior to these improvements.

Keywords
Greater Zurich Scenario, Freight traffic, Cross border traffic, public transit simulation, PlanomatX.

Preferred Citation Style
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1 Introduction

This research is an attempt to improve the travel demand produced by the simulation of the population of the Zurich metropolitan area using the activity-based multi-agent simulation toolkit MATSim (MATSim-T, 2008). MATSim adopts a co-evolutionary learning process that improves the activity schedule of each agent against the background of overall travel costs calculated using a traffic flow simulation (see Sec. 1.3 for more on MATSim).

In order to achieve this goal, the plan of action is to first enhance our inputs (see Sec. 1.1.1) and then to employ new advanced methods (see Sec. 1.1.2).

1.1 Objectives

1.1.1 Adding freight and cross-border traffic

Like any other software, MATSim too requires information to process, which in our case is the initial demand. The existing Zurich scenario (see Sec. 2.1) comprises of population inside our study area with their daily private trips. Our aim is to include the trips produced by freight transport and the cross border travellers. The modelling of additional traffic would require the formulation of initial demand in the form of agents for the traffic flow simulation with certain desires, in this case, activities. Also, the agents would require new facilities to perform their special activities. Apart from that, unlike the private motorized traffic, the handling of new agents would require a different strategy to take advantage of the learning process of MATSim to improve their schedule.

1.1.2 Incorporating Public Transit Simulation and Comprehensive Schedule Optimization

The agent-based transport simulation looks at individual travellers and simulates their movements through a transportation network. MATSim’s new simulation model support large scenarios as well as multiple transportation modes (Rieser, 2010). Marcel Rieser in his PhD thesis has extended the mobility simulation in MATSim to model public transit in high detail along with regular car traffic. Using this new feature for the current scenario, would therefore lead to a transport model of higher quality.
MATSim adopts an iterative demand optimization approach which aims at finding an equilibrium state where none of the agents can further improve their schedule. The optimality of an agent’s schedule depends upon the utility function, the measure against which a schedule is evaluated. For this research, a new scheduling algorithm, PlanomatX (Feil, 2010) that optimizes the number, type, timings and sequence of the activities along with mode and route choices is used. The scheduling algorithm requires a new utility function (Joh, 2004) that is able to realistically handle a flexible number of activities in a schedule.

1.2 Need and motivation for the research

Although commercial vehicles account for a small proportion of all the road users, each vehicle contributes disproportionately to traffic congestion and emissions. In a recent issue on the behavioural insights of the modelling of freight transportation (Hensher, 2007) it has been acknowledged that freight models and related public policy tools have lagged behind logistics and technological advances. Thus, an attempt has been made of extending activity-based modelling ideas from passenger transportation to address freight instead of just assuming it as a fraction of modelled traffic. Similarly, cross-border and through traffic is becoming a rising concern of cities lying on major highways. Thus, it makes sense to include these external trips when modelling the traffic of an entire city.

Public transport satisfies a major share in a city’s transport needs and within public transport different modes have different methods of serving them. Due to the increasing quality and the availability of various modes, public transport has become major part of the decision making process of any trip maker. Even though it runs on fixed transit schedule, its influence, especially on multi-modal networks, is considerable and hence simulating transit is essential.

1.3 Background

A brief explanation of the Multi-Agent Transportation Simulation Tool-kit MATSim (MATSim-T, 2008) is given in the following section since it is used all along. Figure 1-1 shows the schematic control flow of the various stages of MATSim. It starts with the initial demand that describes an initial set of day plans for the simulated population which is then executed by the traffic flow simulation or mobility simulation (mobsim). The performance of the day plans is evaluated during scoring, such that agents can try to optimize their day plans during replanning.
Initial Demand: A set of agents that represents the population or the population itself of the area to be modelled with a set of primary (mandatory) and secondary (optional) activities for an average day. It also comprises of information on attributes like agents’ age, sex, employment status (yes/no), income etc which might be used to predict agents choices. The 0th iteration of MATSim assigns routes and travel times thus generating the complete schedule.

Execution module (Cetin, 2005): It takes the agents’ plans and executes the plans respecting physical constraints and limits on a network of nodes and links. Alternatively, nodes could also be used to model stops, and links would therefore stand for generalized connections between stops. In either case, its function is to return travel times and distances that the agents experience when they share the network together.

Replanning module (Balmer, 2007): For every MATSim iteration, during the replanning, agents can explore the parameter space along the choice dimensions with respect to mode, route, location, activity type, activity order, activity times and activity durations. A number of replanning modules are available that each explores one or more than one dimension. The combination of zero, one or more of such modules builds a replanning strategy which can be chosen according to the scenario in hand.

Scoring (Charypar, 2005): The selected schedules can now be scored in order to evaluate their fitness. The utility function is the measure against which the schedules are scored.

Output: With each iteration, the plans with lower over-all utility are discarded, until the score no longer increases. This demand generated on that iteration corresponds to the final traffic loads.
2 Demand Generation

The generation of the initial demand for freight traffic aims at creating a model population provided with a complete activity-travel schedule. For the purpose of this paper, both the private vehicle plans (including cross-border and private car traffic) and the network description were taken from Chapter 7 (Balmer, 2008) and (Ciari, 2007).

Figure 2-1 Greater Zurich area (30km circle around “Bellevue”)

The different routes show examples of agents included in the scenario.

2.1 The Greater Zurich Scenario

The existing greater Zurich scenario (Figure 2-1) comprises a set of 172,598 agents. They are a 10% random draw from those agents whose initial demand routes cross a 30 km circle around around the centre of the Zürich at Bellevue Platz. This draw is made from the Switzerland scenario which is built with geocoded 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 years 2000 and 2005 of Switzerland.
The road network is represented by a model network of 60,000 directed links and 24,000 nodes. There are 1.3 million home locations and more than 380,000 out-of-home locations. It is the Zurich planning network, remains unchanged.

Agents’ initial schedules have been assembled from the data collected from (Swiss Federal Statistical Office, 2000, 2006)

Eleven activity types are modelled as shown in Table 2-1.

Table 2-1 Activity types in the Zurich scenario

<table>
<thead>
<tr>
<th>Name</th>
<th>Number</th>
<th>Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>2</td>
<td>Home, Inner home</td>
</tr>
<tr>
<td>Education</td>
<td>5</td>
<td>Kindergarten; Primary school, Secondary school, Higher education, Other education</td>
</tr>
<tr>
<td>Leisure</td>
<td>1</td>
<td>Leisure – culture, restaurant et al., sports</td>
</tr>
<tr>
<td>Shopping</td>
<td>1</td>
<td>Shop</td>
</tr>
<tr>
<td>Work</td>
<td>2</td>
<td>Sector 2, Sector 3.</td>
</tr>
</tbody>
</table>

2.2 Adding Freight traffic

Owing to the agent-based capability of MATSim, adding of freight traffic requires creating a population of freight agents with an initial plan. This would require a considerable amount of disaggregate data which is not available. The data available to us is in the form of time-dependent O-D matrices\(^1\). There exist two types of freight agents as shown in Table 2-2. In the following sections, freight agents with an average day schedule are produced in a format that can be fed to the simulation model of MATSim. (as shown in Figure 2-2)

\(^{1}\) The O-D matrices are taken from the Kantonales Verkehrsmodell Zürich (KVM-ZH). Please refer to de “Güterverkehrsmodell Kanton Zürich” by Gottardi and Bürgler (1999).
Figure 2-2: Example of a person and its day plan (MATSim-specific XML format)

```
<person id="1000419" start=e"65" license="yes" can_overload="always" exployed="true">
<traveled type="CT-IM" />

<device>
<actor type="home" doc="22:10-09" />
<actor type="shop" doc="01:30-09" />
</device>

<knowledge doc="(ID x:7799947) [x:779947]">
<activity type="home">
<location id="130461" inform="yes" />
</location>
</activity>

<activity type="shop">
<location id="13060436" />
</location>
</activity>
</knowledge>

<plan id="4.4395178878531387" selected="yes">
<act type="home" link="129583" facility="0234124" id="69410.911691472" y="359676.8800811852" start_time="00:14:00" doc="10:35:56" end_time="11:55:56" />
<leg node="walk" dep_time="00:14:00" arr_time="00:14:14" arr_time="10:50:02" />
<leg type="shop" link="129583" facility="0234124" y="359676.8800811852" start_time="00:19:00" doc="01:38:36" end_time="01:00:36" />
<leg node="walk" dep_time="00:19:36" arr_time="00:23:54" arr_time="12:10:50" />
<leg type="home" link="129583" facility="0234124" y="359676.8800811852" start_time="11:55:36" />
</plan>
</person>
```

Table 2-2: Types of Freight agents

<table>
<thead>
<tr>
<th>ID</th>
<th>Short for</th>
<th>Equivalent to</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKW</td>
<td>Lastkraftwagen</td>
<td>Heavy Trucks (&gt;3.5 tons)</td>
</tr>
<tr>
<td>LI</td>
<td>Lieferwagen</td>
<td>Delivery Vans(upto 3.5 tons)</td>
</tr>
</tbody>
</table>
2.2.1 Extracting agents from O-D matrices

The 24 hour trip data available to us is of discontinuous nature. For a finite population of agents, every single traveller or trip-maker constitutes an integer commodity. Rounding up the data at the aggregate level is an incorrect approach since it causes a loss of 5 – 10% loss of trips in each case. Thus the method adopted in (Nagel, 2009) is used where one needs to generate the appropriate number of travellers for every OD pair and every time slot, and distribute them across a period of time. From there on, the triple (origin, destination, departure time) is fixed for every simulated traveller, and its goal is to find an appropriate path. For every change in traveller size of $\varepsilon \to 0$ an increase of a factor of $1/\varepsilon$ of the number of travellers was applied for each origin until the trip loss was minimal. An example is shown in Figure 2-3.

Figure 2-3: Discretization of trip data.

Raw data:

| 3.12 | 2.79 | 4.34 | 7.00 | 0.02 | 13.88 | 9.11 | 156.45 | Total |

After discretizing for n iterations:

| 3    | 3    | 5    | 7    | 0    | 12    | 10   | 158    | Total |

2.2.2 Allocating departure times.

For each freight agent we have an OD matrix for 3 critical hours of the day, 8 – 9 am, 12 – 1 pm and 4-5 pm. Some key points about freight trips:

Nightly ban on LKW: Between 10:00 pm and 5:00 am heavy trucks are only allowed to drive with special approval. Hence LKWs departing during these times can be assumed to be very few.
LI work hours: Delivering goods is usually done during working hours. Hence, we can assume (as a reasonable approximation) deliveries starting during the night (10pm to 5 am) are negligible.

Peak hours: Unlike private-car traffic which experiences multiple peak hours during time of the day, freight travel demand can be assumed to remain constant throughout the day until evening.

Land use. Its been observed, that the car traffic from the residential outskirts of the city to pour into the city in the morning and leave in the evening. To observe any such behavior in freight traffic the trips between any zone A to any zone B at different times of the day have to be compared. A simple graphical comparison would show us if at all there exists any such pattern. Using the data in hand, comparing the graphs in Figure 2-5 for LI and Figure 2-6 for LKW show that there is no significant difference between the freight loads through the day and hence no such pattern whatsoever.

Keeping these points in mind the following distribution(Figure 2-4) is used to assign the departure:
Figure 2-4: Number of Freight agents departing every 6 mins of throughout the day
Figure 2-5: Number of LI agents originating from each zone at different times of the day
8am(top), 12pm(middle) and 6pm(bottom)
Figure 2-6: Number of LKW agents originating from each zone at different times of the day 8am(top), 12pm(middle) and 6pm(bottom)
2.2.3 Locating facilities

In this case, a freight activity is assumed to be either loading or unloading of goods. Each agent has a origin zone and a destination zone as per the OD Matrix (Figure 2-7). At a disaggregate level, freight activity only can be performed at certain locations referred to facilities in MATSim. MATSim asks for the exact co-ordinates and the links on which the facility resides. On an average day, it can be assumed that freight activities occur at shopping and work facilities. These facilities are directly taken from the existing Zurich scenario (Shopping, Work Sector 2 and Work Sector 3) in the following manner:

The facilities near the centroid of the zone of the trip end were obtained. The closest shopping or work facility eligible to receive or send goods based on a minimum capacity criteria is found. The number of freight activities assigned are proportional to capacity of the facility. If the facility has enough freight activities assigned to it, the search radius is iteratively increased until a new one is found. Repeat these steps for every origin/destination until we have all the freight activities mapped to appropriate facilities.

Along with making these activities part of the freight plans, the mapped locations are made into new facilities and added to the list of facilities (facilities.xml) fed to MATSim.

Figure 2-7: Area of Greater Zurich divided into 1341 Zones
2.3 Forming the daily schedule

On assembling all the above information adding socio demographic information, a total of 46684(LI) + 25674(LKW) freight agents were generated (Figure 2-8 and Figure 2-9). A random 10% sample of both the type of agents was taken for the simulation.

Figure 2-8: Example of a LI freight Plan

```
<person age="55" car Aware="always" employed="yes" id="TL1000002" license="yes" sex="m">
  <desires>
    <court dur="12:00:00" type="tta/>
  </desires>
  <knowledge>
    <activity type="tta">&
      <location id="TL1000001" isPrimary="yes"/>
    </activity>
    <activity type="tta">
      <location id="TL10100001" isPrimary="yes"/>
    </activity>
  </knowledge>
  <plan>
    <act dur="15:19:00" end_time="15:19:00" facility="TL1000001" start_time="00:00:00" type="tta" x="679536.74087" y="239101.96179"/>
    <log dep_time="15:19:00" mode="car"/>
    <act facility="TL10100001" type="tta" x="679767.67452" y="216891.67920"/>
  </plan>
</person>
```

2 Socio-demographic information doesn’t influence the travel decisions of freight agents hence they are all assigned the same values compatible with MATSim
Figure 2-9: Example of LKW freight plan

```xml
<person age="35" car_ownership="always" employed="yes" id="TLX9000002" license="yes" sex="m">
  <desires>
    <act dur="12:00:00" type="tta"/>
  </desires>
  <knowledge>
    <activity type="tta">
      <location id="TLX9000002" isPrimary="yes"/>
    </activity>
    <activity type="tta">
      <location id="TLX9000002" isPrimary="yes"/>
    </activity>
  </knowledge>
  <plan>
    <act dur="12:00:00" end_time="13:00:00" facility="TLX9000002" start_time="08:00:00" type="tta" x="67619.90007" y="23623.25324"/>
    <leg dep_time="10:12:00" mode="car"/>
    <act facility="TLX9000002" type="tta" x="67700.187956" y="233191.463291"/>
  </plan>
</person>
```
3 Simulation

The exec module of MATSim that actually moves the traffic demand as per the agent’s plan has different implementations in MATSim. Mr. Marcel Rieser, in his PhD thesis has added a new implementation to the exec modules of MATSim, QSim, which is capable of doing agent based private car and public transit simualtion (Rieser, 2010).

3.1 QSim Overview

QSim includes not only the simulation of such traffic, but also the agents' mode choice decisions. It uses transit schedules as simulation input which contain information about stop locations, transit lines, their routes, departure times with which it creates a multimodal network by overlapping the transit network on the road network. It uses the route information in the transit schedule for different public transport modes with which it routes the trips made by agents choosing public transportation. Agents use walking for the estimated time to travel between activity locations and stop locations. The transit router uses an activity based approach and modifies the agent plan as shown in the Figure 3-1.

Figure 3-1: Modification of plan by Transit Router.
3.2 Public Transport Data of Zurich

The public transport network of Zurich consists of more than 6500 links and 3000 nodes. The public transportation schedule for Zurich used for the transit simulation is given in a file for PTV VISUM. The network data can be written out to a text-based file format that also contains all data relevant for transit. A converter written within MATSim reads this file and builds a TransitSchedule. This file can then be read in by MATSim and converted into a MATSim TransitSchedule. The converter also creates the corresponding vehicle types based on the data given in the VISUM file. A vehicle of the corresponding type will be created for each departure. The transit schedule and vehicle definitions can then be written out to file in the native XML-based file formats that MATSim uses. (transitschedule.xml and vehicles.xml). Figure 3-2 shows the final network used in this study.

Figure 3-2: The public transport network combined with the existing road network of Greater Zurich
4 Replanning

The MATSim replanning module mutates an agents plan as per strategies requested by the user. In our case, due to the heterogenous population we need to employ different strategies for different types of agents.

4.1 Planning strategy for private-car traffic

The main aim for the general population which contribute the private car traffic is to optimize their daily schedules through different strategies offered by MATSim. Following are the strategies applied and the order in which they are applied:

1. Transit Activity Remover Strategy (Rieser, 2010): Removes all transit interaction activities from a handled plan, reversing the effects of the transit router. This is important since they might cause inconsistencies in the plan when they are sent for location choice, mode choice or activity time mutation.

2. PlanomatX (Feil, 2010): PlanomatX is a new scheduling algorithm based on Tabu Search that generates comprehensively optimized all-day schedules developed and tested by Mr. Matthias Feil in his PhD thesis. It produces optimized combinations of a schedule’s activity chain with respect to the number, type and sequence of activities. The PlanomatX module uses the “TimeModeChoicer” (see Chapter 4 of Feil, 2010) along with the “constrained location choice” (Horni, 2009) strategy for optimizing the activity timings, and the location, mode and route choices. Different moves of PlanomatX are configured as:
   1. 50% changing the number of activities.
   2. 30% changing the sequence of activities
   3. 20% increase the number of activities.

3. Router (Rieser, 2010): Lastly the plans are sent to the transit router to make them compatible with the transit simulation model.
4.2 Planning strategy for freight and cross-border Traffic.

The freight and cross-border traffic plans have been produced directly from O-D matrices and thus have a fixed activity sequence and number. The freight activities occur at their pre-decided timing, so replanning the freight plans with respect to time does not make any sense. Cross-border trips are long trips and adjusting the times using the traffic conditions in the city is wrong since it has very little or no influence on them. MATSim, besides public transport vehicles recognises only car, bike and walk as travel modes. The freight and the cross-border traffic certainly do not use walk, bike, or public transport. Hence their mode remains the same throughout, i.e. car. The only decision that seems relevant to freight and cross-border agents is the route. Hence it is the sole strategy applied for their replanning process.
5 Scoring

PlanomatX makes the number of activities in the schedule a part of the learning process. In such a case, the log form leads to a lot of very short activities due to its decreasing marginal utility function that can cope with a flexible number of activities in the schedule. Hence a new utility function as presented by (Joh, 2004) is used to overcome this problem which also takes into account travel cost and socio-economic attributes of travellers.

Figure 5-1: Generic illustration of the new utility function for the performance of activities

![Utility vs Time](image)

The utility function $U_{act,ij}$ for the performance of activities is now

$$U_{act,ij} = U_{acttype,ij} \cdot S_{ij}$$

where $U_{acttype,ij}$ is activity’s $j$ type-specific utility function (e.g., “home”) and $S_{ij}$ agent’s $i$ socio-demographic utility factor. $U_{acttype,ij}$ is defined as
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The function is an asymmetric S-shaped curve with an inflection point (See Figure 5-1), originally developed in biological science and first presented within transport research by (Joh, 2004). It formulates optimal activity duration by its functional form. Assuming an average value of time, the utility function features segments where its value of time is below the average value of time, and segments where it is above. The optimal activity duration will be found in the latter segments. \( U^\text{min}_j \) is the time-independent minimum utility of performing activity \( j \), and \( U^\text{max}_j \) the time-independent maximum utility of performing activity \( j \). \( \text{duration}_ij \) is the duration for which agent \( i \) performs activity \( j \). \( \alpha \), \( \beta \) and \( \gamma \) are parameters that influence the shape of the curve.

\( S_{ij} \) is an agent-specific multiplicator to the purely activity-type-specific utility function \( U_{\text{acttype},j} \). The multiplicator reflects agent’s \( i \) socio-demographic characteristics that impact his utility experience. It is defined as

\[
S_{ij} = (1 + \sum_m \beta_{jm} \cdot \text{attribute}_{ijm})
\]

where \( \text{attribute}_{m} \) is the value of agent’s \( i \) socio-demographic attribute \( m \) (income, age, gender, etc.) and \( \beta_m \) the corresponding weight parameter.

The travel (dis-)utility \( U_{\text{travel},ij} \) is defined as

\[
U_{\text{travel},ij} = \beta^\text{time}_{\text{mode},j} \cdot \text{time}_{ij} \cdot S_{ij} + \\
+ \beta^\text{cost}_{\text{mode},j} \cdot \text{cost}_{ij} \cdot \left(\frac{\text{income}_i}{\text{averageIncome}}\right)^{\lambda_{\text{income},j}} + \text{constant}_{\text{mode},j}
\]

where \( \text{time}_{ij} \) is the travel time of trip \( j \) of agent \( i \), \( \text{cost}_{ij} \) the travel cost, and \( \beta^\text{time}_{\text{mode},j} \) and \( \beta^\text{cost}_{\text{mode},j} \) corresponding mode-specific weight parameters. \( \left(\frac{\text{income}_i}{\text{averageIncome}}\right)^{\lambda_{\text{income},j}} \) reflects the impact of a traveller’s income level on his perception of travel cost. \( \text{income}_i \) is the travel-
ler’s monthly income. averageIncome is the average monthly income across the population. $S_i$ is the same as in the utility function for the performance of activities.

The utility function parameters have been empirically estimated using an enhanced Multinomial Logit (MNL) model and calibrated to match reported and observed real-life data in (Feil, 2010). They have been directly used for this study (See below).

Table 5-1: Utility function calibrated parameter values for Activities

<table>
<thead>
<tr>
<th></th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
<th>$V_{\text{min}}$</th>
<th>$V_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>12</td>
<td>0.429</td>
<td>1.00</td>
<td>0.00</td>
<td>5.41</td>
</tr>
<tr>
<td>Inner Home</td>
<td>1.9</td>
<td>17.80</td>
<td>1.00</td>
<td>0.00</td>
<td>1.10</td>
</tr>
<tr>
<td>Work</td>
<td>4.50</td>
<td>0.568</td>
<td>1.00</td>
<td>0.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Education</td>
<td>6.00</td>
<td>2.50</td>
<td>1.00</td>
<td>0.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Leisure</td>
<td>2.00</td>
<td>5.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.90</td>
</tr>
<tr>
<td>Shopping</td>
<td>0.70</td>
<td>5.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table 5-2: Utility function calibrated parameter values for Travel

<table>
<thead>
<tr>
<th></th>
<th>$\beta_{\text{travelTime}}$</th>
<th>$\beta_{\text{travelCost}}$</th>
<th>$\beta_{\text{income}}$</th>
<th>$\beta_{\text{constant}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>-3.10</td>
<td>0.0374</td>
<td>0.185</td>
<td>0.00</td>
</tr>
<tr>
<td>Walk</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td>$\beta_{\text{travelTime}}$</td>
<td>$\beta_{\text{travelCost}}$</td>
<td>$\beta_{\text{income}}$</td>
<td>$\beta_{\text{constant}}$</td>
</tr>
<tr>
<td></td>
<td>-0.35</td>
<td>0.563</td>
<td>-0.117</td>
<td>-0.27</td>
</tr>
<tr>
<td>Bike</td>
<td>$\beta_{\text{travelTime}}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\beta_{\text{constant}}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5-3: Utility function calibrated parameter values for Dis-similarity and Socio-demographic attributes

<table>
<thead>
<tr>
<th></th>
<th>$\beta_{\text{femaleAct}}$</th>
<th>$\beta_{\text{femaleTravel}}$</th>
<th>$\beta_{\text{ageEducation}}$</th>
<th>$\beta_{\text{repeat}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.0577</td>
<td>0.0797</td>
<td>-0.0146</td>
<td>-0.50</td>
</tr>
<tr>
<td></td>
<td>$\beta_{\text{ageWork}}$</td>
<td></td>
<td>$\lambda_{\text{dissim}}$</td>
<td>$\beta_{\text{dissim}}$</td>
</tr>
<tr>
<td></td>
<td>-0.00664</td>
<td></td>
<td>-0.949</td>
<td>-139.0</td>
</tr>
</tbody>
</table>
Figure 5-2: Plot of the utility function for activities

(a) Utility function for the performance of activities.

Figure 5-3: Plot of Utility function for travel

(b) Utility function for the performance of travel.
6 Results and Conclusion

With MATSim configured as shown in previous chapters, the scenario was run for 50 iterations with 10% of agents replanned each iteration. The results are compared to Swiss Micro-census data 2005 and the traffic counts collected at 115 counting stations within 10km circle around Zurich city centre (Swiss Federal Statistical Office, 2006). In addition, the travel statistics are compared to those obtained with MATSim runs conducted without the transit simulation and freight & cross-border traffic.

Activities: The average activity chain length of 4.01 activities is observed. This is lower than the average length of 4.65 activities reported by Microcensus. All activity type durations match well but still need improvement. The simulated overall time spent on performing activities is 21:29 and the reported one is 21:49 (see Figure 6-1).
Travel: The average number of mode-specific trips per schedule matches quite well, except for public transport which is under-estimated. The average trip distance for car has improved significantly. On the other hand, the travel times have improved considerably for all the modes due to inclusion of transit simulation (see Figure 6-2).
Figure 6-2: Results: Travel Statistics

**Average Trip distances (km)**

<table>
<thead>
<tr>
<th>Mode</th>
<th>MATSim without transit simulation</th>
<th>MATSim with transit simulation</th>
<th>Microcensus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>6.2</td>
<td>9.8</td>
<td>10.5</td>
</tr>
<tr>
<td>PT</td>
<td>16.9</td>
<td>13.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Walk</td>
<td>10.5</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Bike</td>
<td>1.8</td>
<td>4.1</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Average trips per schedule**

<table>
<thead>
<tr>
<th>Mode</th>
<th>MATSim without transit simulation</th>
<th>MATSim with transit simulation</th>
<th>Microcensus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>2.06</td>
<td>1.66</td>
<td>1.83</td>
</tr>
<tr>
<td>PT</td>
<td>0.66</td>
<td>0.67</td>
<td>0.58</td>
</tr>
<tr>
<td>Walk</td>
<td>0.97</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>Bike</td>
<td>0.23</td>
<td>0.42</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**Average Travel Times (sec)**

<table>
<thead>
<tr>
<th>Mode</th>
<th>MATSim without transit simulation</th>
<th>MATSim with transit simulation</th>
<th>Microcensus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>544</td>
<td>759</td>
<td>1545</td>
</tr>
<tr>
<td>PT</td>
<td>2183</td>
<td>2836</td>
<td>3169</td>
</tr>
<tr>
<td>Walk</td>
<td>403</td>
<td>637</td>
<td>795</td>
</tr>
<tr>
<td>Bike</td>
<td>421</td>
<td>991</td>
<td>870</td>
</tr>
</tbody>
</table>
Figure 6-3: Observed and simulated traffic counts

Figure 6-4: Comparison of public transport link volumes

Following are few conclusions made on observing the above results:
- The alpha value (target duration) of the activities leisure and shop should be even lower (presently 0.7 and 02 respectively) and in case of home and education the same should be even higher than the present values (presently 12.00 and 6.00 respectively) (see Figure 5-4). This would bring the average duration of the activities closer to the reported one. (Figure 6-1: Average Activity durations)
- Since the current transit simulation router divides the pt leg into a set of transit activities and transit legs pt distances are calculated as crow-fly distance between the activities into a factor of 1.5. This has caused low average distances for pt for which our current utility function generates a low utility (see Figure 5-4.). The probability of people choosing pt for small distances has decreased resulting in lower values of average pt trips and pt counts Figure 6-4. On a closer look, there are packs of links that have produced same or similar volumes which might be because most of the load on lines which run on these links comes from long distance travellers.
- For transport mode bike, the utility curve should be slightly steeper than that of car otherwise agents will choose cars over bikes for short distances. (see Figure 5-4)
- Besides the utility function, the configuration of replanning strategy PlanomatX plays a very important role. The weight of activity-increase sub-strategy (see Sec. 4.1) should be slightly higher to overcome the problem of low activity chain length but only to a optimum value (between 0.2 to 0.5) beyond which bizarre activity sequences like (-shop-shop-shop-) or (-leisure-leisure-leisure-) may start to occur (the default value is 0.5).
7 Works Cited


