Generating daily activity chains from origin-destination matrices

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Generating Daily Activity Chains from Origin-Destination Matrices

A Case Study between VISUM and MATSIM based on Kanton Zurich Data—Switzerland

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Microsimulation tools are becoming increasingly important in traffic demand modeling. The major advantage in comparison with traditional assignment models lies in the fact that each traveler is simulated individually. This means, for example, that decision making processes can be modeled for each individual. The traffic demand is a result of the decisions of each individual. Those decisions lead to plans which the individuals try to execute. Because microsimulation includes not all relevant decision making processes, in particular not scheduling, individuals’ plans have to be specified externally.

On the other hand, traditional assignment tools such as VISUM (1) or EMME/2 (2) use OD-matrices as inputs. Those matrices do not include any information about the chains of activities which define plans of the individuals. The question arises, if it is possible to impute (reconstruct) the plans from the given OD-matrices. The paper presents a first approach to achieve this goal. The results compared are those from a VISUM implementation—a traditional assignment model—and of MATSIM (3)—a microsimulation model. The Zurich area of Switzerland is employed for the tests.
INTRODUCTION

Microsimulation is becoming more and more important in traffic simulation, traffic analysis and traffic forecasting (see 4). Some advantages over conventional assignment models are:

- Computational savings in the calculation and storage of large multidimensional probability arrays.
- Larger range of output options, from overall statistics to precise information about each specific synthetic traveler in the simulation.
- Explicit modeling of the decision making processes of the individuals.

The last point is important since it is not a vehicle which produces traffic, it is the person who drives it. Persons do not just produce traffic, instead each of them tries to execute his day (week, life) in a profitable way. They go to work to gain money, they go hiking for their health and pleasure, they visit their relatives for pleasure or because they feel obliged to do so, they shop to cook a nice dinner at home, and so on. Since not all of this can be done at the same location they have to travel, which produces the traffic. To plan a day efficiently, a lot of decisions are made by each person:

- Which route should I take to get to work? - Route choice decision
- Which mode should I use to go to the lake? - Mode choice decision
- Should I drink another beer before going home? - Activity duration choice decision
- Should I go shopping near my home or at the mall? - Location choice decision
- When should I do sports today? - Activity starting time choice decision
- Should I go to visit my friend? - Activity choice decision
- Whom should I take along? - Group composition decision
- Should I go swimming before or after work? - Activity chain choice decision

There are many more decisions to make, some of them are planned hours (days, months) in advance and others are made as a spontaneous reaction to specific situations. Many decisions induce other decisions. For example, if I am late for work, I am supposed to work longer, so there's no time left to go shopping today, so I need some time tomorrow to do the shopping. This example shows the importance of describing plans for each individual in a simulation model, because it is the plan and the decisions made by the person who adhere to this plan that produces the traffic.

To simulate a typical day in an urban area, microsimulation tools need precise information about the plans of each individual and also some knowledge about people's decision making process. But to extract daily plans (activity chains) from persons is not a trivial task. On the other hand conventional assignment models like VISUM (1) or EMME/2 (2) typically use demand matrices which hold the information about the trips from an origin to a destination (usually zones or regions), but these do not provide links back to individuals. This leads to the main question of this paper:

Is it possible to impute (reconstruct) people's activity chains from a set of origin-destination matrices (OD-matrices)?

This paper demonstrates first approaches to answer this question. It is organized as follows: first, the case study to which the approaches are applied is discussed including the description of the OD-matrices and how they have been generated. This is followed by a detailed description of the "activity chain generation process". To assess the quality of the results we compare VISUM and MATSIM (3) results employing OD-matrices and daily activity chains respectively. Finally, concluding remarks and recommendations for future research are outlined.

CASE STUDY OF THE ZURICH AREA

The Zurich area has about 1.3 million inhabitants and is divided into 170 municipalities and 12 additional districts inside the city of Zurich. The following subsections describe briefly how those OD-matrices were generated using VISEM (PTV AG, 2004) (see also 5).

Data Resources

The microcensus (6) is a periodic survey of the travel behavior of the Swiss population. It has been run every five years since 1974. The microcensus is carried out by the Federal Office for Spatial Development-ARE (7) in cooperation with the Swiss Federal Statistical Office-BFS (8) and contains detailed information about the mobility behavior of 30'000 persons from all over Switzerland. Information about population distribution in the
municipalities comes from the federal population census (9). BFS also provides land-use data. The regional transport models (road, rail and other public transport) (see also 10) describes the effective travel times between each municipality. In summary the following is available:

**Municipalities:**
- Location
- Structural properties
- Travel distance matrices
- Travel time matrices for private and public transport
- Accessibility classes
- Local access and egress times to the modeled networks

**Population:**
- Home locations
- Population groups (children, worker, non-worker, senior)
- Mobility (car, season ticket ownership, bike, walking)
- Activity chain distributions by subgroup

About 1670 different activity chains can be found in Micocensus2000. Most of them appear very rarely, therefore only the 100 most frequently used activity chains are included later, which still cover over 90% of all days.

**VISEM output**
VISEM (1) is conceptually an activity-based model. It differentiates population sub-classes (e.g. juniors, working adults, non-working adults, and seniors) by the respective distribution of activity patterns (e.g. from the microcensus2000). VISEM then generates a synthetic population from the census data and assigns an activity chain to each subgroup of the population. Locations for activities are assigned using gravity models, while a logit model is used for mode choice. The results are aggregated into hourly zonal OD-matrices (including the purpose of each trip) on the basis of time-specific transition probabilities between activity types.

It is to mention that the resulting OD-matrices of the case study of the Zurich area produces more traffic than other research studies of that area (i.e. Pendlermatrix, see 11). Three conspicuous traffic peaks (morning, noon, and evening) occur from the OD-matrices. For more detailed information see (5).

**ACTIVITY CHAIN GENERATION PROCESS**
The main input are OD-matrices (hourly and by mode), as discussed above. The matrices do not show which person is generating a specific trip and what the following trips will be. Even more, we do not know how long an activity will be performed before the next trip starts. The question is if it is possible to reconstruct plausible complete daily activity chains from that material and some additional information and assumptions.

Given activity chain distribution information (say, from the microcensus2000, see (6)), population distribution and land uses (say, from the BFS, see (8)) it should be possible to impute activity chains from the given matrices. Unfortunately the additional information available does not contain information about the duration of the individual activities. But to combine different trips to form a complete chain, one needs at least some information about the average time an individual spends on an activity. The activity chain generation process requires such information. So, assumptions have to be made as long no other data is available.

**Target (MATSIM Input Plans)**
MATSIM accepts different kinds of plans: from simple one-trip-plans (corresponds to OD-trips) to full daily activity chains. But to use the advantage of enhanced re-planning rules for individuals daily chains are favored. The first ‘home’ activity should include an end-time which defines when the first trip of the plan starts. In the case, of the daily chain the last ‘home’ activity does not need any timing information because it defines the end of the day. All other activities must have a defined duration. Mode and location (given as x and y coordinates) has to be included for each activity. Table 1 shows an example of a day for a person.

**The Process**
The process creates the MATSIM input plans for each user-defined mode separately. Figure 1 shows the process to create the activity chains for a specified mode. Each step uses specific input files and also produces well
defined output files. Each step can be started independently, which makes it easier to extend the process with additional steps, methods or information. This section describes the different files first, followed by descriptions of each step:

- **villages.txt**: Holds the 182 municipalities / districts, their names and the coordinates of their centroids.
- **population.txt**: Holds the number of persons for each population group and each municipality.
- **patterns.txt**: Holds the share of each given pattern by population group.
- **translation.txt**: Correspondence list between German and English activity codes.
- **villages.xml**: The same information as in `villages.txt` but in XML format.
- **fma files**: The hourly OD-matrices for a specified mode generated from VISEM.
- **population.xml**: Contains the persons by municipality who do not have an activity chain assigned yet.
- **cityplans.xml**: Chains for persons similar to Table 1, but the activities do not have a location assigned yet. However, each person retains the information about their home location and the specified mode.
- **pre-plans.xml**: Chains for all persons similar to Table 1 but only the primary activities have a location assigned. (The definition of the primary activity will be explained in the following section.)
- **landuse.xml**: This file contains land use data. It essentially describes the attractiveness of each area. Since for Switzerland land use information is available for hectares (100 meters times 100 meters), the land use information also refers to that resolution. Attractiveness is described as the number of opportunities by activity type.

Further more, the modal split is given to reduce the population by the specified mode.

### Steps of the Process

- **ascii2xml.pl**: A pre-process to convert the villages.txt file to XML format.
- **poppatterns.pl**: A pre-process which calculates the number of persons by municipality with a particular activity chain and by the specified mode. The given distribution of the activity chains is used to assign a chain to the persons. Notice that minor rounding errors of the number of people can occur because of distributing the population to the municipality, reducing the population according the given modal split and assigning the activity chains.
- **peopleGenerator**: This is the main step of the process. It sequentially goes through each hour of the OD-matrices for the specified mode and generates partially completed chains.

The `peopleGenerator` process reads (sequentially, hour by hour) one line after the other from the OD-matrix. Every cell of the OD matrix represents a number of persons which travel from one location to another. The algorithm selects those persons from the `population.xml` file of the origin of the OD-trip such that their primary activity matches the purpose of the OD-trip. The match also defines the start-time (given by the current hour of the OD-matrix). Since each matrix represents a full hour of the day, the chosen start-time is calculated as a uniform distribution of that hour. Also the number of people in the population list is decreased by the number of assigned persons. Recall that every person already has an activity pattern assigned from the preprocessing stage.

This module is used only to assign locations to the primary activities. In our simplified approach, there is only one primary activity per chain. If there is more than one out-of-home activity (`peopleGenerator` recognizes only ‘work’, ‘education’, ‘leisure’ and ‘shop’ out-of-home activities at the moment), then one of them is declared the primary activity. The idea here is to select the location of the primary activity based on the VISEM output, and then use some other module to select secondary activity locations. This leaves the question of defining the primary activity when there are multiple out-of-home activities in a row. The following simplified approach was adopted:

> The first occurrence of ‘work’ is set as primary. If ‘work’ is not part of the chain, the first occurrence of ‘education’ is set as primary. If ‘education’ is not part of the chain, the first occurrence of ‘leisure’ is set as primary. If ‘leisure’ is not part of the chain, the first occurrence of ‘shopping’ is set as primary.

As the count of available people is decreased while reading one OD-matrix entry after the other, it can happen that there are no more people available in a location to fulfill the travel predicted by VISEM. In this case, no new plans are generated.
Every chosen person together with their plan is written to the _population.xml_ file. When writing, each activity gets a 'standard' duration assigned. Recall that no data about durations of activities are available assumption about the average duration of an activity type spent per plan has to be made (user-defined input of this process). If an activity type occurs more than once in a plan, the duration for each single activity is divided by the number of occurrences of the activity type. This way, the sum of durations of all the activities of one type in the plans matches the assumed default durations.

Even though those assumptions are sensible, sometimes the durations can be quite wrong. For example, the duration of the shopping activity in the activity chain 'home-shop-home' could be just some minutes (i.e. buying a bread at the bakery next door) or it could also be about 10 hours (i.e. a shopping day at the mall). The same question applies for the leisure activities. On the other hand, the average duration of 'work' and 'education' usually has less variance. Nevertheless, for lack of more detailed assumptions the generation process will be employing these assumptions for the time being.

cityid2xy: Until now, all plans have the attribute 'cityid', which MATSIM does not recognize. Instead, it expects the x- and y-coordinates for a location. _Cityid2xy_ achieves this by choosing a random point within the given municipality (here: municipalities and districts), thus disaggregating the locations.

To choose random points the algorithm simplifies the shape of cities into circles. For every municipality the algorithm searches for the nearest neighbor and takes the half of that distance as radius for a circle around the respective center. Using this procedure, the areas of cities will not overlap each other.

_LocationChoice_: MATSIM contains a module (12), which chooses locations for secondary activities in such a way that each agent improves the daily chain. The home-location and the location of the primary activity remain unchanged.

The application uses variant of a genetic algorithms to determine the locations for each agent. Each agent (based on the previously created chain) has limited knowledge about places in the area of interest and searches within these places for a path, such that his chain improves its utility. Additionally, each agent 'knows' some other agents and exchanges information about places after every iteration with them. This way, a _social network_ is built that helps the agents improve the utility of their chains.

The original application as described in (12) assumed that all plans contain the activity 'work', which was interpreted as primary activity. Additionally, the application expected every chain to have one or two secondary activities. As the activity chains (5) do not fulfill these restrictive requirements, the application was modified. In a first step, it was ensured that short plans with no secondary activities (i.e. home-work-home) were processed correctly. Such chains will now be ignored for the iterative calculations, and left unchanged.

In a second step, the code was modified to respect the _primary_ tag for activities instead of checking whether an activity is of the type 'work'. The _primary_ tag is set by the above described process.

After these modifications the _LocationChoice_ module is able to generate the missing locations for the secondary activities for the plans given by the _cityid2xy_ process. The resulting plans file has the required information MATSIM needs (see Table 1).

It must be noted that it this whole plan generation process often does not reach a perfect match with the given OD-matrices. As an example, the output matrix for a whole day generated by VISEM (1) as explained above prevents a perfect match: for many municipalities, the number of trip starts differs from the number of trip ends—making it impossible for persons to be at home at the end of a day. On the other hand, the activity chain generation process generates only roundtrips, so the number of trip starts and trip ends will be the same in each village.

**RESULTS**

The results section describes two types of results. First, the process results (the generated plans) are directly compared to the trips from the VISEM OD-matrices. Second, the OD-matrices are used by VISUM assignment (1) and the generated plans are used by MATSIM microsimulation process using the _route replanning module_ (13). In addition, a direct conversion of the OD-matrices into one-trip-plans was performed for MATSIM which will be also be compared to the VISUM results. The comparison between VISUM and
MATSIM will be performed only for the motorized private transport since MATSIM is only able to handle this mode at the moment.

Both simulations are using the same underlying street network from ARE (7). Some changes made to this network are described in (14). The comparison of the outcome of the simulations will be done for twelve links (see Figure 2) of the given network where also counting data is available (15). But direct comparison with the field volumes will not be made since the VISEM output has already produced too much traffic, mentioned above.

Data used

The case study used is the same as in (5) containing 182 municipalities / districts with a total population of 1'247'566 persons. Using a model share of 45.44% for motorized individual transport, poppatterns.pl generates a simulation-population of 568'853 persons. Because of the above described rounding error, these are about 2'000 persons more than 45.44% of the total population.

Instead of using all 100 activity chains from (5), only a subset was chosen. In a first step, the number of activities was reduced by merging several rarely used activities into the 'work'-activity. These were the activities Begleitung (escort), Service (service), Geschaeftsreise (business trip) and Dienstreise (traveling on company business). The remaining activity types are now 'h' (home), 'e' (education), 'l' (leisure) and 's' (shopping). In a second step, all activity chains matching at least one of the following requirements were chosen:

- Activity chains consist of four or less activities.
- The number of occurrences of the activity chain is at least 1% or more of all occurrences.

This way, 21 activity patterns remained, representing nearly 93% of all occurrences of the 100 chains. It is to mention that the 100 activity chains from (5) do not include 'home' activities in between (which are also called journeys), since VISEM (1) does not allow that. Even the activity chain generation process does not have such restrictions, these chains are used.

Figure 3 shows a graphical example of the used data for motorized private transport mode.

Model Verification

Number of Chains Generated

Generating the chains using peopleGenerator assures that every person gets a chain assigned. The last person is scheduled to leave their home between 7pm and 8pm. This is of interest, since there may be situations where not enough trips from a village are available in the OD-matrices for everyone to leave.

The first time when not all trips listed in a demand matrix can be generated is the hour between 9 am and 10 am. This means also that in this hour the first person will travel further from their first location in the chain (home-location not counted) to the second place.

Number of Trips Generated

VISEM (1) generated a total of 1'372'323 car trips within 24 hours, fractional trips included (see 5). When generating chains, peopleGenerator implicitly generates trips, too, because a trip is needed every time between two activities. Summarizing the number of trips for each chain, peopleGenerator generates a total of 1'269'446 trips. The difference may be explained in the way the activity chains were chosen (see above). Table 2 shows a list of all activity chains with the number of persons and trips generated.

Comparison between MATSIM and VISUM

VISUM output is the reference to which the MATSIM output will be compared. MATSIM is known to produce results similar to VISUM (16). Nevertheless, a similarity check is also done by a one-to-one conversion of each trip of the OD-matrices into 'one-trip-plans', meaning each trip corresponds to a separate person. Of course, these are not 'real' plans but the produced traffic should be similar to the one VISUM generated. The chain generation process is used three times with the different average duration assumptions. The three generated plan files are used as initial plan files for MATSIM iterating 50 times (16). Therefore the following results will be compared to the VISUM reference output:

- **OD2Trips**: Direct conversion from trips to one-trip-plans.
• **OD2PlansW8**: Activity chain generation with average durations: 8 hours work, 4 hours education, 4 hours leisure, 1 hour shopping.
• **OD2PlansW9**: Activity chain generation with average durations: 9 hours work, 6 hours education, 5 hours leisure, 2 hours shopping.
• **OD2PlansW10**: Activity chain generation with average durations: 10 hours work, 8 hours education, 6 hours leisure, 3 hours shopping.

**Hourly Volumes, Error Calculation and Travel Time Distribution**

Figure 4 shows the hourly volumes of four of the twelve links for which counts are available. VISUM shows the three peaks already mentioned above. This differs substantially from the hourly volumes recorded at the counting stations, so a comparison to real world data does not make sense until the calibration of VISEM has been improved. The comparison between VISUM and OD2Trips shows known similarities (16). That confirms again that VISUM and MATSIM produce comparable results.

At a first sight, the hourly volumes of OD2PlansW8 differ strongly from the expected results. This is not really surprising since the activity durations are just assumptions. But giving it a closer look, there are still some similarities:

- The three peaks are still there.
- The morning peak matches pretty well.
- The others appear too early in the day (noon peak around 11am, evening peak around 4pm).

This leads us to the other two duration definitions (OD2PlansW9 and OD2PlansW10). Especially OD2PlansW10 matches the first two peaks quite well. Also, the third peak appears at the right time, but with too low volumes while later in the night, the volumes are too large.

This also shows up if we compare the absolute and relative errors (see Figure 5) from each MATSIM run with VISUM averaged over the twelve given links in Figure 2. OD2PlansW10 matches the best. Until 5pm the errors of OD2PlansW10 and OD2Trips are surprisingly similar. Larger discrepancies do not appear until the evening peak.

The reason for this difference lies again in the duration definition. The duration of a chain therefore can differ between 3 hours (h-s-h chain) to 16 hours (h-w-l-w-h). If more activity chains were used, the duration of a chain could go up to 27 hours (h-w-l-e-s-h)! In one sentence, short chains normally produce too short out-of-home durations while the reverse is true for longer ones. The results are still surprisingly good for the crudeness of the assumptions made.

Figure 6 shows the travel time distributions of VISEM and MATSIM. First, one can recognize that the three peaks again show up in VISUM, OD2Trips and also in OD2PlansW10, since the travel times increase at these times of the day. OD2PlansW9 and OD2PlansW8 on the other hand just show the first two peaks. Even more, OD2PlansW8 produces very long trips during noon time which is not surprising because the noon and the evening peak are squeezed together.

Another interesting point shown in Figure 6 is that VISUM produces less average trips (10-30 minutes) than OD2Trips but more short and long ones. The reason for that could be due to the fact that all individuals in MATSIM try to optimize their travel times by using the MATSIM router. If individuals find faster routes, they slow down the other individuals using those routes. But during the MATSIM iteration process, the width of the travel time distribution decreases as well as the average travel time (10).

**CONCLUSION AND FUTURE WORK**

The chain generation process shows a promising approach to reconstructing chains from OD-matrices, even if this problem is highly underdetermined. Moreover, since the behavior of individuals is not easy to observe without expensive surveys, chain reconstruction can be a worthwhile alternative.

Because this case study is based on microcensus2000 data (6), of course there is also a direct way-without using VISEM OD-matrices-to construct chains, but traditionally only common census data are available. By using additional information like land-use data, population census data, modal split and activity chain distributions, the imputation can be performed, as demonstrated here.

This case study shows several issues where further research is required:
• In a simple step, the definition of the average duration could be extended to be chain-type specific. For example, a 'h-l-h' activity chain defines an average duration of leisure which is longer than the leisure activity in 'h-w-l-w-h'. With this extension, the problems mentioned above should become smaller.

• The chain generation process can be extended, so that also secondary activities can be matched for a given activity chain. The MATSIM LocationChoice module then can be used to fill up the remaining activity locations which cannot be matched anymore.

• Another promising, partly explored approach for MATSIM optimizes departure time and the duration of an activity (10), so that badly chosen activity durations will be corrected. Before it can be applied, the utility function needs to be properly estimated, but see (17) for first experiences.

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REFERENCES

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Table 1: Example of a MATSIM day plan (XML format)

<table>
<thead>
<tr>
<th>Person ID</th>
<th>Plan Selected</th>
<th>Activity Type</th>
<th>Start Location</th>
<th>End Location</th>
<th>Start Time</th>
<th>End Time</th>
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Table 2: Generated activity chains and trips

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<th>Activity chains</th>
<th>Number of persons</th>
<th>Trips per pattern</th>
<th>Number of trips</th>
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<tr>
<td>h-l-h</td>
<td>157'392</td>
<td>2</td>
<td>314'784</td>
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<tr>
<td>h-w-h</td>
<td>149'849</td>
<td>2</td>
<td>188'782</td>
</tr>
<tr>
<td>h-s-h</td>
<td>94'391</td>
<td>2</td>
<td>188'782</td>
</tr>
<tr>
<td>h-e-h</td>
<td>69'097</td>
<td>2</td>
<td>138'194</td>
</tr>
<tr>
<td>h-w-l-w-h</td>
<td>17'442</td>
<td>4</td>
<td>69'768</td>
</tr>
<tr>
<td>h-l-l-h</td>
<td>13'867</td>
<td>3</td>
<td>41'601</td>
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<tr>
<td>h-w-s-w-h</td>
<td>9'960</td>
<td>4</td>
<td>39'840</td>
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<tr>
<td>h-s-l-h</td>
<td>8'996</td>
<td>3</td>
<td>26'988</td>
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<tr>
<td>h-l-s-l-h</td>
<td>6'214</td>
<td>4</td>
<td>24'856</td>
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<tr>
<td>h-w-w-h</td>
<td>10'014</td>
<td>3</td>
<td>30'042</td>
</tr>
<tr>
<td>h-s-s-h</td>
<td>5'027</td>
<td>3</td>
<td>15'081</td>
</tr>
<tr>
<td>h-l-s-h</td>
<td>4'568</td>
<td>3</td>
<td>13'704</td>
</tr>
<tr>
<td>h-l-w-h</td>
<td>4'113</td>
<td>3</td>
<td>12'339</td>
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<tr>
<td>h-w-l-h</td>
<td>5'643</td>
<td>3</td>
<td>16'929</td>
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<tr>
<td>h-w-s-h</td>
<td>4'516</td>
<td>3</td>
<td>13'548</td>
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<tr>
<td>h-e-l-h</td>
<td>2'309</td>
<td>3</td>
<td>6'927</td>
</tr>
<tr>
<td>h-s-w-h</td>
<td>2'698</td>
<td>3</td>
<td>8'094</td>
</tr>
<tr>
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<td>1'217</td>
<td>3</td>
<td>3'651</td>
</tr>
<tr>
<td>h-l-e-h</td>
<td>659</td>
<td>3</td>
<td>1'977</td>
</tr>
<tr>
<td>h-w-e-h</td>
<td>494</td>
<td>3</td>
<td>1'482</td>
</tr>
<tr>
<td>h-e-s-h</td>
<td>387</td>
<td>3</td>
<td>1'161</td>
</tr>
<tr>
<td>total:</td>
<td>568'853</td>
<td>weighted average = 2.23</td>
<td>1'269'446</td>
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Figure 1: Activity chain generation process
Figure 2: The six counting stations (twelve links) in the Zurich area

<table>
<thead>
<tr>
<th>Counting Station ID</th>
<th>Link 1</th>
<th>Link 2</th>
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<tbody>
<tr>
<td>106</td>
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<td>3013</td>
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<td>5026</td>
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<tr>
<td>221</td>
<td>2147</td>
<td>2146</td>
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</tbody>
</table>
Figure 3: Graphical example of the used input data - motorized individual transport mode
Figure 4: Hourly volumes of VISUM, MATSIM and counting stations
Figure 5: Average absolute and relative error of the twelve links of MATSIM compared to VISUM
Figure 6: Trip travel time distribution from VISUM and MATSIM