CHAPTER 56

Zürich

Nadine Rieser-Schüssler, Patrick M. Bösch, Andreas Horni and Michael Balmer

The MATSim team frequently uses the Zürich scenario, based on the Switzerland scenario described above. The Zürich scenario, however, is more detailed; it was enhanced by data available only for the smaller region; e.g., traffic light data or freight demand data was only included for Zürich city and the canton. It is under continuous development, calibration and validation and has been applied in numerous projects, serving as a real-world research example.

Horni et al. (2011b) provide a technical overview of the first scenario branch; Balmer et al. (2009a) describe its generation for the "Westumfahrung" project.

The study area was delineated by a circle, with a 30 kilometer radius around Bellevue, a central and prominent Zürich location. This delineation led to two versions, the *Zürich diluted scenario* and the *Zürich cut scenario*. For the first, all agents crossing the study area during the simulated day were considered (Figure 56.1), resulting in almost two million agents. For the second, only agents remaining in this area the whole day were modeled. The *Zürich cut scenario* was employed as an experiment in Hackney (2009), but using the *Zürich diluted scenario* for production runs is preferable.

Demand was taken directly from the Swiss model; freight traffic was added to the Zürich scenario, as follows. Canton Zürich raw freight traffic data was taken from the KVMZH (Kantonales Verkehrsmodell Zürich), provided by Amt für Verkehr, Volkswirtschaftsdirektion Kanton Zürich (2011) and documented by Gottardi and Bürgler (1999). Zonal level matrices were disaggregated to single MATSim plans (Shah, 2010). Matrices for small delivery and heavy trucks were combined into one activity called *freight*. An additional 180 000 agents were generated for the Zürich region.

For the diluted Zürich scenario, all Swiss facilities, as described above, were used as activity locations and the networks were not thinned out. For public transport simulation, network and transport schedules were derived from the KVMZH. Walk and bike modes were "teleported".

Calibration was mainly done for modal split and distance distributions and utility function values set accordingly.

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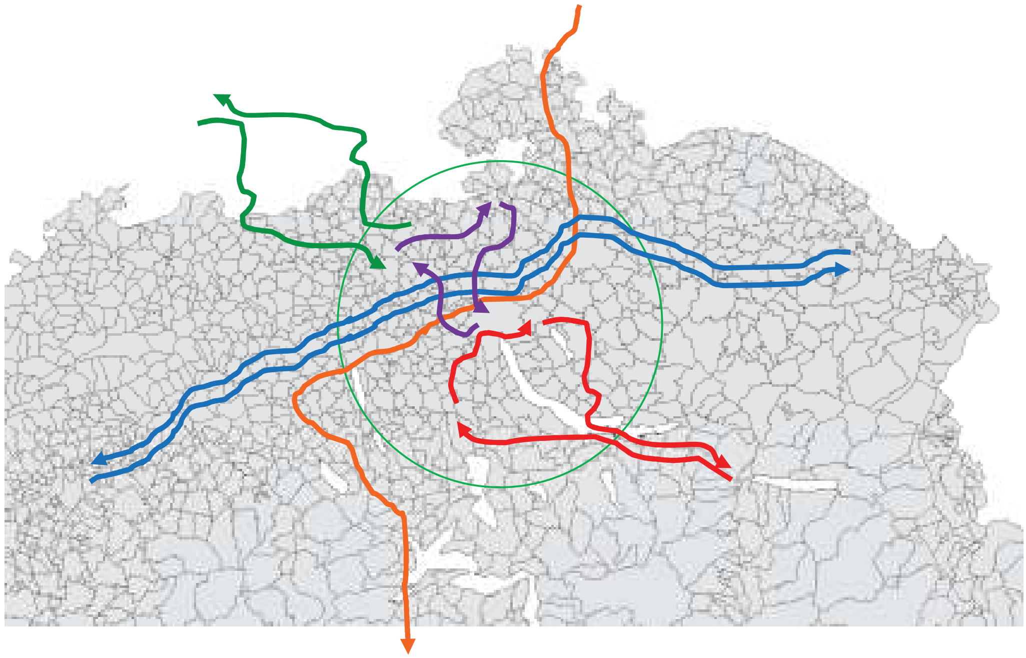

Figure 56.1: The diluted Zürich scenario

For validation, count data on city level, cantonal level and national level (ASTRA, 2006) were available from various sources, resulting in 123 links measured for the Zürich inner city, delineated by a 12 kilometer radius around Bellevue. The reduced count analysis radius was applied to reduce boundary effects resulting from demand reduction outside the 30 kilometer radius study area. An average working day (Monday to Thursday, excluding public holidays) was used for comparison in current scenarios.

Some traffic signal data was available for Zürich city (Stadt Zürich, Dienstabteilung Verkehr, 2008); this was integrated for the Westumfahrung project.

56.1 Studies Based on the Zürich Scenario

Besides its widespread use for the development of new MATSim functionality—e.g., the contributions for destination innovation (Chapter 27), joint decisions (Chapter 28), parking (Chapter 13), or electric vehicles (Chapter 14)—the Zurich scenario has also been used in policy studies. The most prominent one was the study Westumfahrung (Balmer et al., 2009a), where MATSim was used to estimate the effects of opening a new motorway section and different accompanying measures. In addition to classic evaluations such as link volumes and spider analyzes, the project focused on estimating who the winners and losers of the Westumfahrung were and where they lived. Other policy studies looked at the potential for Park & Ride, organized as well as informal ride sharing, the effects of a substantially improved public transport offer, and the influence of road capacity changes on transport behavior.

A more recent example for a study based on the Zürich scenario is described by Heyndrickx et al. (2016); Boesch et al. (2014); Heyndrickx et al. (2014); Pilli-Sihvola et al. (forthcoming); Boesch and Ciari (2014); Boesch (2014). It was conducted as a part of the EU project ToPDAd (Tool supported Policy Development for regional Adaptation). ToPDAd tried to find the best strategies for decision makers to adapt to the expected short and long term effects of climate change. The international project focused on the three potentially climate sensitive and important economic sectors Energy, Transport and Tourism.

For each sector different case studies were investigated to develop the tools required to find suitable adaptation strategies. In the transport sector the IVT together with the TML (Transport & Mobility Leuven), Belgium, conducted a study on the potential influence of extreme weather events, which are predicted to increase in frequency and intensity for Western Europe due to climate change, on the transport system.

The Zürich scenario was used to identify the transport system reactions on different, weather-induced disturbances. The number of trips, activities, and their durations were compared for different scenarios. The applied scenarios represented variations both on the supply side and on the demand side. On the supply side, next to the baseline scenario eight different scenarios were simulated. A medium and a high disturbance scenario, where the capacity and the free-flow speed on the entire network were reduced due to unfavorable weather conditions and a medium and high disruption scenario where certain, exposed street and public transport links were (temporary) blocked. These disturbances and disruptions occurred only in the peak hour or for the full day, resulting in the eight scenarios on the supply side. On the demand side the agents were allowed five different degrees of flexibility to react to this situation: 1. Worst case (no reaction allowed); 2. Rerouting; 3. Rerouting and modal change; 4. Rerouting, modal change and rescheduling; and finally 5. Rerouting, modal change, rescheduling and relocation.

It was found that rerouting and mode choice together have the highest impact in terms of reaction to the disturbances. If the public transport system is disrupted, the expected shift to car and slow modes is observed. The opposite, expected shift to increased pt-usage is also correctly observed if the transport system is disturbed by unfavorable weather conditions (e.g., rain or snow).

The results of these scenarios were used by TML to calculate the direct and indirect economic costs of extreme weather events through an impaired transport system. Extreme events with a return value of five to ten years are estimated to cause costs of up to 19 million EUR per event for the region of Zürich, while the more extreme events with a return value of only 50 to 100 years would cause costs of up to 100 million EUR per event. Compared to estimations for historic events these are relatively low values (costs of billions per event). One of the reasons for this difference is assumed to be in the inability of MATSim agents to drop activities. So, while in reality people would for example likely drop work activities in the case of severe floods and thus cause additional economic costs, MATSim agents will always try to find a way to get to their work location and to work { no matter how bad the circumstances. Current efforts at IVT try to overcome this limitation while still producing realistic simulation outcomes.

CHAPTER 57

Singapore

Alexander Erath and Artem Chakirov

The MATSim Singapore scenario (Erath et al., 2012) was implemented and is maintained at the FCL (Future Cities Laboratory), a research program of the SEC (Singapore-ETH Center for Global Environmental Sustainability) and part of Singapore's National Research Foundation CREATE (Campus for Excellence and Technological Enterprise). The scenario covered the whole Singapore area, with a population of approximately five million and included traffic to and from neighboring Malaysia. Singapore provides an excellent study case for an agent- and activity-based modeling approach: a fairly densely populated city, with an extensive public transport infrastructure and advanced transportation and pricing policies.

57.1 Demand

In the absence of a full-population census for Singapore, a synthetic population was generated based on data from the HITS (Household Interview Travel Survey) 2008 (Choi and Toh, 2010) and population breakdowns of Singapore's population census 2010. The synthetic population was derived using the fitting and sampling method (Müller and Axhausen, 2011), where a reference sample of household and person records was weighted, using an IPF technique, until the weighted sample matched marginal census control totals. In our case, the reference sample was from travel survey records; fitting technique was the entropy optimization method proposed by Bar-Gera et al. (2009) and implemented by Kirill Müller, IVT, ETH Zürich. Then, the reference sample records were replicated through weighted sampling until the population total was met.

Car ownership was modeled on a household level and driving licenses were assigned to individuals, using discrete choice methods. Given the high car tax in Singapore, the model reflected lower car ownership level than in other developed nations. The model presented by van Eggermond et al. (2012) included not only socio-economic, but also spatial variables and proved to be essential to the MATSim Singapore model, leading to accurate mode choice and mode share predictions.

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Activity locations were defined on an individual building level, with information on building and facility types compiled from various sources: i.e., the land-use master plan (URA, 2008), government websites and online directories, as well as points of interest information provided by NAVTEQ. In the absence of a business census, an innovative approach for location identification and corresponding number of work places was developed, drawn from the full smart card data record of public transport journeys and enriched with information on land-use and estimates of building floor space. In a first step, a probabilistic model was applied to a daily public transport journey record to identify types of activities performed between two subsequent public transport trips. Estimated and calibrated using HITS 2008 records, the model combined variables such as time of day, activity duration and land-use around each stop or station to ensure an accurate differentiation between home, work, or other activities. After accounting for mode shares in 53 different zones, an optimization technique employing accessibility computation was applied to distribute work activities to individual buildings. More details on the newly developed methodology and its practical application were reported by Chakirov and Erath (2012) and Ordóñez Medina and Erath (2013a).

Assignment of households to buildings was performed using detailed information on residential developments; for public housing, which represented about 80 % of Singapore's residential building stock, information on distribution of different dwelling types was employed, while for privately owned condominiums, only information on number of apartments per building was available. Work locations were assigned using a zone-based gravity model using prior estimated number of work activities in each building as additional information for distribution of workplaces within each zone. Activity chains were assigned based on their observed frequency in HITS, taking into account key socio-demographic parameters like sex, age, occupation and income. Activity chains of type home – work – home were by far the most frequent, accounting for approximately 50 % of the trips. Freight and cross border traffic, as well as tourist travel demand, were derived based on a set of origin destination matrices provided by the LTA (Singapore Land Transport Authority). These matrices were converted into special daily plans. Information on the temporal distribution of freight trips was derived from loop detector data for freight and temporal attraction profiles of major tourist sites.

57.2 Supply

Using a semi-automatic map-matching algorithm (see Chapter 9), a high-resolution navigation network provided by NAVTEQ was map-matched to, and enhanced with, LTA's planning network lane and capacity information. Without access to traffic signal cycle time data, traffic lights were not specifically modeled. Extensive attention was paid to public transport modeling; interaction between private and public transport with Singapore's high density and limited space was very important. Simulating dynamic effects, such as bus bunching, was crucial for obtaining realistic travel times and mode shares. Public transport network and schedule data provided by LTA included bus and train routes, as well as stop and station location. This information was matched to the road network, using yet another map-matching algorithm presented by Ordóñez Medina and Erath (2011); Ordóñez Medina (2011b). Recently, the scenario was updated using public transport schedule data derived from public transport smart card data records (Fourie, 2014). Such schedule information provided actual vehicle dispatch frequencies and headways, which are continuously adjusted and, in some cases, can substantially deviate from published schedules. Additional features of public transport simulation in Singapore's model included advanced bus dwell time model (Sun et al., 2014b), as well as an approximation of the distance-based public transport fare scheme.

Other modes, specifically walking and cycling, were "teleported" with constant travel speeds without any interaction with other users.

57.3 Behavioral Parameters

Behavioral parameters specific to Singapore's context were borrowed from Land Transport Authority (2009) and used with the widely applied Charypar-Nagel function for activity scoring (Charypar and Nagel, 2005). Thus, the same parameters were used for all agents, ignoring user preferences, heterogeneity, and time values in the initial scenario implementation. Furthermore, no additional crowding penalties (impacting travelers' discomfort) were considered at this stage; public transport overcrowding effects were taken into account only with physical vehicle capacity limitations, as well as their implications for dwell time and the bus bunching phenomenon.

57.4 Policy

The MATSim model for Singapore also included ERP (Electronic Road Pricing) scheme, featuring time and vehicle-dependent road pricing. Based on two data sets, with location and time-dependent price levels, prevailing tolls were specified for 73 network links where toll gantries had been installed, as of February, 2012. To account for the numerous dedicated bus lanes, additional links attributed to exclusive bus use were added to the network. The existing links' capacity was reduced accordingly, even if, in some cases, dedicated exclusive bus lanes by buses existed only during peak hours. Such a simplified setup, insensitive to the time-dynamic operation of dedicated lanes, led to actual road capacity underestimation during periods when bus lanes were also open to other motorized traffic. However, as most links featuring bus lanes consisted of three or more lanes, the effect on modeled traffic conditions during off-peak hours appeared to be low.

57.5 Calibration and Validation

Road usage data is available for around 200 count stations at hourly intervals. Public transport smart card data availability provides an additional validation dimension. For the future, the opening of new MRT lines—since setting up the model in 2012—presents a unique opportunity for comparing observed ridership with predicted ridership in the model. However, systematic calibration and detailed validation have not yet been conducted.

CHAPTER 58

Munich

Benjamin Kickhöfer

The MATSim scenario for the Munich metropolitan area was set up during 2010.[1] The main goal was, and is, simulation of local air pollutant and global greenhouse gas emissions and how their levels change with different policy measures—on aggregated and spatially disaggregated levels. Thus the scenario was used for development and testing of the EMT (Emission Modeling Tool, see Chapter 36). For an example illustrating where overall NO_2 private car and freight vehicle emissions are produced over one day, see Figure 58.1.

Network information from VISUM was converted into MATSim format, resulting in a network of 17 888 nodes and 41 942 links. This transport supply was then linked to travel demand from different sources; an inner-urban traffic activity-based demand from survey data was created, based on MiD (Mobilität in Deutschland (MiD 2002, Follmer et al., 2004)). This synthetic population segment consisted of roughly 1.4 million individuals, with detailed vehicle information for every household. Commuters and reverse commuters were modeled with data provided by the German Federal Employment Office (Böhme and Eigenhüller, 2006). This part of the population consisted of approximately 0.5 million individuals, with 0.3 million commuting to Munich for work. The rest lived in Munich and commuted to their workplace outside the city. Freight traffic was also introduced into the model using data from the German Ministry for Transport (BVU Beratergruppe Verkehr + Umwelt GmbH und Intraplan Consult GmbH, 2007). This consisted of roughly 0.15 million freight vehicles, performing one commercial trip per day.

The scenario was used for several case studies: Hülsmann et al. (2011) used a single street corridor to validate simulated travel times and emission levels against actual data obtained from a test vehicle. Kickhöfer et al. (2013) investigated the relationship between the price elasticities of car travel demand and air pollutant emissions. Hülsmann et al. (2013) identified city areas with

[1] Detailed descriptions of the scenario can be found in Kickhöfer et al. (2013) and Kickhöfer (2014).

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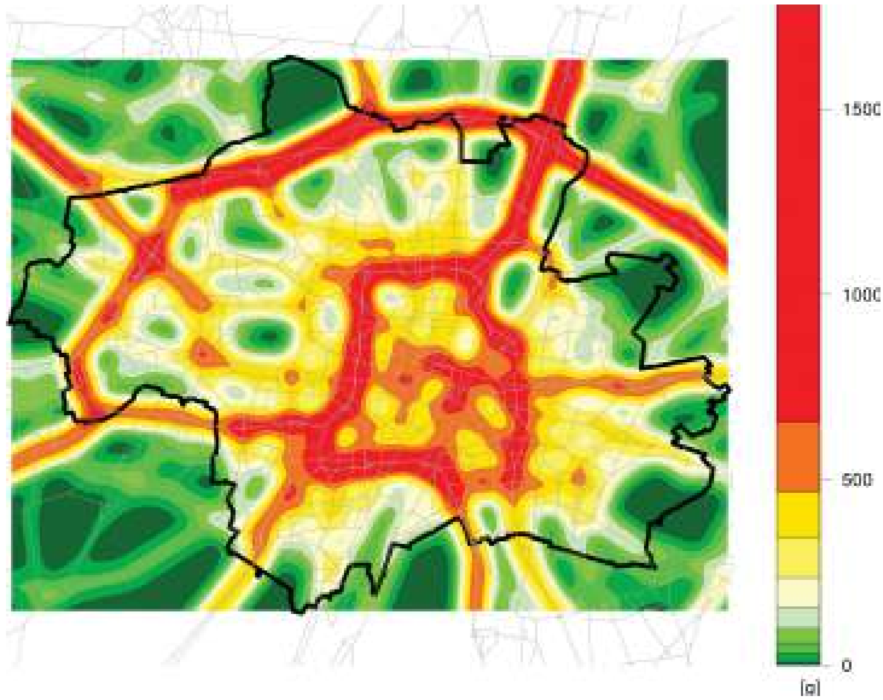

Figure 58.1: NO_2 emissions in Munich

high air pollution concentration. They defined these areas as "hotspots", exceeding the EU limits for NO_2 (Nitrogen Dioxide). The authors raised toll levels incrementally for vehicles passing these hotspots, until high pollution concentrations disappeared, to estimate true threshold value EU avoidance costs. Kickhöfer and Nagel (2013) derived time-dependent, vehicle-specific, first-best air pollution tolls to create a benchmark for real-world policy evaluation. Kickhöfer and Kern (2015) went one step further and calculated time-dependent, vehicle-specific air pollution *exposure* tolls.

CHAPTER 59

Sioux Falls

Artem Chakirov

The Sioux Falls scenario provided a convenient test-case, combining fully dynamic demand fitted with realistic socio-economic and demographic attributes with a small-scale road network including an integrated public transportation system. Based on the Sioux Falls road network commonly used for tests and demonstration purposes in transportation literature (Bar-Gera, 2013), it allowed quick and convenient experiments on new policy or software implementations with MATSim on a heterogeneous agent population, with a high degree of spatial resolution, but without significant computational requirements. However, it is important to stress that, despite the use of real world data for the generation of the enriched Sioux Falls scenario, it did not aim to replicate the real City of Sioux Falls in South Dakota, US and remains a fictitious test case. Detailed report on scenario generation and its characteristics is provided by Chakirov and Fourie (2014) and can also be found at `http://www.matsim.org/scenario/sioux-falls`.

59.1 Demand

A realistic, socio-economically and demographically diverse demand population—with heterogeneous use preferences—was crucial for unlocking the full potential of an agent-based simulation like MATSim. However, generation of a disaggregated demand description on individual and household levels close to reality was challenging; not only for trip origins and destinations, but also with respect to travel pattern relation and socio-demographic travelers' characteristics.

To address this challenge for the Sioux Falls scenario, and represent the household structure, demographic profile and income distribution as realistically as possible, a synthetic household population, using the Bar-Gera et al. (2009) entropy optimization technique, was generated. It matched the aggregate distribution of demographic attributes (age, sex and household income) recorded during the 2010 US Census. It contained census tracts inside, and adjoining, the city center of

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Sioux Falls and was composed of household and person records taken from the (anonymous) 5-year American Community Survey sample (2007-2011), covering 5 % of all households.

To keep the scenario accessible, as well as facilitating interpretation and understanding of possible effects on policies studied, only two simple activity chains were initially included: "home – work – home" and "home – other – home". Activity locations were identified using building stock data set provided by the City of Sioux Falls GIS division. Each household's home location was assigned randomly to a residential unit within the household's tract. Because no information on the real number and distribution of work places within the relevant area was easily accessible, the static O-D matrix from LeBlanc et al. (1975) was taken as a workplace attraction indicator for each zone. Then, assignment of work places to individual workers, as well as locations of secondary (other) activities, was performed using a parameter-free radiation model presented by Simini et al. (2012).

To exploit the full potential of disaggregated demand and add another degree of realism to the scenario, car ownership on the household level was modeled using an ordered probit model, presented by Giuliano and Dargay (2006) and based on the NPTS (US Nationwide Personal Transportation Survey) 1995. In addition to socio-demographic household characteristics (number of adults, children, pensioners, household income), the model used residential location attributes (population density, public transport access and dwelling type), which better described specific Sioux Falls scenario characteristics, as well as its area-wide bus network.

59.2 Supply

A realistic transportation test network should ensure sufficient complexity of travelers' choice dimensions while limiting computational effort. To this end, the Sioux Falls test network was introduced by Morlok et al. (1973) and later adapted as a benchmark and test scenario in many publications (see Chakirov and Fourie (2014) for overview). The network structure captured the major arterial roads of Sioux Falls, South Dakota, but was never intended to replicate the real city, or all characteristics of its transportation system, such as travel times or modal split. The original network was comprised of 76 arcs, 24 nodes and 552 O-D pairs. For this scenario, road capacities were adjusted according to values provided by the Highway Capacity Manual Transportation Research Board (2010) and other related research publications (e.g., Ng and Small, 2012). The public transportation network added to the scenario included five bus lines, as initially proposed by Abdulaal and LeBlanc (1979), with bus stops placed at regular intervals of 600 meters.

Due to the design of MATSim queue simulation, agents were handled only at the beginning and end of each network link and could not enter or leave a link along its length. Therefore, origins and destinations located along very long links led to spatial detail loss, as all origins and destinations along the length of the link were effectively assigned the same coordinates. Consequently, to improve spatial detail level, all links of the Sioux Falls network were evenly split into smaller links, with maximum length of 500 meters each. Following this operation, number of nodes was increased to 282 and number of links to 334, without changing effective network topology.

In addition to car and bus modes, walking as "teleported" mode, with constant travel speeds, and with no interaction with other users, is used as the non-motorized transportation mode.

59.3 Behavioral Parameters

Behavioral parameters used in utility functions were based on estimated demand model for Sydney by Tirachini et al. (2014). Before applying parameters in an activity-based context, time-related parameters had to be adjusted to account for utility gained from activity performance. Thus, to provide a value for marginal utility of performing an activity, the travel mode with smallest the disutility was set as a baseline, under the assumption that traveling with this mode was equivalent to idling/doing nothing. Corresponding parameters were split into opportunity costs of time and a mode-specific disutility of traveling, as has been done in previous MATSim-related publications (e.g., Kickhöfer et al., 2011).

59.4 Results, Drawbacks and Outlook

Sioux Falls scenario stability and performance was tested using two sets of activity timing constraints, as well as five different random seeds, which all delivered stable and realistic results. Chakirov and Fourie (2014) also investigated MFD (Macroscopic Fundamental Diagram) existence and hysteresis characteristics, as discussed in Geroliminis and Daganzo (2007, 2008); Geroliminis and Sun (2011).

However, recent experience has shown certain coarse network drawbacks; it represented only major arterial roads and neglected minor neighborhood and collector road links. With an elaborate synthetic population and high rush hour demand peaks, the network seemed to be sensitive to network breakdowns under high loading conditions.

Along with the coarse road network, the coarse public transport network level and the resulting low level of accessibility (for parts of the population) represented another drawback, particularly relevant to simulation and evaluation of policies sensitive to, or requiring, a certain share of public transport users.

Replacing the original Sioux Falls network with a finer network obtained from the crowd-sourced OSM and adding additional public transport lines would address the above-mentioned scenario weakness. However, this introduces a different set of drawbacks and would require further attention. First, the significantly larger number of network links and nodes increases time and resources for routing and dynamic queue simulation and could erase the advantages of a small-scale network. Extended simulation times can be tackled with the new pseudo-simulation methodology, currently developed by Fourie et al. (2013). Second, total network capacity increase leads to reduction or even disappearance of congestion during peak hours, although including freight and through traffic in the scenario can make it more realistic and address congested conditions during peak-hours.

CHAPTER 60

Aliaga

Pelin Onelcin, Mehmet Metin Mutlu and Yalcin Alver

Aliaga, in Turkey, is situated about 50 kilometers north of Izmir; it is one of the 30 Izmir province districts in the Aegean region of Turkey and is crucial to the national economy.

Aliaga is home to Petkim, one of the largest petrochemical enterprises of Turkey. In 2011, Petkim was ranked as the 12th largest company in Turkey's 500 top industrial list (Istanbul Chamber of Industry, 2012, accessed 03.07.12); the enterprise includes 14 plants and seven auxiliary units.

According to the Turkish Statistical Institute, the 2011 population of Aliaga was 68 432; 56 440 lived in central neighborhoods and 11 992 in surrounding villages (Turkish Statistical Institute, 2011).

Many chemical factories are located near residential areas. The evacuation zone was determined using a scenario developed for a chemical accident in one of the Petkim factories. Chemical substance elements and NFPA (National Fire Protection Association) (704) ratings, ranging from 1 to 4 for flammability, health and reactivity, were compared. The most dangerous substance was acrylonitrile (ACN), rated 3, 4 and 2 for flammability, health and reactivity, respectively.

Risk zone radii were found using Aloha software developed by the Office of Emergency Management and Emergency Response Division. The software divided the risk area into three zones, based on the chemical substance type, wind speed and wind direction. The wind data, obtained from Aliaga wind measurement station, showed that maximum wind speed was 17 meters per second (WolframAlpha, 2012, accessed 02.08.12) and the prevailing wind direction was WNW. Wind blowing from the west would be the most dangerous for Aliaga, carrying the smoke over residential areas and increasing the number of persons to be evacuated.

The evacuation zone was divided into 19 TAZs (Traffic Analysis Zones). Trips generated from these zones were directed to six destinations TAZs, three of which are health care centers and three gathering places. The Petkim area iwa divided into six zones; the first in the impact area. The evacuation planning zone is shown in Figure 60.1.

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Figure 60.1: Evacuation planning zone.

Number of evacuees was calculated considering both permanent residents and employees, who were classified as transients. The scenario was prepared assuming the following conditions:

- The explosion occured in the evening when there were no students in schools and people were awake.
- All employees in the first risk zone, and some in the second, were taken to the Aliaga state hospital in zone 30, as well as to other health care centers in zones 26 and 27. The first risk zone was the most vulnerable; thus, persons needing medical intervention in this area would be taken to hospital. The typical behavior pattern in Turkey is to flock to hospitals in emergency situations. When generating scenarios, this behavior was considered; in the first and second risk zones, health care centers were designated as destination zones.
- People in residential zones would self-evacuate. Since Aliaga is a small town, public transportation service is weak and in the evening, public transportation frequency is low. Therefore, public transportation was not considered in this study.
- Employees in Petkim and in Tupras worked in three shifts; factories were active 24 hours a day and employees were always present.

There were 3 883 employees in the area studied; number of employees to be evacuated from factories was computed using the following assumptions:

- The total employee figure was divided into three, as they worked in three shifts.
- The explosion did not occur during shift change.

Evacuations from residential buildings were calculated using these steps:

- Number of persons living in an evacuation zone neighborhood was divided into the number of neighborhood buildings, giving the mean number of persons living in one building.

- Number of buildings that remained in the evacuation zone was multiplied by the mean number of persons in one building.

To estimate the number of evacuation vehicles needed, car occupancy ratio rate was used. This rate was 1.57 in normal situations—as given in the Urban Transportation Plan of the Istanbul Metropolitan Area by the Istanbul Metropolitan Municipality Directorate of Transportation Planning—however, in emergency situations, it was expected to be higher. In this study, car occupancy ratio rate was taken as two, number of evacuees was computed as 14 472 and number of vehicles 7 236.

The Aliaga network was taken from OSM and converted to a shape file and MATSim network file with the tutorial's `PNetworkGenerator` class. Zones used in generating synthetic population for MATSim were created in QGIS.

Three different scenarios were identified for the evacuation simulation. In Figure 60.2, O-D matrices for each scenario can be seen. These three scenarios were selected based on destination zone location and traffic demand criteria; free spaces close to the risk zone were designated as gathering areas. The time required for evacuees to reach health care centers was very important in emergency situations like this. The traffic demand generated for health care centers was distributed between zones 26, 27 and 30 in the scenarios, though the first risk zone was always directed to Aliaga State Hospital, which had the most capacity of all health care centers; severely injured persons would be transferred to this state hospital. Evacuating vehicles departing from the second risk zone were directed to health care centers in zones 26 and 27. Changing the number of evacuating vehicles in any given zones resulted in different evacuation times; thus, these different scenarios enabled observation of traffic demand effect on traffic and whether this led to evacuation time reduction.

Initial demand refered to synthetic population derived from numbers and locations of evacuees to be transferred to health care centers or gathering-areas, sorted by distance. A starting place for

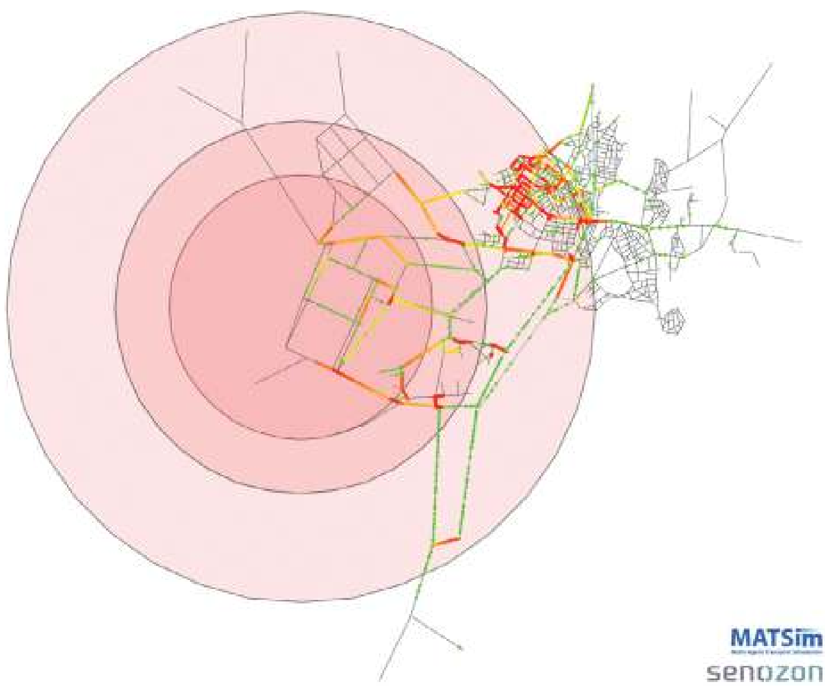

Figure 60.2: MATSim simulation snapshot.

initial demand generation was found in the tutorial's `DemandGenerator` class. Zones were modified according to both actual population density in given zones and road links where evacuees could start their trips at the time of a possible chemical accident to generate a relatively realistic scenario. Population zones were set for a group of origin zones, which were assigned for a predefined destination. For each agent, random activity coordinates were generated: home, work and leisure, or in this case, evacuation zones, hospitals and gathering areas. Agents' departures and arrivals took place on the nodes closest to activity coordinates and, in the first iteration, shortest path was calculated for route choice.

MATSim assigned trip start to the node closest to agent activity coordinates (i.e., home or work) for each agent. MATSim simulation results were analyzed by Senozon AG Via. Figure 60.3 shows a simulation snapshot.

Clearance time for three risk zones and total arrival time for three different scenarios were listed in Table 60.1. For the first scenario, evacuation times were 45 minutes for the first risk zone, 83 minutes for the second, and 86 minutes for the third. For the second scenario, evacuation times were 44 minutes for the first risk zone, 82 minutes for the second, and 91 minutes for the third. Finally, for the third scenario, evacuation times were 47 minutes for the first risk zone, 86 minutes for the second, and 88 minutes for the third. The third scenario yielded the best results, with minimum clearance time for the entire risk area. Scenario results confirmed that clearance times were insufficient for people to evacuate safely, especially from the first risk zone.

		Scenario 1						Scenario 2						Scenario 3					
		26	27	30	32	33	34	26	27	30	32	33	34	26	27	30	32	33	34
R.Z. 1	1			33						33						33			
	3			17						17						17			
	4			33						33						33			
	6			83						83						83			
	7			50						50						50			
R.Z. 1-2	10			221						221						221			
	13	16						16						16					
	14	90						50		40				50		40			
R.Z. 2-3	11				837						837						837		
	15		320					120	200						120			200	
	17				53						53						53		
R.Z. 3	16						660						660						660
	18					151						151						151	
	19					158						158						158	
	20					216						216						216	
	21					137						137						137	
	22					175	280						280						280
	23											175						175	
	24						88						88						88

Figure 60.3: OD matrices for evacuation scenarios.

	Risk zone 1	Risk zone 2	Risk zone 3
Scenario 1	45	83	86
Scenario 2	44	82	91
Scenario 3	47	86	88

Table 60.1: Risk zones evacuation times in minutes.

CHAPTER 61

Baoding: A Case Study for Testing a New Household Utility Function in MATSim

Chengxiang Zhuge and Chunfu Shao

61.1 Introduction

Baoding is a medium-sized city in Hebei Province, China. The Baoding case study—testing a new household utility function—proposed two scenarios to compare the performance of two utility functions: the household and individual utility functions. In Scenario 1, it was assumed that each household sought to maximize their overall household utilities when they scheduled; thus, family members' communication and coordination was communal in each household. In Scenario 2, the individual utility function—the default utility function in MATSim—was utilized to score plans; here, each agent tried only to maximize his own utilities without communicating with other family members.

Overall, Scenario 1 differed from Scenario 2 only in the utility function; other input data and parameters in these two scenarios were kept the same. The scenarios simulated only urban residents' travel behavior. In 2007, the study area population was 1 060 783, in 299 850 households, encompassing 355 465 privately owned cars.

61.2 Population and Demand Generation

Population The scenarios' agent population was created using a new population synthesis, which starts with initial household weights obtained from the 2007 Baoding Household Travel Survey. The final household weights, used for creating the population, were calculated by iteratively adjusting initial household weights in a directed way. Gender and household car ownership were also used as person- and household-level control variables, respectively. In the scenarios, only 20 % of Baoding's total population, approximately 212 000, was synthesized and used, to speed up the simulation.

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Travel Demand Generation For initial demand generation, a GA (Genetic Algorithm), adopting utility maximization theory, was implemented. For Scenario 1, this GA used the new proposed household utility function as the fitness function; this was employed to generate initial individual daily plans for each household in the synthetic population. Specifically, in the GA, each chromosome represented a household's set of daily plans and each gene represented a family member's daily plan. During evolution (including mutation, crossover and selection), each chromosome was scored; only those with higher household utilities remained. Then, a set of daily plans with the highest household utility function were selected and allocated to the household. Similarly, other daily household plans in the synthetic population were generated, one by one. It should also be noted that the travel time in the initial daily plans was estimated. Therefore, elements like travel time and activity duration in the initial daily plans would be adapted (optimized) when executed in MATSim.

In Scenario 2, the GA incorporated the individual utility function to search for each agent's (family member's) plans.

61.3 Activity Locations, Network and Transport Modes

Activity Locations Five typical activity types, including work, home, leisure, education and shopping, were taken into account in the scenarios. The activity facilities numbers for these five types were: 1 647, 462, 246, 372 and 445, respectively.

Transport Network The scenarios contained two network types, including road and public transit networks. Figure 61.1 demonstrated Baoding's 2007 road and transit network. The road network was composed of 1 650 nodes and 539 links; the transit network contained transit routes and transit schedules, with 49 transit lines and (98 transit routes).

Transport Modes The simulated transport modes included car, public transport, bike and walk. Car drivers and public transport passengers used the road network and transit network. Because agents who traveled by bike or on foot had no access to the transport network, they were teleported from origin to destination and assigned no exact routes, but their travel time was calculated.

61.4 Historical Validation

Historic validation. composed of the following two steps, was carried out to assess MATSim's performance and applied to both scenarios.

Step 1: Comparison of both real and simulated car flows and comparison of real and simulated transit passenger flows were carried out in each scenario, to assess MATSim's performance for car and transit simulation. The MRE (Mean Relative Error), calculated by the equation (61.1), was employed to assess performance.

$$MRE = \frac{\|F_{simulated} - F_{real}\|}{F_{real}} \times 100\,\% \tag{61.1}$$

where, $F_{simulated}$ and F_{real} denotes the simulated and the real flow (car flow or passenger flow), respectively.

Step 2: Comparison of both scenarios' performance for car and transit simulation, based on results from step 1.

61.4.1 Comparison of Two Scenarios: Car Traffic

Car flow data on six road links (equal to 12 links in MATSim scenario) from 7 am to 9 am, was used for comparison of car simulation and was manually counted in 2007.

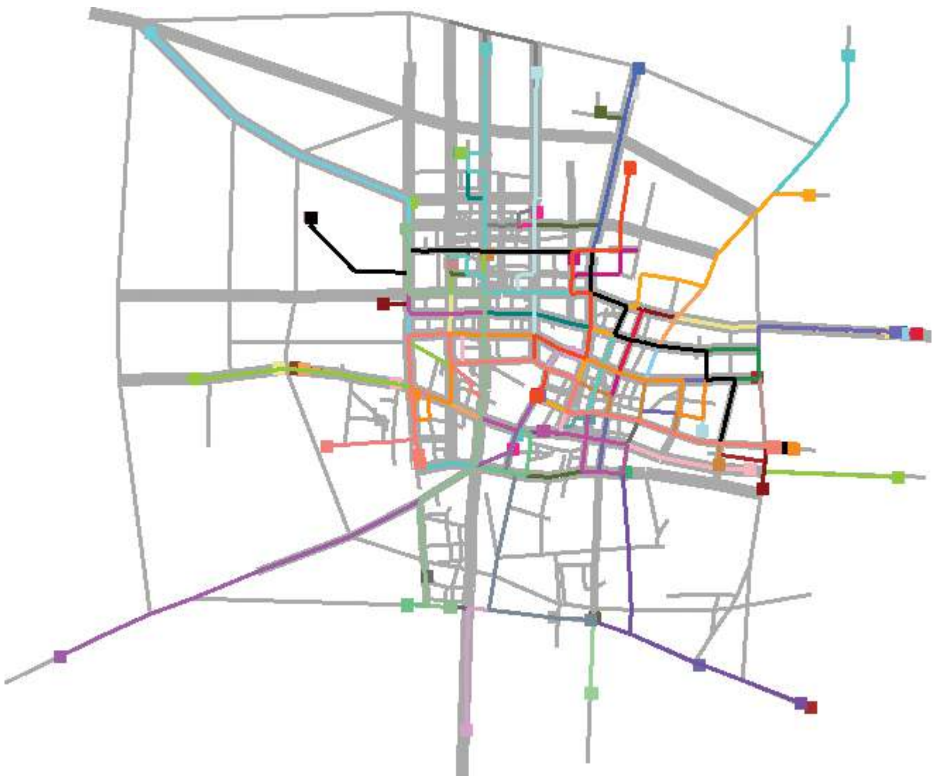


Figure 61.1: Road and transit network of Baoding in 2007.

Figure 61.2(a) demonstrated car simulation performance for both scenarios. Four dots were approximately located in the $y = x$ line and the other two dots, below the line, also were very close to it. Mean relative error margins of Scenario 1 and Scenario 2 were 44.8 % and 47.5 %, respectively. It can thus be concluded that the performance of Scenario 1 (using household utility function) was slightly better than Scenario 2 (using individual utility function).

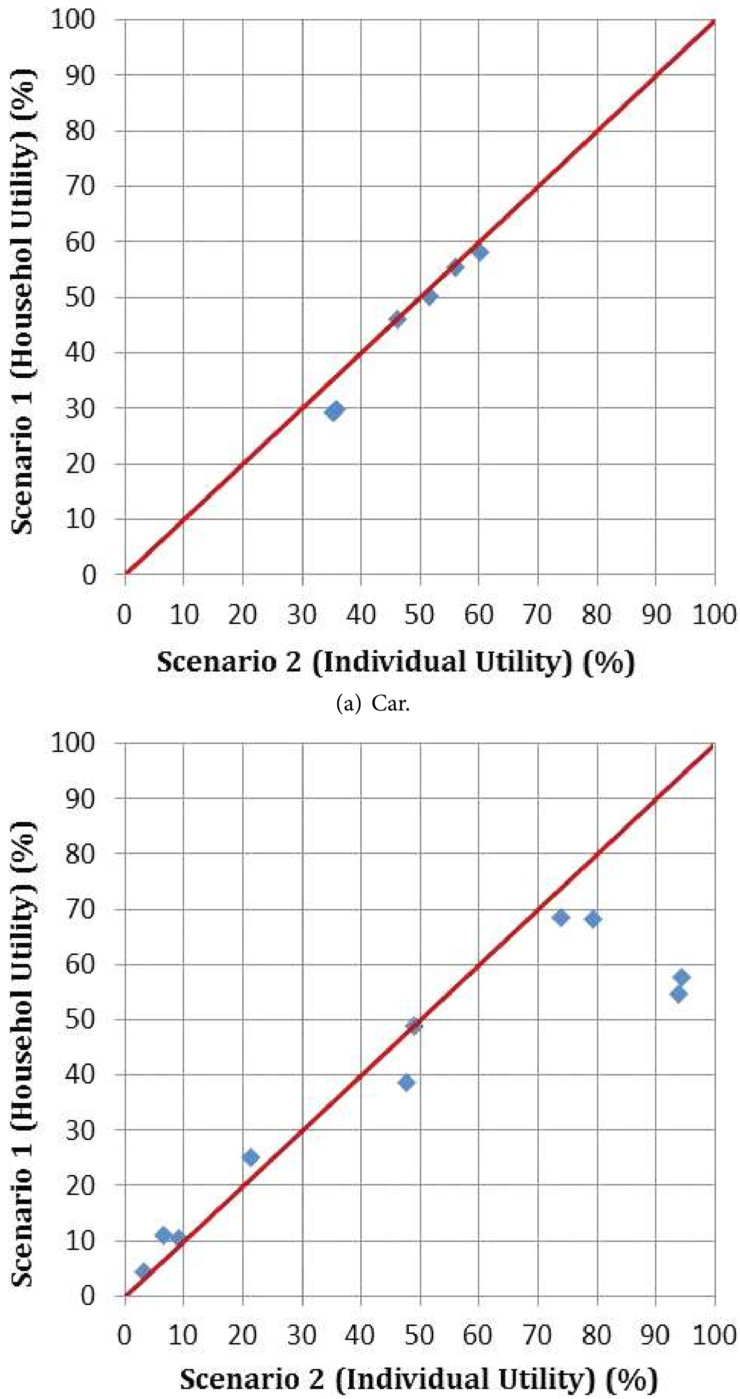
61.4.2 Comparison of Two Scenarios: Transit Traffic

Data (passenger flow for nine transit lines from 7 am to 9 am) used for transit simulation comparison was also manually counted in 2007. Figure 61.2(b) illustrated both transit simulation scenarios' performance. Clearly, most dots did locate close to the $y = x$ line, however, two dots below the line were significantly distant from it. Also, mean relative errors of Scenario 1 and Scenario 2 were 38.7 % and 47.9 %, suggesting that Scenario 1 better represented transit passenger flows than Scenario 2.

61.5 Achieved Results

A proposed MATSim household utility function was tested comparing two scenarios using household and individual utility function. Historical validation confirmed that MATSim improved its own car and transit simulation performance by using the new utility function. However, more case studies are needed to further confirm this new proposed utility function's advantages.

More information on the Baoding scenario can be found in Zhuge (2014) (in Chinese).



(a) Car.

(b) Public transit.

Figure 61.2: Performance comparison of Scenario 1 and 2.

CHAPTER 62

Barcelona

Miguel Picornell and Maxime Lenormand

The Barcelona scenario is one of the three case studies (together with London and Zürich) carried out under the framework of the EUNOIA (Evolutive User-centric Networks fOr Intraurban Accessibility) project. The main goal of the Barcelona case study was to evaluate the impact of different public bike-sharing schemes in the city. The study area covers the metropolitan Barcelona area, with special focus on the city center, where public bike-sharing stations are located. For this study a novel bike-sharing module was developed by ETH Zürich.

62.1 Transport Supply: Network and Public Transport

The road network was extracted from the TransCAD (Transportation Computer Assisted Design) model used by the city of Barcelona. Public transport supply was also considered, comprising: bus, underground, tram, train and bike-sharing. Information about stops and schedules was obtained from the public information available at the Barcelona Open Data platform, as well as from the Barcelona transport authority website.

62.2 Transport Demand: Population

Agent plans were defined using anonymised mobile phone registers CDRs (Call Detail Records). From mobile phone data, it is possible to identify places where agents perform activities and corresponding trips. Activities have been classified as “home”, “work” and “other” (including as “other”, “leisure”, “shopping”, etc.). A sample of around 15 % of the population was used in the simulation. Modes used in the simulation model include: walking, cycling, public transport and car.

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Picornell, M and Lenormand, M. 2016. Barcelona. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 397–398. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.62.

62.3 Calibration and Validation

Different data sources were used to calibrate and validate the model. First, to validate agent plans obtained from mobile phone data, results were compared to EMEF (Enquesta de Mobilitat en dia Feiner), indicating that mobile phone data provides information similar to traditional surveys. Additionally, agents' utility function was calibrated using the modal split from EMEF and road counts.

62.4 Results and More Information

At the time this summary was written, the calibration process was still ongoing. More detailed information about the scenario and main results can be found at: `http://www.eunoia-project.eu/publications/` (project deliverables/Report on Case Study 3: Barcelona).

CHAPTER 63

Belgium: The Use of MATSim within an Estimation Framework for Assessing Economic Impacts of River Floods

Ismaï Saadi, Jacques Teller and Mario Cools

63.1 Problem Statement

With the history of river floods in Belgium and the significant probability that such events will again take place in the near future, assessment of both direct and indirect economic impact was deemed essential to allow formulation of an adequate policy program and efficient flood risk management. One proposal would assess flood risk at the micro-scale level: i.e., individual buildings for exposure analysis and direct economic damage estimation, individual companies for indirect economic damage estimation, 10 meter grid spacing for land-use modeling and individuals/vehicles for transportation models. To enable this assessment, an integrated modeling framework combining different simulation theories from a multidisciplinary perspective is being developed. Figure 63.1 describes the procedure to measure the annual flood risk. A more detailed description of the whole modeling chain is available in Dewals et al. (2015).

A basic modeling framework premise is that different spatial pattern 'families' might influence the damage intensity caused by river floods (e.g., land use change, transportation systems). In this chapter, we focus on how MATSim is being integrated into this overall framework, thus focusing on the TSA (Transport System Analysis) within the overall estimation procedure. For TSA, two configurations (freight and passenger model) are distinguished. For the passenger model, a MATSim scenario is developed on a national scale to simulate travel demand at base year 2010 and its evolution during the following years. The main objective is to study the effects of river floods on the transportation network and, consequently, on travel demand from an economic point of view. In addition, a freight travel demand model has been developed, to enable interactions between

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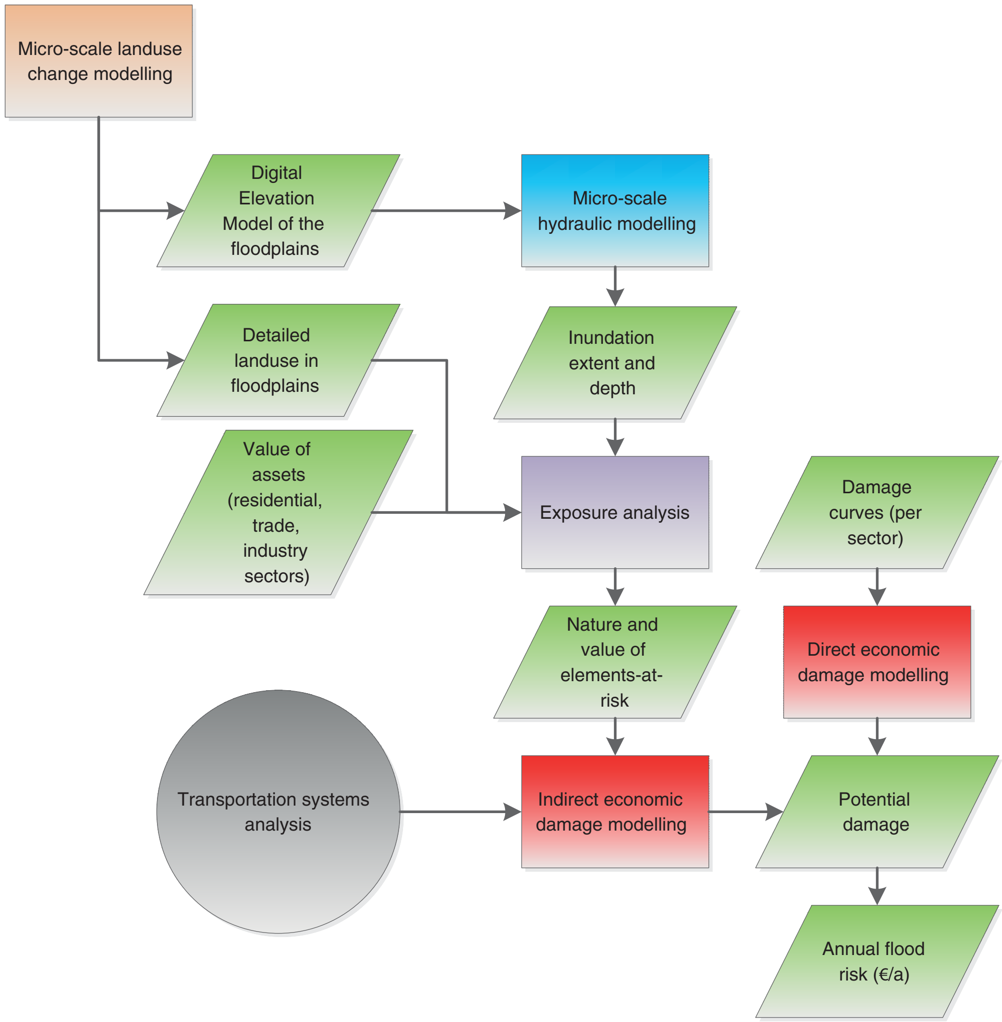

Figure 63.1: Economic impact estimation procedure.

passenger and goods flows. Note: at this time, this is still an aggregate four-step model, but development is ongoing to develop an agent-based model for the freight side.

63.2 Data Collection

As inputs, MATSim requires a synthetic population (or travel demand) file, as well as the related transportation network. Unfortunately, no recent census is available for the first input; the latest dates from 2001. To compensate, a synthetic population was derived from more recent travel surveys (e.g., Cornélis et al., 2012) by employing a Gibbs sampler (Farooq et al., 2013). The Belgian National Household Travel Survey (e.g., Cornélis et al., 2012) contains socio-demographics and activity travel diaries with a detailed description of activity start, end times and durations. Activity locations are also available, but at the municipality code level. They are generally accessed by using the new municipalities referencing system: LAU (Local Administrative Unit) level 2. For the transportation network, OSM network data has been used.

63.3 Input Preparation

63.3.1 *Network*

The network data of Belgium, downloaded in 2015, is available online from the OSM server. It consists of 100 467 nodes and 232 715 links. Network quality is generally acceptable, according to many MATSim users, even if manual adjustment is necessary for specific links.

63.3.2 *Synthetic Population*

Preparation of a synthetic population presents a significant challenge for this case study; only micro-data are available to enable population synthesis. From these partial views of the actual population, use of a Gibbs sampler enables the joint distribution (re-)construction. The outputs seem to be encouraging when comparing computed predictions to the reference dataset. Here, we propose testing the methodology by synthesizing some relevant variables for both transportation and urban systems simulations at the household level (see Figure 63.2).

63.3.3 *Activity-Based Pattern Generation*

After the synthetic population has been generated, *activity types*, *activity times* and *activity locations* are generated and associated to the agents, using an activity-based pattern generator. Using a combined set of machine learning techniques, daily activity planners are generated for each agent. As shown in Figure 63.3, the model suggests some promising first results. The activity-pattern generator is calibrated by using micro-data, such as activity travel diaries extracted from travel surveys.

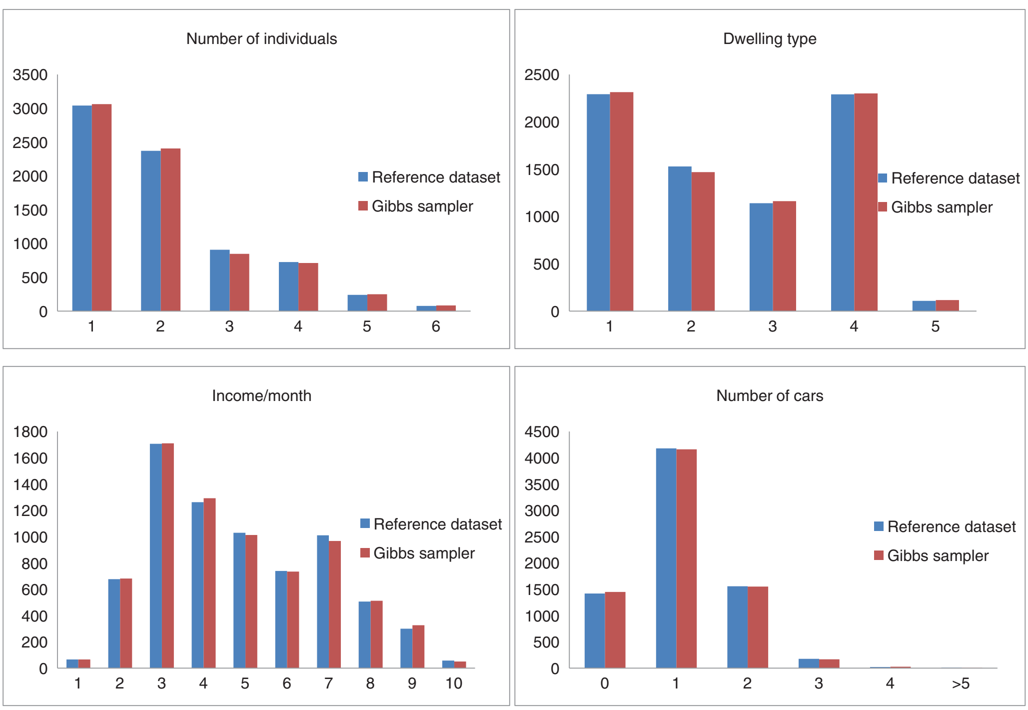

Figure 63.2: Examples of households synthesized attributes.

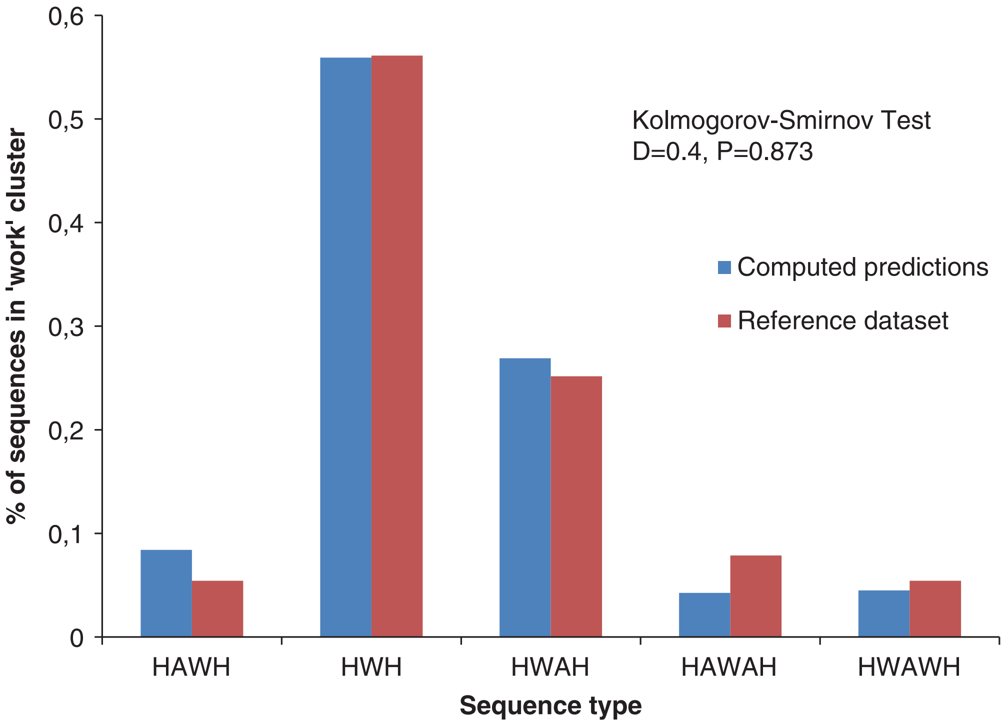

Figure 63.3: Activity chains generation.

Calibration quality will be measured after analyzing MATSim scenario outputs when traffic counts are compared. If the comparison between observed and simulated traffic counts suggests a significant deviation, a direct approach based on traffic counts (Cools et al., 2010) could work to adjust activity-based pattern generator parameters.

As outlined by Cools et al. (2011), uncertainties introduced by statistical distributions of random components in most activity-based models might be significant. Thus, some key indicators (e.g., sequences type proportions) will be investigated to measure micro-simulation error impact.

63.4 General Modeling Framework

In Saadi et al. (2014), the overall modeling framework is presented, as well as the integration of scheme components. This paper covers all concepts expected to be used in building the future MATSim scenario. Figure 63.4 is a partial view of the overall modeling framework being researched at the moment.

63.5 Modeling Network Disruption

As mentioned, this study also suggests modeling network inaccessibility occurring after river floods. This approach assumes that link capacities subjected to river floods are reduced, depending on flood intensity. Given that damage is mainly a function of water depth, the idea is to intersect a steady-state inundation map with the transportation network or, at least, the area impacted by floods (Saadi et al., 2014). Then, an analysis extension will be achieved by including a time series of river floods for a better understanding of dynamic effects: e.g., response to river floods propagation, return way and time to the new equilibrium point between transport supply and demand.

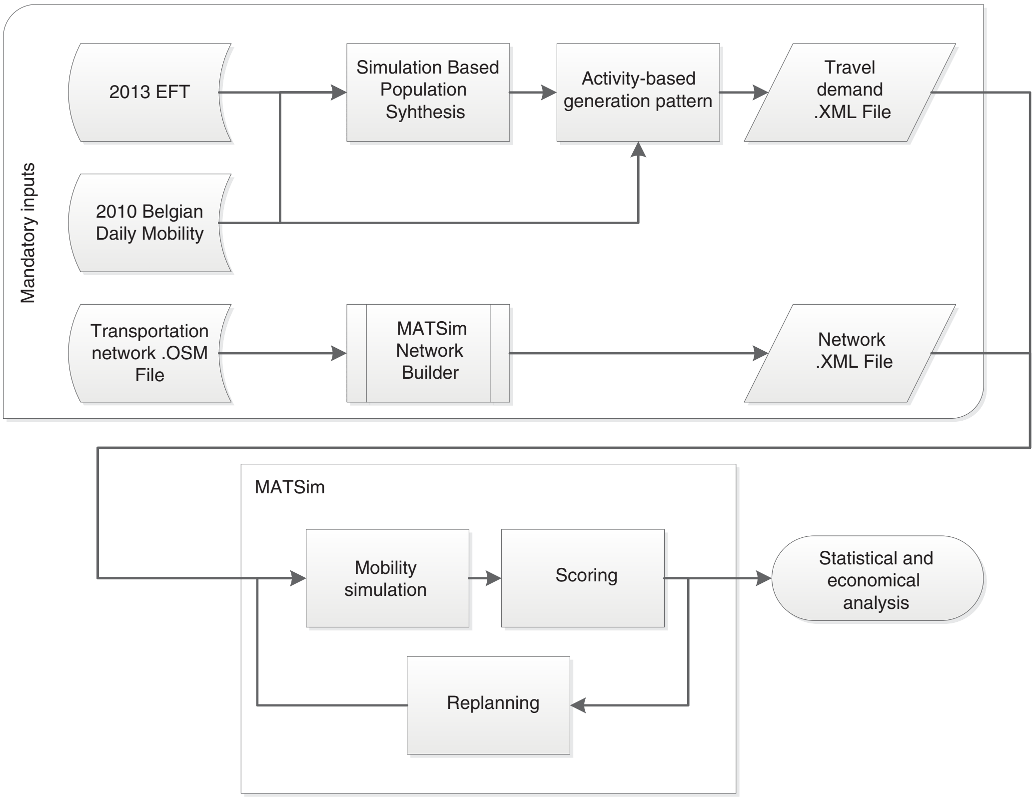

Figure 63.4: Partial modeling framework.

A similar problem was studied in a tsunami evacuation scenario simulation in the city of Padang (Lämmel et al., 2010) (Chapter 76) and was particularly interesting in terms of network dynamic evolution during the scenario simulation.

63.6 Next Development Steps

When the complete integrated agent-based transportation model is ready, combination with the land-use change CA (Cellular Automaton) based model proposed by Mustafa et al. (2014) will to allow more interactions between those two patterns. This connection will be the basis for an innovative micro-scale LUTI (Land-Use and Transport Interaction) model, allowing more accurate predictions about future river floods influenced by different micro-scale patterns.

CHAPTER 64

Brussels

Daniel Röder

The MATSim scenario for Brussels was developed as part of the SustainCity project. This project's goal was to couple an urban land use model, in this case UrbanSim, with the MATSim mobility simulation, to evaluate transport policy impact on urban land use and vice versa. A detailed description of this coupling is given by Nicolai (2013) and others. A detailed description of the scenario development is found in Röder et al. (2013).

The scenario covered the greater Brussels area in Belgium; input data was derived from two main sources. The population was directly generated from the UrbanSim model, covering a total of 860 214 persons. At home- and at work-locations (per person) were given and converted into a daily home-work-home plan. For computational reasons, a randomly-drawn population sample of one percent was used. OSM was sourced for the street network generation, which consisted of 10 861 nodes and 19 830 links, i.e., using mainly the trunk road network.

For the modeling of public transport, two different approaches were tested: first, the MATSim default approach for scenarios where no detailed transit schedule is available, based on either: beeline distance and average speed, or network-based freespeed travel times and a designated factor. The second approach was not part of the MATSim core during the project, but was available as a contribution (`matrixBasedPtRouter`, see Chapter 20). It was based on O-D travel time matrices between transit stops, i.e., travel times for all relations were computed in a pre-process. The travel times can based on a real-world-schedule or certain assumptions which can take spatial coverage into account. Advantages of this model are obvious; on one hand, it may depict spatial coverage with public transport supply—here, distance to the next transit stop influences travel time. On the other hand, it may depict the real network, i.e., routes and lines and possible waiting times for switching. Both approaches were compared against travel times and mode share measures from a SATURN (Simulation and Assignment of Traffic to Urban Road Networks) model. Since the matrix-based approach came closer to this model, further investigations were based on that.

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Röder, D. 2016. Brussels. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 405–406. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.64.

To evaluate the model's sensitivity to certain policies, a cordon toll scenario was set up, where a toll is charged between 6 and 10 am every time a car passed a cordon border, i.e., every time a car entered a link crossing a cordon border defined by the Brussels freeway ring. Accessibility was calculated and compared for both scenarios. Röder et al. (2013) provides a detailed analysis.

CHAPTER 65

Caracas

Walter J. Hernández B. and Héctor E. Navarro U.

Capital of the country, Caracas is the largest city in Venezuela, with serious vehicle traffic issues. Its daily estimated circulation of 1.5 million units represents three times the load originally estimated for the city's growth. Despite the lack of official statistics, it is possible to estimate the amount of Caracas' traffic using other national figures, such as the *Time Travel Index* employed by the Federal Highway Administration (2013). This index estimates approximately 50 % longer than *free-flow travel* to traverse inner city circles and 75 % around metropolitan areas. This is in stark contrast to an average city in the US, which normally does not go beyond 35 %, even in the worst case.

Apart from obvious budget-related deficits these delays cause in work force productivity for companies and organizations, the country itself loses an estimated $2.1 billion per year. This includes the precious subsidies that have helped to maintain the country's world lowest prices of gas for decades (Wilson, 2008); $1 billion could be saved by reducing the average circulation time by just 30 minutes. Equally important, the accompanying significant reduction in CO_2 (Carbon Dioxide) emissions would help meet greenhouse targets for the country.

In recent years, several measures have been initiated to cope with increased traffic in Caracas:

- HOV (Highly Occupancy Vehicle) lanes (Turnbull, 1990), implemented in a *contraflow* fashion to increase traffic flow on central roads and highways,
- bus lanes for rapid bus trips and bicycle lanes, to stimulate use of alternative means of transport, and
- shifting job starting hours to non-peak times and increasing the number of at-home working hours for certain types of jobs, to cut back vehicle use and general costs to public transport.

In addition to the these measures, other mechanisms could be implemented, such as weekday circulation restrictions (e.g., based on license plate numbers) and smart traffic lights. Especially in the case of smart traffic devices and planning of special lanes, careful study and simulation of traffic

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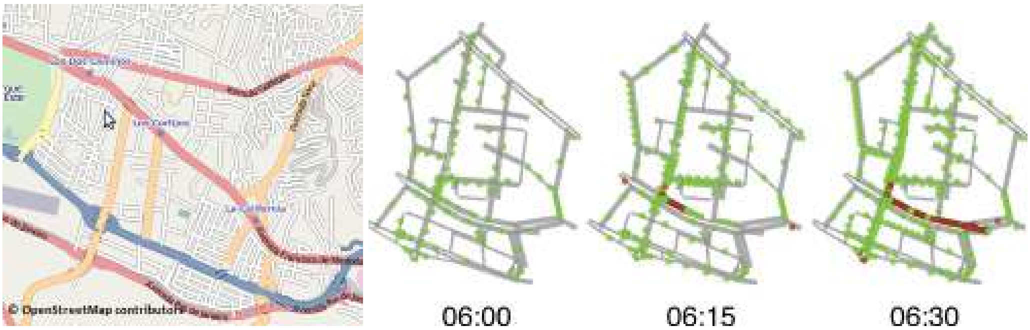


(a) Snapshot obtained from OSM. (b) Three snapshots of a simulation ran in MATSim between 6:00 and 6:30 am, depicting the increasing traffic in the zone.

Figure 65.1: An area of "Los Cortijos" in Caracas, Venezuela.

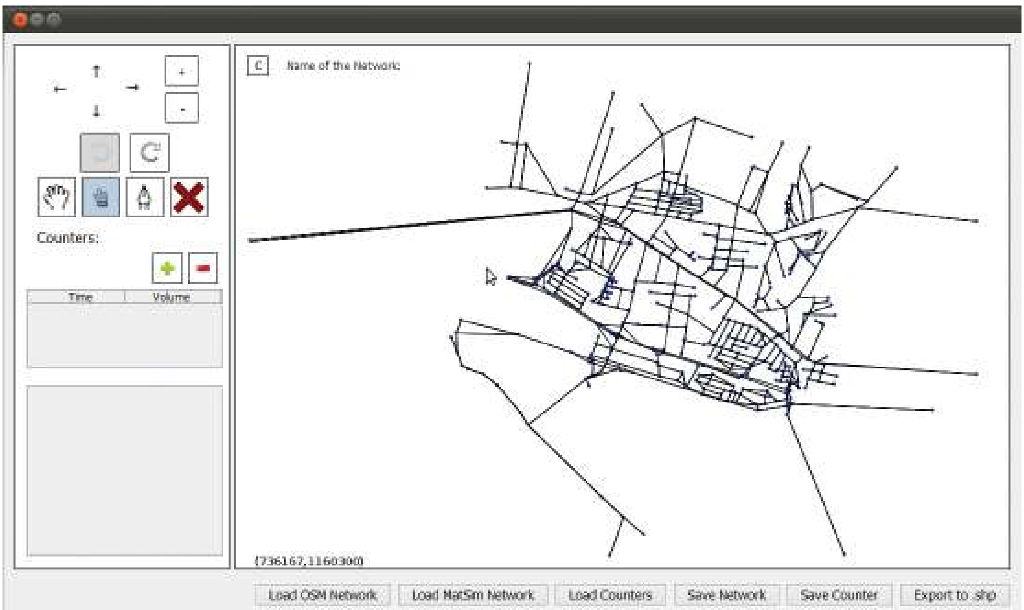


Figure 65.2: Interface of the software tool developed in Java showing the area studied. Blue dots over the roads in the map represent the counters positioned in the area to capture vehicle flow used as input for the simulation.

patterns must be undertaken. To help achieve this, a software tool was envisioned with the following objectives:

- to envision creation and editing of traffic networks on MATSim format and assign validation points to the network,
- to study and analyze simulation results, especially the traffic volumes assigned to roads,
- to translate data obtained in O-D format for input to MATSim, and
- to run the simulations and validate outputs in order to calibrate the parameters involved.

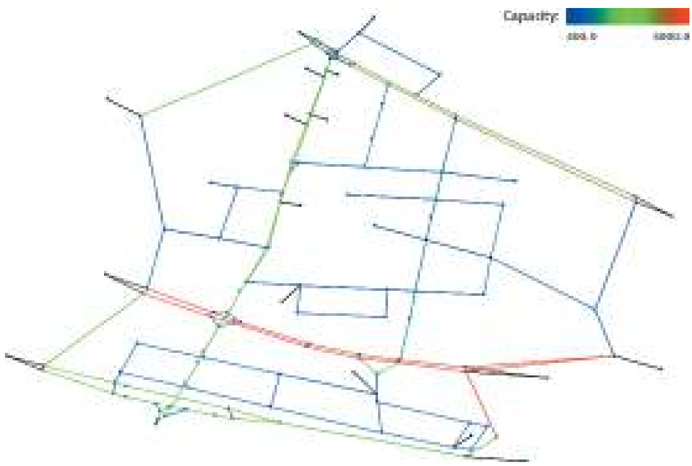
The tool was tested with real data traffic in a Caracas area "Los Cortijos" (Figure 65.1(a)), one of the most heavily traveled zones on the city's east side. The simulation model belongs to the *microscopic* category, made by Gartner et al. (2001), since only individual elements are taken into account (i.e., vehicles).

The network was created by using data from OSM, then manually modifying it (i.e., setting correct speed, capacity attributes) based on information delivered by a company conducting a study in the same area. Demand was given in a O-D matrix by the same company, but only for the morning period. As the area researched is mainly a consuming zone in the morning and a producing zone in the afternoon, values from the O-D matrix were used to create day-plans for the agents. An initial departure time around 7:30 am was assigned to the plans.

Several scenarios with different re-planning rates were run to test how much agents have to change their departure time in the morning to allow the network to accommodate all travel demand. Figure 65.1(b) shows how traffic jams builds up in the scenario where simulated demand best matches real-world traffic count.

Figure 65.2 shows the interface of the tool providing options to: load a map from OSM, load a network from MATSim, load counters (blue dots in the map image), save the map and export to a shape file (an open file format for GIS systems).

Figure 65.3(a) shows an image output of the same area after running a simulation generated with MATSim and including a vehicle-density color map. Figure 65.3(b) shows a sample score



(a) A snapshot of the area at 7:00 am with a color map for vehicle flow.

(b) MATSim sample score statistic for one of thescenarios defined.

Figure 65.3: Simulation results.

graph from one of the many tests run: *avg. trip time* of 02h:06m:38s and *avg. distance per agent* of 1727.83 meters; *total run time* of the simulation was 41 minutes 56 seconds.

In spite of differing approaches between the company's study and our own results, through simulations, the numbers were quite similar with a range of difference not exceeding 3 % (-0.42 % to 2.52 %). Examining these promising results, but also the limitations encountered, the following future lines of work were defined:

- Run a larger number of simulations and compare with real data, to fine-tune accuracy of results.
- Improve capacity to incorporate simulation plans from censuses and polls, among other alternative data sources different from O-D and develop a methodology allowing disaggregated collection of data.
- Include more options for network creation, such as generating links based on characteristics like zebra crossings, speed humps, curb extensions and/or a number of traffic signs.
- Create options to manage a simulation project incorporating the internal organization made by the tool, where all iterations of simulations are separated in folders with all outputs produced. This also implies the creation of a more refined reporting tool that could be used to support the decision making process of smart traffic devices, contraflow lanes, etc.

Acknowledgements The authors wish to acknowledge Daniel Ampuero Anca and Jesús Francisco Gómez Ortíz, for their Bachelor's degree final work at *Universidad Central de Venezuela*. Also to óscar Anzola, founder of *URVISA S.A.*, who provided the logistics for the capture of real traffic data used on the simulations.

CHAPTER 66

Cottbus: Traffic Signal Simulation

Joschka Bischoff and Dominik Grether

The Cottbus (Germany) scenario is used for traffic light simulation (see Chapter 12). It is explained by Grether (2014, pp. 87); this chapter briefly reviews the main points. The scenario data is generally available to the public, and can be found from `http://matsim.org/datasets`.

The network was derived from OSM data in summer 2010 (Bischoff, 2010), and covers all streets within the city boundaries, as well as main roads in the surrounding Spree-Neiße administrative district. It is designed as a 100 % sample. The population is based on the German federal employment agency commuter statistics for both Cottbus and Spree-Neiße (Wiethölter et al., 2010). As such, the population has only home-work-home plans spread over the usual commuting times, resulting in two peaks, including 33 479 agents traveling exclusively by car. The scenario is generally not very busy; the area does not usually have major congestion issues.

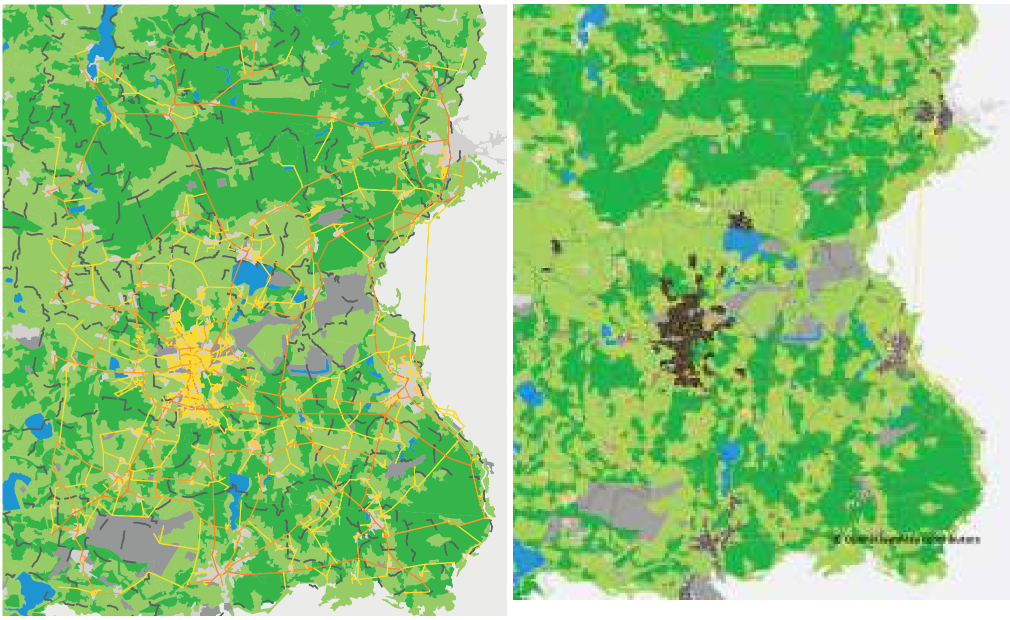
Figure 66.1(a) shows the network over the "Corine Land Cover" landuse (European Environment Agency, 2011), provided by European Environmental Agency. Woods and agricultural areas are depicted; most of the region is agricultural use area. Virtual persons in MATSim need a geographic coordinate for their activities. If this coordinate is drawn randomly (solely based on municipality borders), home and work activity locations are uniformly distributed over the area, i.e., most of them in woods and fields. Thus, activity locations are drawn randomly in combination with land use data. The coordinate must be in the municipality area and for home activity, it must be located in urban fabric areas; for work locations, industrial or commercial areas are also allowed. The resulting home activity locations are shown in Figure 66.1(b).

The scenario contains data for 22 traffic signals within the city center, based on the city's 2009 signal plans; junction layout is also modeled in detail. Fixed-time control data is taken from Köhler and Strehler (2010). Due to higher transport network resolution, several originally recorded fixed-time control schedules are invalid and were removed; data for 22 junctions is available. Figure 66.2 shows their transport network location.

Public transit, not part of the original scenario, is available based on 2011 schedules, although it is not currently used.

How to cite this book chapter:

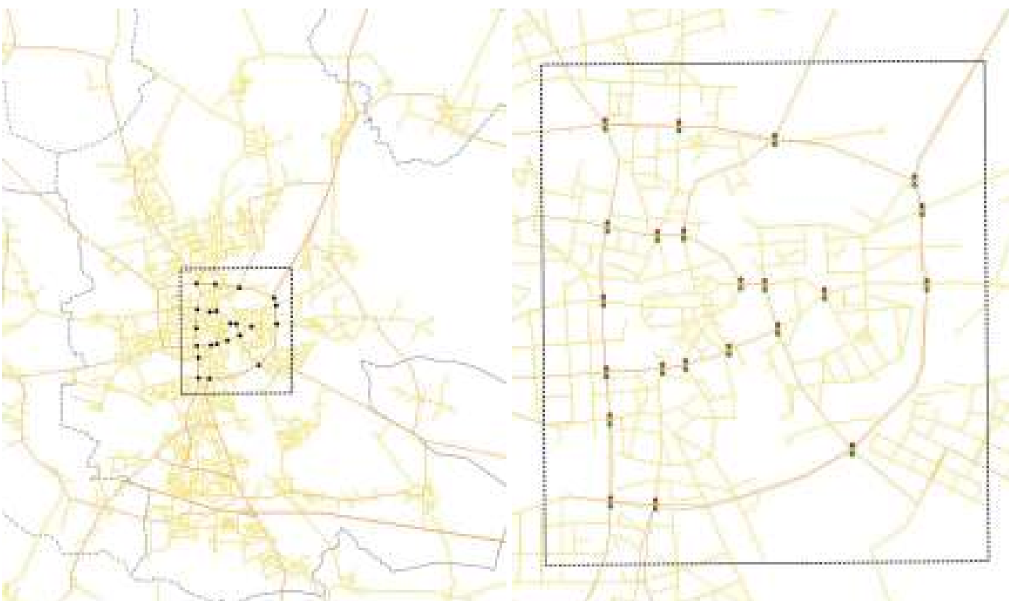
Bischoff, J and Grether, D. 2016. Cottbus: Traffic Signal Simulation. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 411–412. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.66.



(a) Cottbus network and municipality borders.

(b) Synthetic population for the Cottbus scenario, geospatial location of home activities.

Figure 66.1: Cottbus scenario: Network and population.
Source: Grether (2014)



(a) Location within city of Cottbus.

(b) Signalized area in detail.

Figure 66.2: Cottbus scenario: Network, area with traffic signals within the city of Cottbus.
Source: Grether (2014)

CHAPTER 67

Dublin

Gavin McArdle, Eoghan Furey, Aonghus Lawlor and Alexei Pozdnoukhov

67.1 Introduction

To demonstrate a new spatial choice model, a microsimulation of urban traffic flows for the greater Dublin region was implemented using MATSim. The scenario simulated leisure activities and commuting trips completed by individuals using private cars over a twenty-four hour period. For commuting trips, detailed information from the Irish Census was used; a new spatial choice model, inspired by the radiation model, was developed for leisure trips. The effectiveness of the approach was validated using hourly data from count stations on the main motorways around Dublin City. The results show that the microsimulation accurately reproduced traffic volumes.

67.2 Study Area

County Dublin, in Ireland, covers an area of approximately 115 square kilometers and encompasses several administrative areas. Dublin is a coastal county with the Irish Sea lying to the east. To capture both intra-city and inter-city flows, the scenario considered individuals who live or work in Dublin, capturing those who commute to or out of Dublin, as well as those who live and work there.

67.3 Network

To capture the desired study area for the scenario, the network consisted of all roads in the greater Dublin region and major roads for the remainder of the country. The road network was a mix of motorway, national routes and local roads and was extracted from OSM, along with other information such as speed limits and number of traffic lanes. This OSM network was prepared for use in

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MATSim. This study focused on private vehicles; the public transport network was not considered, but can be incorporated into the microsimulation in future studies.

67.4 Population Generation

The population for this scenario consisted of all car drivers who live or work in the greater Dublin region and was prepared from a variety of data sets. To obtain home and work locations, the 2011 Irish Census was used, particularly a census subset called POWSCAR (Place of Work, School or College Census of Anonymised Records). This provided home and work locations, mode of commuting transport used, time of departure for work or school and a variety of socio-economic data at an individual level. The individuals relevant to this scenario (drivers who live or work in Dublin) were extracted from the data set. In POWSCAR, home locations are anonymized by aggregating them into a statistical unit called the small area, consisting of 80 to 100 households. In the greater Dublin region, this represents a street or an apartment complex. We translated this to an individual address point by selecting a random address point within the small area. For this process, we used a commercial database of addresses and their coordinates in Ireland called Geodirectory. To account for non-workers, we used census statistics to generate the spatial distribution of the number of sick, unemployed and retired persons along with car ownership details to produce the non-working population for the greater Dublin region. These were also assigned to individual address points, providing us with a population of 600 000 agents for the scenario (see Figure 67.1).

67.5 Demand Generation

Individuals from the population were assigned work and school locations according to POWSCAR (Figure 67.1). In POWSCAR, work and school locations are given at a 250 meters grid level and we translated them into individual address points using Geodirectory. For school and collage locations, the address point was checked using NACE (from the French title 'Nomenclature générale des Activités économiques dans les Communautés Européennes') codes, to confirm its status as an educational institute. Departure times for work and school were assigned using a Gaussian curve centered at the declared 30 minute departure time from POWSCAR. INTS (Irish National Travel Survey) was used to create non-commuter demand for the road network. Through a survey, the INTS collected a 24 hour travel diary for an Irish population sample recording journey origin, destination, departure time and mode. We extracted the private car mode and combined the data with the commuter data to create a 24 hour activity chain for each individual in the population.

67.6 Activity Locations

A set of activity locations were obtained from an in-car navigation system's POIs (Points of Interest) database and augmented with additional POIs from OSM. While work locations were assigned from demand generation, locations for secondary activities, such as shopping and leisure, were not specified in the INTS and so had to be modeled to create spatial and temporal activity chains for the population. We developed a radiation model variant that applied emission-absorption ideas to compute interaction probabilities for a set of origins and destinations. The radiation model was parameter-free and distance decay was replaced by a ranked-based decay (Simini et al., 2012). While generally used for modeling movement between regions or cities, we used this approach to produce probabilities of selecting different locations capable of fulfilling a given activity. Where the radiation model uses known populations of locations to produce region ranking, we used attractiveness scores for areas and facilities that could fulfill an activity. A facility, venue or area's

Figure 67.1: The distribution of work (upper image) and home (lower image) locations for part of the Dublin scenario.

attractiveness was derived from venue size, which was calculated using domain knowledge and the model was calibrated with trip distribution patterns from social media check-in statistics. This radiation model variant was used to assign locations to secondary activities in the agents' day chains for the Dublin scenario demand.

67.7 Validation and Results

Network, population and demand data were prepared for use with MATSim. For efficiency reasons, a 25 % sample of the population was used for the simulation. The location choice model described above was used to generate the initial demand. On each interaction of the simulation, agents could be rerouted or rescheduled according to the MATSim default settings, but the locations defined in activity chains remained constant. The simulation reached a stable state after 350 iterations. The road volume data output was scaled according to the sample used, aggregated to an hourly count and compared to the observed count data from 6 count stations on motorways around Dublin. In order to compare the effect of the new location choice model, the simulation was re-run using the MATSim nearest neighbor algorithm for selecting secondary activities' locations.

67.8 Achieved Results

Aggregated hourly counts were compared with those observed at the 6 count stations which determine the number of vehicles traveling in two directions. A typical hourly distribution was obtained by averaging mid-week traffic volumes for a 3 month period. The results produced by the radiation model showed a stronger correlation between simulated and observed counts than those from the nearest neighbor approach. Figure 67.2 shows hourly observed and simulated count data for two count stations; the inset shows the relative percentage error for the two approaches being tested. The results indicate that both techniques are effective for estimating commuter traffic during morning and evening peaks. This was to be expected as the location of school and work activities were provided from real world data, but it did confirm the MATSim routing algorithm effectiveness. For daytime traffic, which consisted mostly of secondary activities, our variant of the radiation model outperformed the nearest neighbor approach; it included individuals who were willing to travel further for better opportunities, producing more accurate results.

67.9 Associated Projects and Where to Find More

The Dublin scenario validation results demonstrated the effectiveness of MATSim as a traffic simulation tool and also showed the power of our spatial choice model which adapted the radiation model to predict individual movement at a small spatial scale. In the future, the research will be expanded by considering a multimodal transport network and scaling the scenario from an urban simulation to a national one. Full details of the Dublin scenario can be found in McArdle et al. (2012) and McArdle et al. (2014).

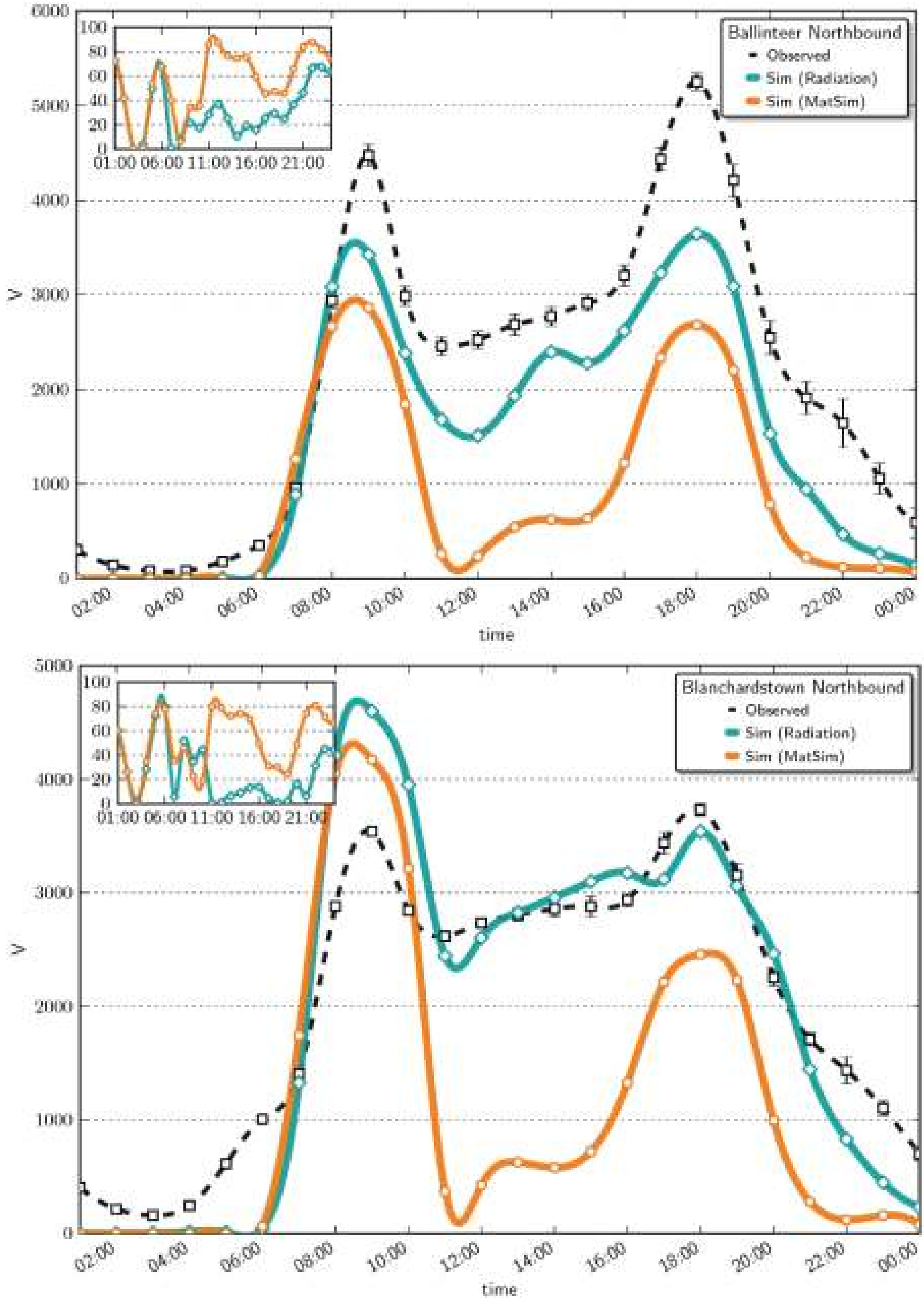

Figure 67.2: Hourly observed traffic volumes (dashed line) compared to the estimated traffic volumes produced by MATSim using the radiation model (green line) and nearest neighbor model (orange line).

CHAPTER 68

European Air- and Rail-Transport

Dominik Grether

This chapter discusses simulation of air- and rail-transport technology and passengers using MATSim. There is no great difference in overall travel times between middle-range rail and air transportation. Airports and railway stations are affected by capacity and opening time constraints. For passengers and goods, geospatial location is an important property. Both modes, but especially air transport, are faced with difficult capacity restrictions at certain departure times.

This chapter discusses how MATSim can be applied to capture these constraints and how interaction between passenger demand and constraints on technology supply can be modeled. The public transit model of MATSim (Chapter 16) is applied. Airports and aircraft are microscopically modeled the same way as bus stops and buses. Passengers are represented microscopically as multi-agent demand for air transportation. Their choices of transport mode, routes, and departure time are restricted by the air transport technology simulation model's capacity. The modeling of rail transport is based on teleportation. With appropriate data, the modeling approach for air transport could also be applied to rail transport (Quick, 2012).

The modeling of technology and demand is sketched in Section 68.1. On the basis of simulation results for a pure air transport model, rail transport is added and effects of mode choice are presented (Section 68.2). Section 68.3 then interprets simulation results and highlights some modeling aspects requiring further study. The choice set generation and plans removal algorithm of MATSim is discussed in detail; that is also the subject of Section 97.4. Modeling, results, and studies of this chapter present the highlights of Grether (2014, Chapter 6, pp. 119), in more detail.

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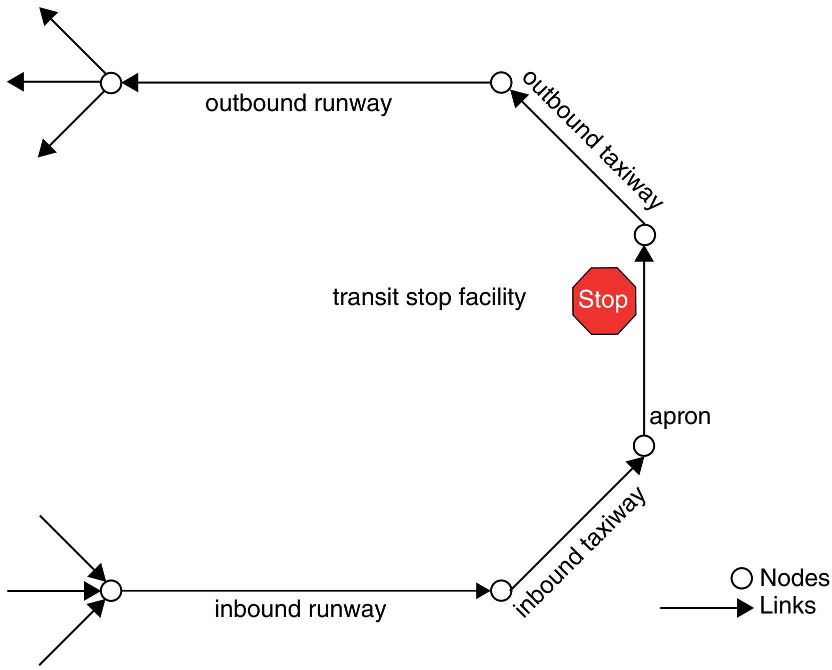

Figure 68.1: Layout of airports in the air transport network: In- and outbound runways are modeled by separate links connected by taxiways and a link representing the apron. There the transit stop facility is attached.
Source: Grether et al. (2013)

68.1 Air Transport Scenario

68.1.1 Modeling & Simulation of Air Transport Technology

The air traffic technology model uses data provided by OAG Aviation.[1] Relevant data for schedule and network generation is taken from the September 2009 OAG data, using all flights departing on a Tuesday, taking each specific flight number into account only once. This may not always result in complete flight cycles, e.g., when the outbound and inbound flight operate on different days of the week. Compared to using all flights of an entire week, the network may be incomplete, as certain destinations are only served on specific days.

The air network modeling aims at a simulation with MATSim. The network consists of airports, each showing an identical layout and point-to-point connections in between. Every runway is solely used either for inbound or outbound flights, with taxiways connecting the runways to the apron. The latter accommodates a transit stop, i.e., the terminal, where flight movements originate and terminate (Figure 68.1). Each airport pair is directly connected by airway links, one for each flight and direction of travel (Figure 68.2). Maximum speed on any of these links is calculated based on distance and flight duration provided by OAG. Times for taxi, take-off, and landing are also taken into account, i.e., flight duration is reduced by the time needed from push-back to airborne before the maximum speed for an airway link is calculated. Each flight has an individual link that could be interpreted as route, each possessing individual characteristics. Figure 68.3 shows parts of the network for European air traffic.

[1] `http://www.oagaviation.com`, last access 08.08.2012

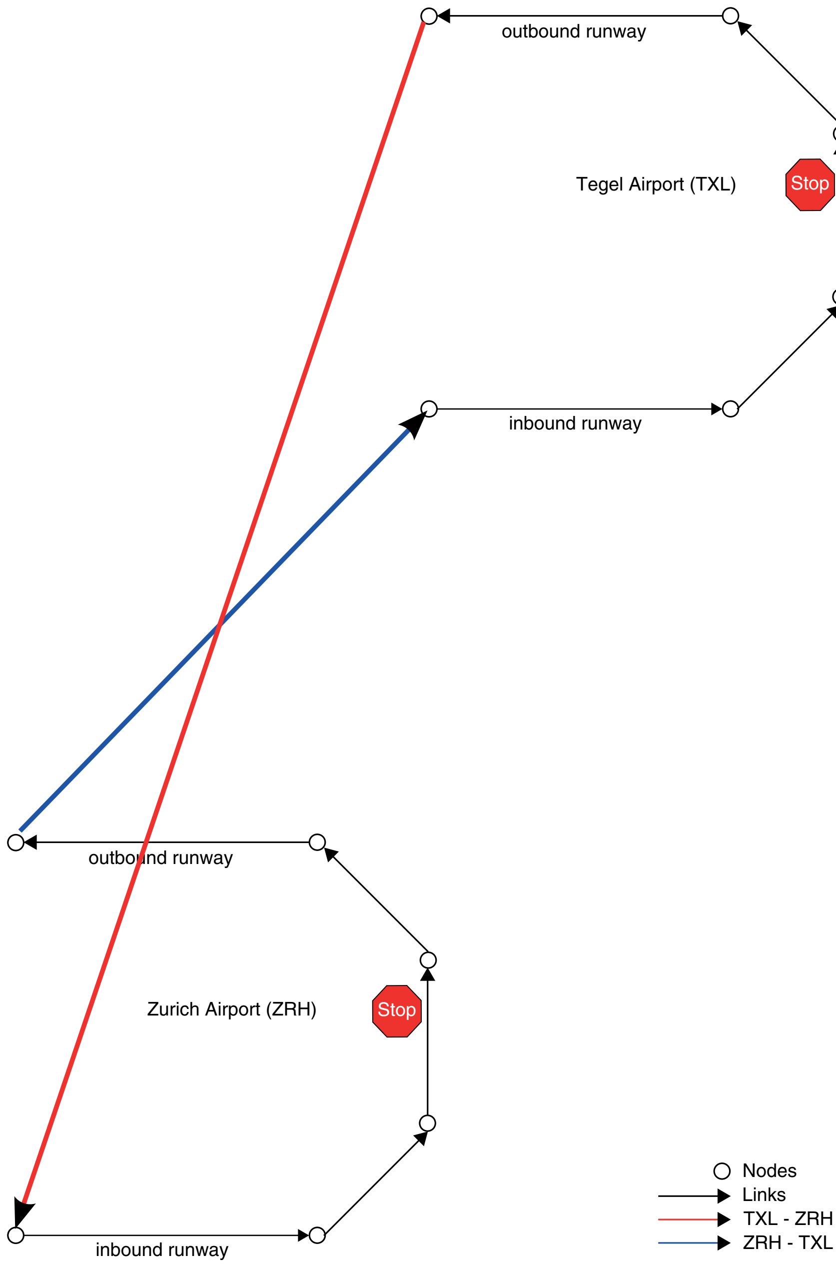

Figure 68.2: Layout of airways in the air transport network: each airport pair is directly connected by two airway links, one for each flight and direction.
Source: Grether et al. (2013)

Flight schedules are taken from the OAG data and translated to a MATSim transit schedule containing information about each line, route, and departure. For each airline offering a connection between two airports, a transit line is generated. A transit route, which represents the route on the air traffic network, is created for each flight offered by this airline. Mutual interferences of aircrafts en-route are not included in the studies presented in this chapter.

Figure 68.3: European air network with country borders in the background (country borders © http://www.openstreetmap.org).
Source: Grether et al. (2013)

To represent individual aircraft in the simulation, transit vehicles are created on the basis of OAG data. IATA aircraft codes, operating airlines, and seating capacities are reflected in the respective aircraft representation for every flight. Information about boarding times, i.e., passenger flow per door over time, is not available, but could be set for each aircraft type. One aircraft per flight is generated, thus delays resulting from a delayed incoming aircraft are not modeled. Accordingly, no aircraft rotations and vehicle trip chains are implemented at this time. The maximum velocity of each aircraft is set to twice sonic speed, since speed limitations are set for each network airway link.

68.1.2 Passenger Demand

As soon as the technology side of air transport is modeled, passenger demand simulation can begin. The passenger demand for trips in Germany created and used for the results of this section is based on O-D data of DESTATIS.[2] For each O-D pair and trip a virtual person is created. Each virtual person performs two activities, one at the origin and the other at the destination airport. Both activities are of same type, thus time spent performing both activities is accumulated before it is evaluated by the utility function according to Section 3.2. A typical duration, $t_{typ,q}$, of 21 hours is set for this activity type. The time virtual persons arrive at the origin airport and start waiting for a connection is drawn randomly from a uniform distribution in 4 am to 6 pm, UTC. This reflects estimated typical opening hours of European airports. No other time constraints are set, thus the only incentive for virtual persons is to reduce overall travel time and maximize time spent at the activity. A flight leg is scheduled between the two activities, connecting origin and destination. As

[2] Deutsches Statistisches Bundesamt, http://www.destatis.de, Fachserie 8 Reihe 6, last access 10.09.2012

usual, the demand does not specify if a direct flight from O to D is chosen or the virtual person is on a route containing one or more transfers. The synthetic population contains 51 832 virtual persons, 1 550 trips from the original data are neglected as origin and destination are equal.

68.2 Simulation Results

68.2.1 Air Transport

As a scenario for air transport technology, a coverage model from Europe to world wide destinations is used; with the synthetic population, it serves as input for the simulation. The assignment of flights to the desired O-D connection, i.e., the passenger routing, is calculated by MATSim's default public transit routing module.

Each simulation is run for 600 iterations. In each iteration, 10 % of the virtual passengers may shift their departure time randomly within a 2 hour interval. Another 10 % may seek a new route, i.e., a connection between origin and destination. Each passenger chooses from a set of 5 plans using an MNL. The outcome is stable after 500 iterations, then departure time choice and routing are switched off. For another 100 iterations only the MNL is used by passengers to select a plan.

Results are then taken from the output of the 600th iteration. Filtered by flights in Germany, Figure 68.4 depicts passengers in aircraft (red) and seats (black) over time of day and reveals passengers' tendency to depart early.

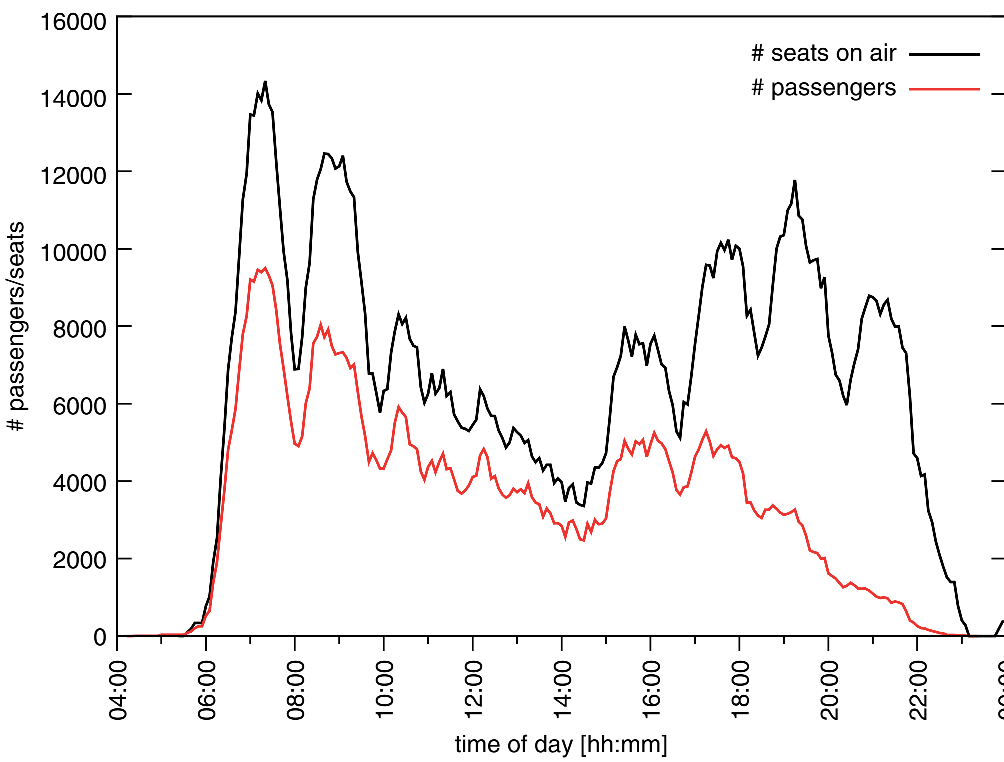

Figure 68.4: Passengers in aircraft and available seats over time in Germany: At any time, there are more seats than passengers. Air transport-only scenario based on O-D data for Germany, iteration 600.

Some passengers fail to reach their destination and are "stranded". This is unrealistic; only trips within Germany are modeled. These are usually completed within a few hours, with no requirement for an overnight airport stay. 320 passengers are stranded at the end of the day. Getting stranded is not a result of insufficient seating; at any time of day, there are more seats than demand. There are many reasons why passengers could be stranded in such a situation. Further analysis of the $c_{lineswitch} = 0$ scenario simulation results indicates:

- 92 passengers are stranded because there is no seat and no other flight on the same airline later that day, to which they could be shifted.
- 228 passengers are stuck at an airport because there is no connection after their departure time between that airport and their destination airport.

Behavioral aspects: neither departing early, nor getting stranded, are explicitly modeled.

68.2.2 Adding an Alternative Mode

To gain further insights, in the following a slightly different simulation setup is applied. A second option for mode choice is added. Each virtual passenger can now choose between the microsimulated air transport options and an alternative mode. The alternative mode has no capacity restrictions. Passengers traveling with the alternative mode can start directly at their randomly selected departure time. The travel time, tt, is computed by the microsimulation, with an estimation of the beeline distance between the O-D pair d and a velocity v, i.e., $tt = d/v$. This velocity is varied in several simulation runs, i.e., $v \in \{100, 150, 200, 250, 300\}[km/h]$. If the alternative mode is chosen, the (dis-)utilities for traveling are calculated accordingly in the scoring.

With this population, the simulation is again run for 600 iterations. As in the previous simulations 10 % of the virtual passengers may shift their departure times, while another 10 % seek a different route between origin and destination in the air transport network. Additionally, further 10 % of virtual persons may change mode, i.e., they can switch between the air traffic mode and the alternative mode. After 500 iterations all choice modules are switched off; thus, for the last 100 iterations, passengers use the logit model to select a plan.

Simulation results for the 600th iteration show that the increasing speed of the alternative mode affects the modal split. While for a $v = 100\,km/h$ the alternative mode is chosen by 1.2 % of the passengers, a mode alternative with a speed of 300 kilometers per hour attracts 15.69 % of travelers. The number of stranded passengers for the alternative mode with $v = 100$ kilometers per hour is substantially reduced, from approximately 320 to 67. Higher speeds of the alternative mode further reduce the number of stranded passengers. Slow speeds of the alternative mode imply dominance of the air transport mode. If there is a seat on a flight, travelers receive a higher score than when they use the alternative mode. However, travelers risk getting stranded, which can be hard to analyze and interpret. The implemented algorithm is also an open issue; if the number of plans per traveler exceeds a threshold of 5, the plan with the lowest score is removed from the plan database.

Instead of this deterministic plan removal, a probabilistic algorithm can be implemented: e.g., plans for removal can be selected based on a path size logit model. With this modification, simulation runs are repeated. Figure 68.5 shows the resulting travel patterns over time for alternative modes at speed 100 kilometers per hour and 300 kilometers per hour. Traveler distribution on the alternative mode over time of day is quite homogeneous. The alternative mode speed increase attracts more passengers, as reflected by the modal splits in Table 68.1. At most, one passenger is stranded at the end of day.

Simulation results are compared in more detail with DESTATIS data serving as a base for the virtual population. Synthetic population is generated based on O-D pairs that may contain transfers ($od_{transfers}$), while other DESTATIS data counts the number of passengers on actual direct flights

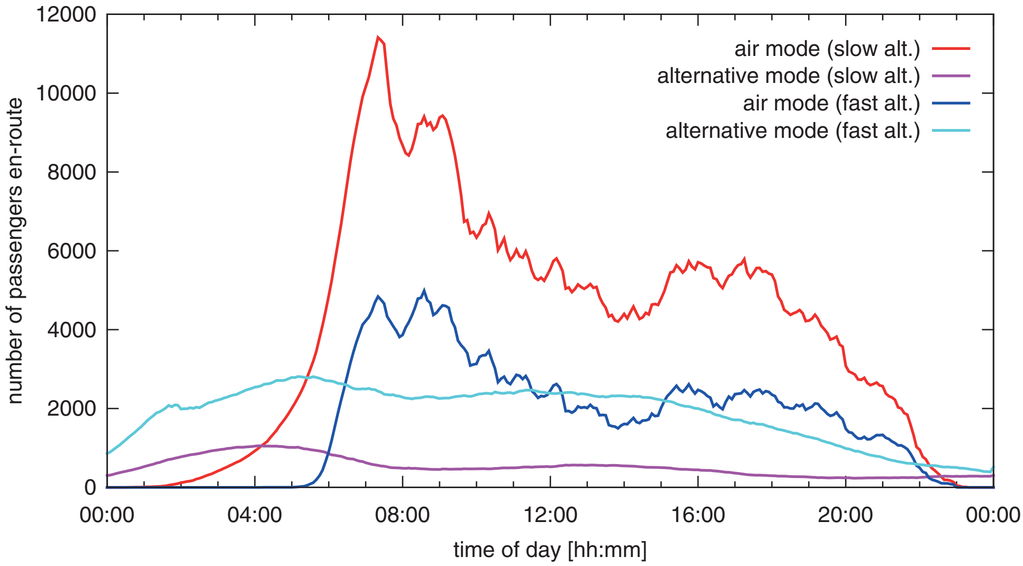

Figure 68.5: Passengers waiting for a flight, traveling by plane, or by alternative mode over time of day. Air transport and alternative mode scenario for Germany, iteration 600. Results with random selector for plan removal.
Source: Grether (2014)

v[km/h]	# air mode	# alt. mode	# stuck	air mode[%]	alt. mode[%]	stuck[%]
100	49280	2551	1	95.08	04.92	00.00
150	44835	6996	1	86.50	13.50	00.00
200	39929	11902	1	77.04	22.96	00.00
250	34332	17499	1	66.24	33.76	00.00
300	27270	24562	0	52.61	47.39	00.00

Table 68.1: Modal split for different speeds v of the alternative mode. Air transport and alternative mode scenario for Germany, iteration 600. Results with random selector for plan removal.

(od_{direct}). The latter is used to evaluate model accuracy. For comparison, number of passengers on direct flights is calculated for each O-D pair (sim_{direct}) from the simulation results. Based on these data sets, the mean square error and the mean relative error are calculated.[3]

Table 68.2 shows the outcome of these calculations. The first line is the comparison of two input data sets from DESTATIS.[4] This serves as reference, as it would assume that all demand is served by direct flights. All simulation runs explain the data better than that reference. Mean square error and variance increase with the speed v of the alternative mode; logical, as the demand covers only air transport trips.

[3] The mean square error σ^2 is computed as $\sigma^2 = \frac{\sum_{i \in OD}(sim_{direct}(i) - od_{direct}(i))^2}{|OD|}$, whereby $|OD|$ denotes the number of O-D pairs, $sim_{direct}(i)$ the simulated passengers on a direct flight between the O-D pair i, and $od_{direct}(i)$ the same, but retrieved from data. With the same values, the (unsigned) mean relative error for each O-D relation is calculated as mean rel error $= \frac{\sum_{i \in OD} |(sim_{direct}(i) - od_{direct}(i))| / od_{direct}(i)}{|OD|}$.

[4] In the calculation, sim_{direct} is replaced by $od_{transfers}$.

v[km/h]	σ^2	σ	**mean rel error**	**stuck**
$od_{transfer} - od_{direct}$	12640	112	1.75	-
100	10367	102	0.35	1
150	13820	118	0.43	1
200	18651	137	0.56	1
250	25291	159	0.68	1
300	36059	190	0.76	0

Table 68.2: Error calculations for different speeds v of the alternative mode. Air transport and alternative mode scenario for Germany, iteration 600. Results with random selector for plan removal.

68.3 Interpretation & Discussion

The alternative mode can be defined as a combination of train, bus, or car connection availability. Clearly, the results hinge on the assumption that the alternative mode is always available and not capacity-restricted. All passengers on the alternative mode travel at the same speed, but this assumption is too coarse for the scenario presented. For example, average speed and temporal availability of train connections depends on the O-D pair. In principle, the alternative mode could be refined by including O-D pairs' dependent average speed data. Alternatively, train, bus, and car can be simulated explicitly, featuring capacity restrictions and mutual interactions. Even considering these factors, a homogeneous velocity for the alternative mode seems to be more appropriate for the overall modeling approach illustration. Effects triggered by the alternative mode availability are illustrative. Data for the demand provides O-D pairs for air transport, but not for car, train or bus trips. For more plausible interpretations, further demand data for other modes is required.

All the presented modeling approaches explain passenger routing in more detail than technically possible from the input data. Most passengers use a direct connection, which is very plausible, considering the geospatial demand extent. Flying within Germany is often not worthwhile if the connection includes a transfer; empirically it is faster to travel by train, car, or bus. For further insights, the geospatial extent of the modeled demand could be increased; but this depends on data availability, not on the overall simulation approach.

Passengers are modeled without specific desired departure or arrival times. This study's input data does not contain any information about time distribution. The simulation approach can capture such individual time constraints and the information can be added, without too much effort, with some more data, thus resolving several departure time choice problems.

Stranded passengers are an unwanted product of the simulation. Without the alternative mode, the only available transport mode is a capacity-restricted flight connection provided in discrete, irregular time intervals. The number of stranded passengers is higher than for the simulation runs with the alternative mode. Passengers are more likely to get stuck in O-D pairs, where demand is higher than seat capacity, for extrinsic and intrinsic model reasons.

The quality of the simulation model's outcome hinges on the data available. For older studies of air transport passenger demand, DESTATIS data for 09-2011 was used, but the air transport technology model was created on an 09-2009 flight schedule. The number of flight starts within Germany increased slightly between 2009 and 2011 (DLR, 2012, p. 23). Assuming that the number of available seats increased accordingly, the simulation model provided too little capacity, at least on certain O-D pairs. As result, the number of passengers not reaching their destination (stranded) was much higher. With the availability of 09-2009 DESTATIS data, the overall quality of results improved. Replacement of the 2011 data with 2009 data reduced the number of stranded passengers significantly, from around 1 500 to 350 travelers.

Data is provided on a monthly basis, while the simulation model time horizon is one day. Number of trips per day is retrieved using the assumption that trips are uniformly distributed over all days of a month. The remaining 350 stranded passengers might be resolved by a more accurate distribution. Otherwise, a longer time horizon could be simulated.[5] This would also include flights not departing on a Tuesday. With these alternations,the issue of stranded travelers might be solved.

The problem of stranded passenger can be model-intrinsic. The algorithm removing plans is apparently critical to avoid stranded passengers. Replacing the deterministic formulation with the probabilistic resolves most of the stranded passenger problem. The applied path size logit modeling approach seems to be feasible, but requires further studies for parametrization and interpretation. In general, this modeling approach allows the generation of more heterogeneous choice sets, see also Section 97.3. With the deterministic plan, removal plans with a high score (but similar structure) dominate all other generated plans. In combination with capacity restrictions, lack of alternatives results in stranded passengers. All other approaches to simulate more heterogeneity—discussed on the following—should consider these effects.

In further studies, departure time choice and cost structures can be refined. If there is only one early connection to a hub per day, some passengers' departure times might be too late to make connections. The random departure time mutation may not be able to find a connection for all passengers. This has been ruled out for the current setup, but should be considered in further studies.

Alternatively, passengers could have a connection that works in theory, but are "crowded out" by other passengers arriving earlier at the gate; these passengers would reach their destination if they would take a different route. The current approach would not find such a solution, since passengers do not consider costs they impose on others; see Lämmel and Flötteröd (2009) for an approach taking that into account. The real-world solution, presumably, would be to raise prices on seats during congestion periods until a passenger re-routes. Currently, all passengers have homogeneous time values. For a more meaningful price modeling, additional heterogeneous passenger attributes can be included. As the present model is based on only O-D data, it does not include such a process. In principle, other data, e.g., Lorenz curves and median incomes, can be merged with the O-D data (Kickhöfer et al., 2011).

An alternative approach to improve heterogeneity is a router generating a greater route diversity for the same departure time. Such a router would be able to direct a passenger to a route where seats are available, without actually knowing about seat availability. That approach would, however, not address the issue that some passengers might need to switch their path to allow others to obtain a feasible path. In Graf (2013), a first prototype of such a router is tested in a different context, with first tests for the flight model revealing only slight improvement. As more diverse routes are dominated by the direct connection, they are removed by the algorithm similar to routes on slow alternative modes. After this general problem is solved, a more diverse routing should be reconsidered.

68.4 Conclusion

Overall, the results show that a microscopic, agent-based simulation of passenger demand for air transport is feasible. Most passengers are able to learn the constraints of air transport technology and arrive at their desired destination.

The technology modeling is similar to the Clarke et al. (2007) approach, although the level of detail is coarser. In the same way as Clarke et al. (2007), further models for, e.g., gates, taxiing, weather

[5] Note, that this requires some changes in the source code that may not be resolved by sole customizations of MATSim. Please ask the developers before running MATSim for a longer time horizon.

or airline operations can be added to the approach. As the open source code of MATSim comes with options for extension, more detailed models of the technology side hinge on the availability of data. In contrast, and going beyond Clarke et al. (2007), passengers are captured at all stages of their trip and passengers traveling on alternative transport modes can be simulated. The chapter discusses certain open general issues not specific to air transport systems. Interested users should support the MATSim team in solving these more general questions first, which will aid the model in achieving a more detailed picture of mid-distance travel patterns.

Clearly, potential applications of the proposed model depend on type and detail of information included. In general, application for policy planning allows a more detailed evaluation of mid-distance travel policy effects, including mode alternative consideration. The approach could also be useful for private companies' planning of flight-schedules and capacities to their connections. The impacts of these changes on customers can be assessed in close detail.

CHAPTER 69

Gauteng

Johan W. Joubert

Gauteng is a landlocked province in South Africa, with three main metropolitan areas: the city of Johannesburg, city of Tshwane (formerly Pretoria) and Eurhuleni. Although the province covers less than 3 % of the country's surface, it is the country's economic hub and contributes a third of the country's GDP (Gross Domestic Product). The 2011 census reported a population of 12.2 million inhabitants, a quarter of the South African population.

The first Gauteng scenario was developed in 2008/9 and appeared in Fourie (2009) and Fourie and Joubert (2009). The population was synthesized from 2001 census data and travel demand was inferred from the 2003 NHTS (National Household Travel Survey). Initially, the network was created from a proprietary source made available for research purposes this has been replaced with a much richer OSM network.

Early comparisons already showed that the Gauteng MATSim scenario provided far more detailed results than the four-step models available at the time (Fourie, 2010). The scenario was also extended to include freight vehicles (Joubert et al., 2010).

With the introduction of an open-road tolling scheme referred to as the GFIP (Gauteng Freeway Improvement Project), the scenario was used to study the diversion patterns of different road user groups. The population was extended to included background traffic, in the form of public transport (buses and minibus taxis) and external through-traffic. This data was taken from Saturn O-D-matrices made available by the sponsor, the SANRAL (South African National Roads Agency Limited). The impact of the tolling scheme, using vehicle-specific values of time, and a complex toll pricing regime was reported in Nagel et al. (2014).

The most recent update to the synthetic population generation for the Gauteng scenario is documented on MATSim's `https://matsim.atlassian.net/wiki/display/MATPUB/South+Africa` Confluence site.

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CHAPTER 70

Germany

Johannes Illenberger

The Germany scenario was developed by DB ML AG (DB Mobility Logistics AG), a subgroup of DB AG (Deutsche Bahn AG), the German state-owned railway company, in 2014. To help evaluate MATSim's applicability in the strategic planning process, as well as defining its compatibility in the traditional zone-based four-step process, this scenario has been constructed to establish a Germany-wide O-D matrix for private car travel. A solid understanding of the transport market for private car travel (rail's major competitor) is required for the strategic planning process at the DB ML AG. This scenario intentionally focuses just on road transport since, on one hand, there are already well-established models for rail transport at the DB ML AG and, on the other hand, this scenario is meant to be the first step towards MATSim's application.

Considering this scenario's objective, MATSim is used here as a tool to build a microscopic representation of the current transport market. Unlike the majority of MATSim studies, the focus is not to build and calibrate a behavioral model with forecasting power to answer the "what if" question. Hence, this study emphasizes reproducing empirical measurements, rather than on modeling plausible causalities and behavioral processes.

The final outcome of this exercise is a O-D matrix with average daily trip volumes. Although a higher temporal resolution is possible and also available from travel data, this dimension will not be considered during calibration and validation of the scenario. The matrix is based on a zonal structure with approx. 10 K TAZs, with a granularity comparable to municipalities (LAU 2) and a higher detail in large cities.

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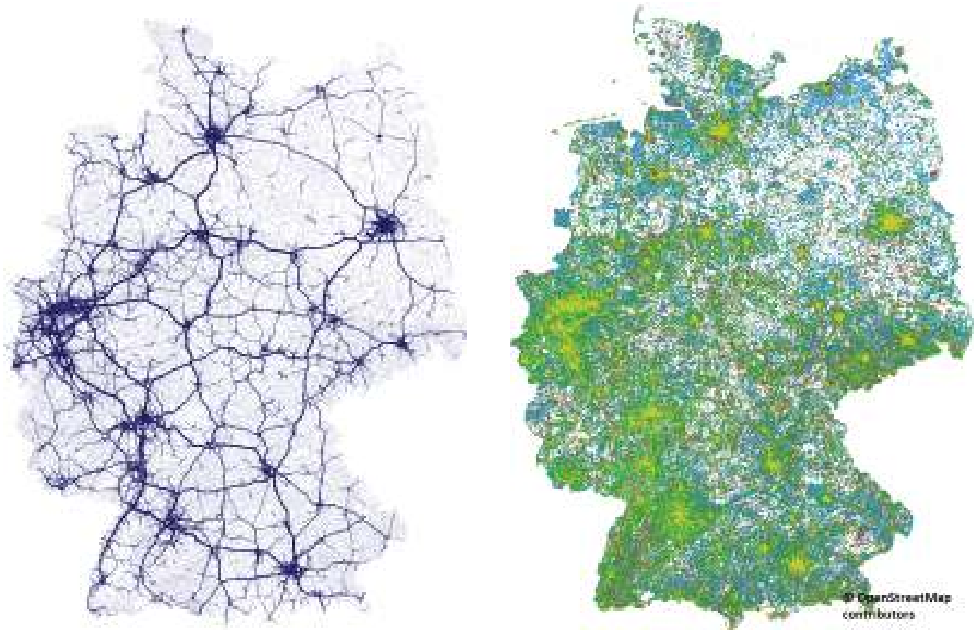

Figure 70.1: Left: Simulation road network including roads down to the level of major arterials. Right: Spatial distribution of activity facilities colored according to activity type.

70.1 Demand and Supply Data

The German national travel survey MiD from 2008 (Follmer et al., 2010) builds the foundation for the synthetic population and its travel plans. The survey features approx. 60 K person records with one-day travel episodes. A travel episode specifies trip sequences with mode, purpose, travel distance and day of reporting. Home locations are known at the level of states and municipality type (urban/rural). From each record, a synthetic person with one travel plan is generated. Initially, activity locations are set to random facilities and each person is cloned multiple times (according to the person's weight), so that in total a population of 4 M persons results.

The road network is extracted from OSM. The geographical resolution of the O-D matrix allows omission of minor roads (everything below "tertiary" in OSM terminology) and the network is further simplified so that connected nodes with a distance less than 50 meter are merged to one node. The resulting network consists of 126 K nodes and 360 K links (Figure 70.1).

Activity facilities are taken from OSM as well. A facility can be synthesized from a OSM node representing a point-of-interest (shop, restaurant, bar, etc.), a polygon representing a building and a polygon representing a region with specified land use. In the latter case, multiple facilities are generated proportional to the polygon's area. Activity options are inferred from meta information associated with the node or polygon. Given the huge amount of "home" facilities, only a 20 % subsample is used. This still yields a total of 5.6 M activity facilities.

70.2 Imputation and Calibration

The location of activities—origin and destination of trips—are required for building the O-D matrix. The travel survey does not provide any information on activity locations. Thus, the study's main task is to impute plausible activity locations, given the sequence of trip distances and underlying geographical distribution of activity facilities. The intermediate solution resulting from this imputation is calibrated against count stations and selected O-D flows from car navigation devices.

The imputation process implementation can be considered as a Monte Carlo Markov Chain simulation converging into a distribution where the activity locations configuration best fits the constraints imposed by trip distances, count stations and selected O-D flows. Solving this task in one simulation process would be congruent with theory. However, considering the scenario size and computational limitations, the process is split into three steps: (i) assigning "home" locations, (ii) generating an initial state with assigned "non-home" activity locations, and (iii) varying a subset of "non-home" activity locations to meet car volumes at count stations and selected O-D pairs' flows. Steps (i) and (ii) can be considered as imputation processes and are realized outside of the MATSim iteration framework. Step (iii) can be considered the calibration step and is realized with a MATSim-Cadyts setup configured as a Monte Carlo engine (see Chapter 48).

70.2.1 Imputation of Home Locations

Home locations are known at state and municipality type levels. The municipality type is divided into six categories by number of inhabitants. Initially, each person is placed on a random home facility, while inhabitants' geographical distribution is given at the TAZs level. A Monte Carlo simulation relocates persons to best meet their specified state and municipality. More formally:

1. Generate an initial configuration $\mathcal{P}_k$:
   (a) Randomly assign each person n a home facility.
   (b) Evaluate the configuration: $H(\mathcal{P}_k) = \sum_n \theta_1 \delta_n + \theta_2 \left| m_n - m_n^* \right|$, where δ_n is 0 if the person is located in the correct state and 1 otherwise, m_n denotes the category index of the current person's municipality and m_n^* its target category. Parameters θ_1 and θ_2 control how close the simulation converges to the target values.
2. Generate a new configuration $\mathcal{P}_{k+1}$ by switching the home facilities of two random persons.
3. Accept the new configuration $\mathcal{P}_{k+1}$ with probability $\pi_{k+1} = 1/\left(1 + \exp\left(H\left(\mathcal{P}_{k+1}\right) - H\left(\mathcal{P}_k\right)\right)\right)$, otherwise return to $\mathcal{P}_k$.
4. Repeat step 2 and 3 until the system reaches a steady state distribution.

Switching home facilities, instead of assigning a random facility, ensures that persons' spatial distribution remains constant. Running the simulation for 10^9 iterations results in a configuration where more than 90 % of persons are located in their correct state and, on average, three of four persons are located in their correct municipality; the forth persons is just one category index distant from its target index.

70.2.2 Imputation of Non-Home Locations

Activity locations (non-home) are assigned with an analogous process, like home locations. The simulation relocates activities so that resulting trip distances best meet their empirical target distances. In this imputation step, distance always refers to the beeline distance and thus avoids expensive route search.

About one forth of all trip chains are composed of more than two trips; that is, trips are not symmetrical. Accordingly, drawing a random activity location on a annulus centered at the origin activity location, with radius according to the target distance, does not necessarily fulfill the target distances of succeeding trips. The simulation process is specified as follows:

1. Generate an initial state $\mathcal{P}_k$:
   (a) Assign a random facility to each non-home activity by considering the activity type and the facility's activity options.
   (b) Evaluate the configuration: $H(\mathcal{P}_k) = \sum_n \sum_q \theta_3 \left| \frac{d_{nq} - d^*_{nq}}{d^*_{nq}} \right|$, where d_{nq} denotes the realized distance of n's trip to activity q and d^*_{nq} the target distance.
2. Generate a new configuration $\mathcal{P}_{k+1}$ by assigning a random facility to a random non-home activity (by considering activity type and activity options).
3. Accept the new configuration $\mathcal{P}_{k+1}$ with probability $\pi_{k+1} = 1/\left(1 + \exp\left(H\left(\mathcal{P}_{k+1}\right) - H\left(\mathcal{P}_k\right)\right)\right)$, otherwise return to $\mathcal{P}_k$.
4. Repeat step 2 and 3 until the system reaches a steady state distribution.

A configuration is evaluated based on the relative error or realized distances to target distances, so that short and long trips are treated equally. Parameter θ_3 controls the randomness. That is, if $\theta_3 = \infty$ each trip would exactly (if possible) meet its target distance, which, however, is not the desired solution. Rather, θ_3 is adjusted so that there is some randomness in realized trips distances, but without distorting global target distance distribution.

70.2.3 Calibration

The outcome of step 2 (Section 70.2.1) and 3 (Section 70.2.2) is a valid population with imputed home and activity locations. In the third step, the population is calibrated against measurements of count stations and flows of selected O-D pairs. This step is implemented in a "standard" MATSim-Cadyts combination. The scoring function accounts only for the "linear plan effect", agents are allowed to have only one plan and `SelectExpBetaForRemoval` is used for the `planSelectorForRemoval` parameter. All Cadyts parameters are left to their defaults.

During replanning, non-home activities that are not part of a complex trip chain are relocated. More specifically, an activity is valid for relocation if:

- The facility of the previous and succeeding activity is equal (round trip), or
- the activity is the origin of the first trip, or
- the activity is the destination of the last trip.

The above conditions ensure that complex trip chains that have been adjusted in step 2 (Section 70.2.2) are not distorted. New activity locations are randomly chosen within a distance of ± 10 % of the trip's target distance, so that global distance distribution is conserved.

70.2.3.1 Counts Calibration

The German Federal Highway Research Institute, BASt (Bundesanstalt für Straßenwesen), provides average daily vehicle volumes (distinguished in car and trucks) yearly, measured at about 1500 count stations on motor- and highways. After separating each station's data into both directions of traffic and validating measured vehicle volumes, about 2 500 link volumes are available for calibration. Empirical car occupancy rates (depending on trip purpose) are taken from the MiD to convert person volumes to car volumes.

70.2.3.2 O-D Calibration

O-D calibration is based on an O-D matrix representing car navigation device flows. Since occupancy rate of devices in cars is unknown, only the distribution of flows is used for calibration.

Further, comparison with other data sources shows that the O-D matrix is only valid for O-D pairs above a distance of 100 kilometers. This appears reasonable, considering that navigation devices are probably not switched on for short (likely commuter) trips. Accordingly, only O-D pairs above 100 kilometers distance and, from those, only the 6 000 pairs with the highest volumes are extracted into a reduced *calibration matrix*. The latter conditions ensures that only pairs with a sufficient sample size are used.

The reduced calibration matrix is normalized to the sum of all trips in a *reference matrix*. The reference matrix contains all trips from the initial population that correspond to all non-null O-D pairs (matrix entries) in the reduced calibration matrix. This yields a calibration matrix with valid absolute trip volumes.

For each O-D pair, a virtual link is inserted into the road network at runtime. A virtual count station with the corresponding count value from the reduced calibration matrix is attached to each virtual link. In the mobility simulation, after a person arrives at its destination, it then travels the virtual link corresponding to the traveled O-D pair. This travel, however, is only communicated towards the Cadyts calibrator by injecting additional `PersonDeparture`, `LinkLeave`, and `PersonArrival` events.

70.3 Simulation Results and Travel Statistics

The synthetic population of 4 M persons corresponds to approx. 8.5 % of the German population that conducts at least one car trip per day. This yields a scaling factor of 11.8 by which all simulation statistics need to be multiplied. The simulation produces an overall trip volume of 57.5 M trips, quite close to 57.2 M trips in the official statistics (DIW, 2014). Passenger mileage of 947 G person-kilometers is slightly overestimated compared to 917 G person-kilometers in the official statistics, yet still reasonable.

Figure 70.2 visualizes the calibration results in a scatter plot. Each dot represents a count station (left) or a O-D pair (right), respectively. On average, absolute value of the relative error yields 0.18, considering vehicle volumes at count stations and 0.16 considering O-D flows. A median relative

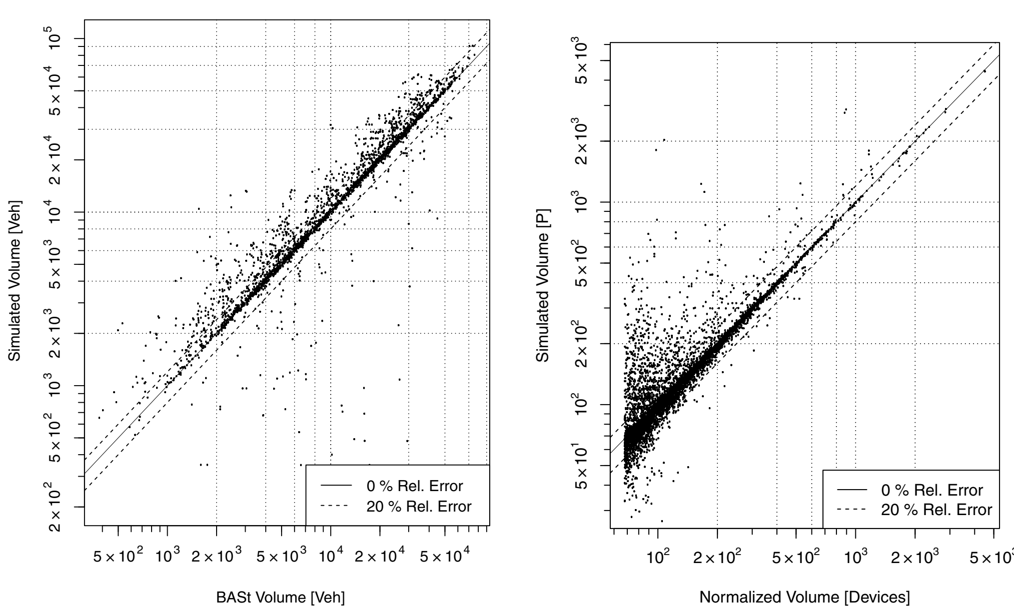

Figure 70.2: Comparison of simulation and empirical measurements. Left: count stations. Right: O-D pairs.

count station error of 0.12 indicates that there are a few count station that are significantly off. These two issues should be noted; first, there is only a description of the count station's location, which is not always unique and may be misinterpreted by the matching algorithm. This can yield a false assignment of count stations to network links. Second, there is no information on the count stations' measuring error, or on temporarily capacity reductions (for instance, caused by construction sites) modeled in the simulation network.

O-D flows error correlates with the O-D pairs' volumes; thus, pairs with low volume show, on average, a higher error. This is related to this scenario and MATSim's characteristics: a population sample size (8.5 %) and the discrete nature of MATSim. For instance, a real-world O-D flow with 118 individuals is represented by ten agents in the simulation. A variation during re-planning to this O-D pairs by, say, one agent already has a significant impact on the scaled real-world value. Averaging over multiple iterations reduced the variance but does not entirely remove the effect.

CHAPTER 71

Hamburg Wilhelmsburg

Hubert Klüpfel and Gregor Lämmel

The following describes the evacuation of Hamburg-Wilhelmsburg as a case study. The scenario has been created using MATSim's evacuation contribution. Technical details about the evacuation contribution are given in Chapter 41.

Wilhelmsburg was severely flooded in 1962. Since then, many structural and operational improvements have been implemented. Back then, the housing situation was rather bad, many people lived in provisional housing due to destruction in World War II. Additionally to the by far more stable buildings, precautions for flooding have been taken and the walls have been heightened. Evacuation is nevertheless necessary under certain circumstances. The relocation of one of the major roads in Wilhelmsburg, the B75, will also influence the evacuation traffic, since it is one of the major north-south arterial roads. In this case study, the consequences of this relocation on the evacuation of Hamburg-Wilhelmsburg is investigated.

71.1 Brief Description

The scenario investigated here is the relocation of highway B75 in Wilhelmsburg. Two cases are investigated, as summarized in the following table. The investigation highlights differences in the evacuation traffic for both variants of the B75 trail. As seen in Figure 71.1, the new trail "B75 new" is located generally next to the existing railway track. In the south, the new variant is connected to the existing highway at the junction "Hamburg Wilhelmsburg Süd" (just north of the bridge across the river Elbe); in the north, it is connected to the existing highway just before the junction

1	Current location of B75 with restricted directional choice
2	New location of B75 with restricted locational choice

Table 71.1: Scenarios.

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Figure 71.1: The current trail of highway B75 is shown in the center of the image. The new trail is east of it next to the railroad.

"Hamburg Georgswerder". The main differences between the two variants are the location of the access routes to highway B75 in the center of Wilhelmsburg.

71.2 Road Network

The MATSim road network is generated ("imported") from the Hamburg OSM file, downloaded from `http://www.geofabrik.de`. Fortunately, the OSM file already contains the new B75 highway track, marked by an attributed "open 2016". Therefore, the two networks for the "B75 old" and "B75 new" variants could be derived from the same OSM file. For the variant "B75 old", this file could be directly imported. For the variant "B75 new", the section of B75 to be relocated has been removed in a first step. In a second step, the new B75 track has been connected to the existing road network, i.e., the B75 north at junction "Georgswerder" in the north and junction "Hamburg Wilhelmsburg Süd" in the south.

(a) (b)

Figure 71.2: Comparison between network for the old and new track of the B75.

Figure 71.3: Roads closed during evacuation.

Additionally, the on and off-ramps to the B75 have been added. The two variants of the resulting road network, i.e., "B75 old" and "B75 new" are shown in Figure 71.2.

In an evacuation, some roads would be blocked to avoid intersecting and inbound traffic. The following streets were thus deleted in the OSM file:

- Neuenfelder Str.
- Im Schönenfelde
- Elsterweide
- Kirchdorfer Str.

An illustration is given in Figure 71.3.

71.3 Evacuation Scenario

The comparison of the two variants is based on overall evacuation time, clearing time of different cells (squares in the area that had to be evacuated) and the number of cars using the road network (utilization).

As described in Section 41.4, the input files for the network (OSM), the area (ESRI shp), and the population (ESRI shp), as well as the parameters for sample size and departure time distribution, have been specified and assessed via a GUI. The scenario XML file for the existing (or "old", in German "alt") track of highway B75 is shown in the following listing.

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<grips_config
 xsi:schemaLocation="http://www.matsim.org/files/dtd
 http://matsim.org/files/dtd/grips_config_v0.1.xsd"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <networkFile>
        <inputFile>osm/hamburgB75_alt.osm</inputFile>
    </networkFile>
    <mainTrafficType>vehicular</mainTrafficType>
    <evacuationAreaFile>
        <inputFile>area/area.shp</inputFile>
    </evacuationAreaFile>
    <populationFile>
        <inputFile>population/population.shp</inputFile>
    </populationFile>
    <outputDir>
        <inputFile>matsim_output_B75alt</inputFile>
    </outputDir>
    <sampleSize>0.1</sampleSize>
    <departureTimeDistribution>
        <distribution>normal</distribution>
        <sigma>1800.0</sigma>
        <mu>1800.0</mu>
        <earliest>0.0</earliest>
        <latest>3600.0</latest>
    </departureTimeDistribution>
</grips_config>
```

71.3.1 Departure Time Distribution

The departure time distribution is specified in the file `scenario.xml`. The values were in seconds, i.e., a normal distribution with a mean value (mu) and a standard deviation (sigma) of 30 minutes in the range of zero (earliest) to one hour (latest) was chosen. More details about time distributions are discussed in Section 41.4. This distribution reflected certain assumptions made about evacuation procedure. The overall time frame, based on the warning time, is minimum 7 hours. The preparation phase is projected with three hours. Available time for the evacuation is three hours, with a one-hour buffer. The warning via radio will start at t=0 hours and local warning (e.g., by police cars, sirens, and via short messages) at t=1 hours; simulation reference point was set to t=3 hours. The overall time acceptance criterion for the simulation is the a required safe evacuation time (for simulation by car) of less than three hours (including reaction time). The reaction time set in the simulation could be interpreted as decision-making time after readying personal belongings. In short: ASET (Available Safe Evacuation Time) determined by flooding is 3 hours and the RSET (Required Safe Egress Time) is estimated by the simulation. The criterion for a successful evacuation is ASET $>$ RSET.

71.3.2 Population Size

As explained previously, the population is not stored in the scenario file, but in the population shape file, possibly consisting of several polygons. The number of persons is stored as an attribute for each polygon. Here, one must assume that only part of the population would have to evacuate; for many, escape to higher ground might be sufficient. Detailed information on the different procedures can be found at `http://www.hamburg.de/sturmflut/3425646/sturmflut-download-1/` (in German).

Figure 71.4: The initial distribution of the agents for the evacuation of Wilhelmsburg (for both cases, B75 new and old).

Each agent represented one evacuee traveling by car. To independently check the number of agents based on the simulation files, one could open the file `population.dbf` with a database or spreadsheet editor. Note that the number specified in the `population.shp` (resp. `population.dbf`) is multiplied with the `sampleSize` when converting the files to MATSim input, i.e., in this case, the `population.xml.gz` located in the output directory.

The population is initially distributed as shown in Figure 71.4. The algorithm that converted the area and population (i.e., `area.shp` and `population.shp`) is described in Section 41.2. It assigns agents to the edges of the network. In the case study, harbor areas are left out and agents are equally distributed to streets in the housing (and agricultural) areas of Wilhelmsburg (Figure 71.4). Of course, this could have been further refined by going to a block, or even house level and assigning the population according to detailed statistical housing data. This has not been undertaken for this simulation, for two reasons. First, many assumptions are made about behavior, initial location, and share of population that had to evacuate. Therefore, the level of detail seemed to be sufficient. Second, each agent represented a car driver, i.e., in the simulation, all cars registered in Wilhelmsburg left the area. Considering that inbound, as well as through traffic would be prohibited when flooding level exceeded a certain threshold, this is a "worst case" assumption resulting in a heavy traffic load. To summarize, the overall approach is justified to assess highway B75 relocation based on heavy traffic load with a reaction time span between 0 and 1 hour.

71.4 Simulation Results

The simulation results are summarized in Table 71.2. The 0th iteration is based on shortest distance only. This might have resulted in "strange" behavior, as illustrated in the following Figure 71.5 (south of the bridge across the Elbe river, near the junction "Großmoordamm"). The road network had a circular shape; it was cut out from the OSM road network according to the `area.shp`, which is, in this case, just a circle. Since all the agents are taking the shortest path in iteration 0, they headed to the nearest road out of the evacuation area. Technically, the boundary links in the network are connected to a super link when creating the MATSim network from the OSM file and the

Figure 71.5: Results for B75 old, iteration 0.

	B75 old	B75 new
Iteration	Time	(hh:mm)
00	04:45	05:00
10	01:52	01:58
20	01:42	01:46
30	01:40	01:42

Table 71.2: Results.

`area.shp`. This super-link is the destination in all evacuees' plans. A second factor that contributes to congestion in iteration 0 is a short cut via an on- and off-ramp of Autobahn A253 at "Großmoordamm". Capacity of the on- and off-ramp is 1 500 cars per hour, compared to 4 000 cars per hour on the highway. Thus, the short cut (which is shorter in distance, the reason agents chose it) was a bottleneck, resulting in artificial congestion in iteration 0. Therefore, the 0th iteration was unsuitable for assessing the overall evacuation time. As can be seen from Table 71.2 above, for both cases, from iteration 10 on, time presumably converges to some realistic value. This was also illustrated in Figure 71.6 where the situation at t=1:30 hours was shown for iteration 20.

In summary, relocation of highway B75 had no major influence on the overall evacuation time. The evacuation time of about two hours was also within the available safe egress time, as described in the previous section.

It would certainly have been possible to analyze the results further. The two screenshots above, for the situation in iteration 0 at t=3 hours and for iteration 20 at t=1.5 hours, were created with Senozon AG Via (the visualizer presented in Chapter 33). As a conclusion to this chapter and an illustration for the built-in capabilities of the evacuation contribution for analyzing simulation results, road utilizations of the two variants are shown in Figure 71.7.

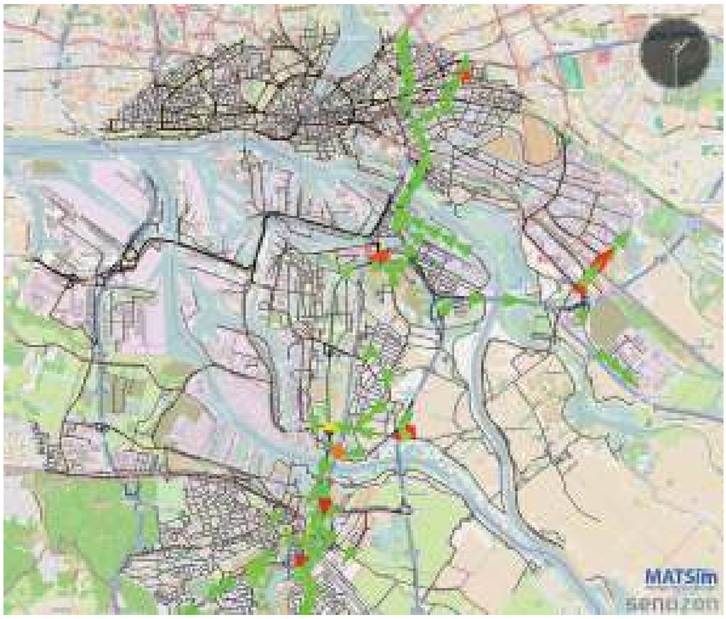
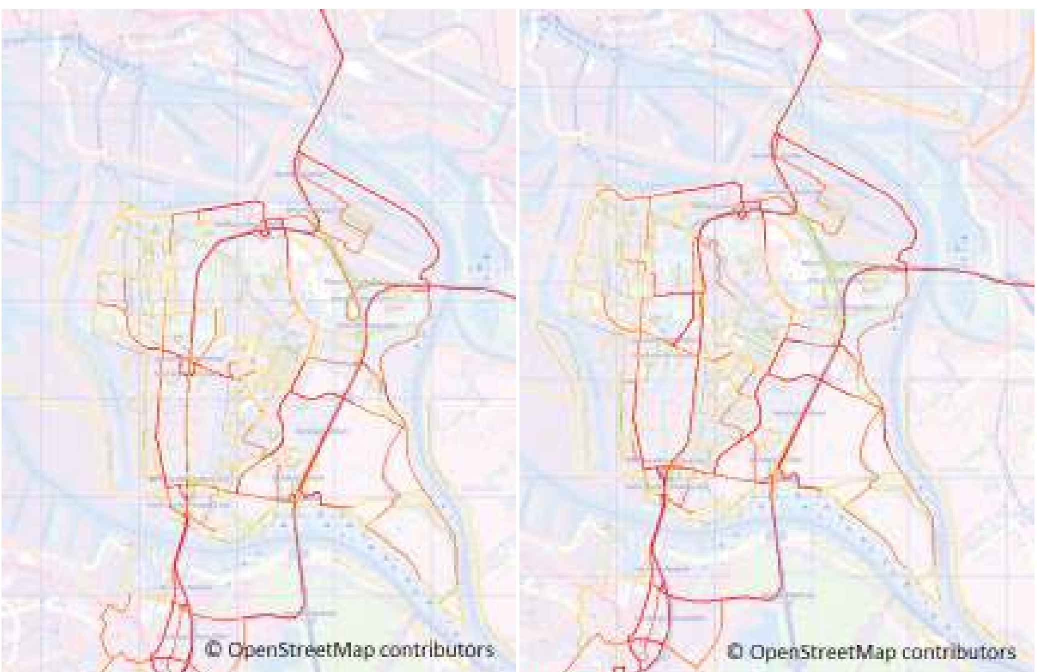


Figure 71.6: Results for B75 old, iteration 20.



(a) (b)

Figure 71.7: Comparison between network utilization for the old and new track of the B75.

CHAPTER 72

Joinville

Davi Guggisberg Bicudo and Gian Ricardo Berkenbrock

Joinville Prefeitura Municipal de Joinville (PMJ) (2015) is a mid-sized industrial city in the south of Brazil, with around 550 000 inhabitants. It has a large workforce, including commuters from neighboring cities and an intense industrial activity profile, meaning that companies work often in three shifts, causing peculiar traffic patterns. Many people also have 12-hour daily routines, encompassing work and higher education.

The Joinville traffic model was built as an initial step of a project to simulate the entire northeast region of Santa Catarina state, including air traffic, shipping, state highways and neighboring cities. The project aims to build a complete data base of people and freight movement in the region. The first version of the urban Joinville model is now complete, produced as a graduate thesis at the Federal University of Santa Catarina (UFSC) `http://ufsc.br`, Transportation and Logistics Engineering course `http://transporteslogistica.joinville.ufsc.br`.[1]

The scenario population was generated with data from the 2010 Brazilian census combined with demographic information from the city's travel survey; travel demand was generated from the same survey. Both were designed to fit into the MATSim, using Tutorial classes (with some adaptations).

The network was produced with vector data provided by the local Urban Sustainable Planning Institute of Joinville (IPPUJ) `https://ippuj.joinville.sc.gov.br`. The data came as a shapefile, with numerous connectivity problems. We were able to fix them using scripts in Python with the `NetworkX` module (Hagberg et al., 2008). Information was transformed from vector data into a graph, addressing issues with the help of QGIS and finally writing as the MATSim XML network format. The facilities were produced from land-use data provided by the city government.

For now, the model runs only with cars, using a full sample of the population. From the available data, we inferred 135 652 agents traveling by car; the rest were removed from the simulation. Figure 72.1 shows a screenshot of the Events using Via.

[1] The authors would like to thank their sponsors Federal University of Santa Catarina (UFSC) and Urban Sustainable Planning Institute of Joinville (IPPUJ).

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Figure 72.2 shows the comparison between simulated and count data for 20 links in the morning peak from 7 to 8 am. The count data available for comparison is still sparse and could not be used as effectively as we hoped; we know that calibration is needed for the next model versions. The good news is that the local authorities are installing more than a hundred counting stations throughout the city within the next couple of months and a new travel survey will be conducted this year.

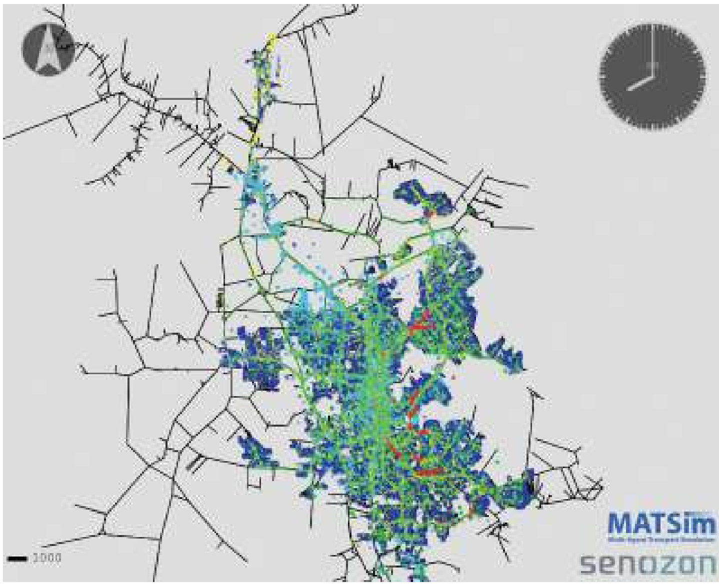

Figure 72.1: Screenshot of the simulation using Via.

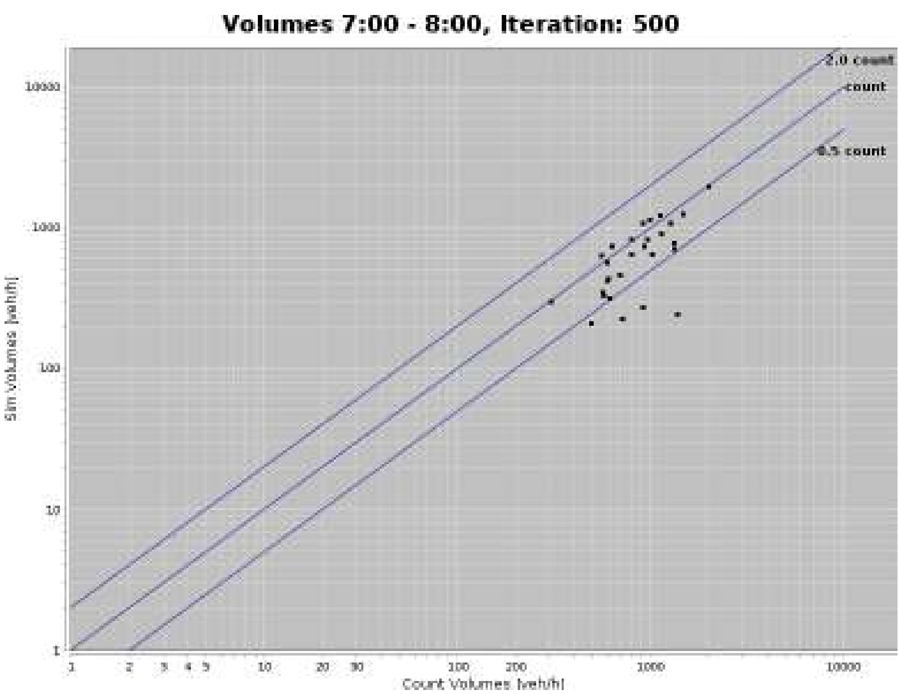

Figure 72.2: Count comparisons for the morning peak at 7-8 am.

CHAPTER 73

London

Joan Serras, Melanie Bosredon, Vassilis Zachariadis, Camilo Vargas-Ruiz, Thibaut Dubernet and Mike Batty

The building of a travel demand model for London started to take shape under the EUNOIA Project.[1] The core decisions around the model design were taken after two meetings with TfL (Transport for London), which was part of the Advisory Board in the project. In that respect, the main suggestion by TfL was the adoption of an activity-based approach.

The main traits from the current implementation of the London model are listed next:

- Our baseline year is 2010.
- The geographic extent of the case study area is contained within the M25 and includes around 9,4 million inhabitants (Census 2011).
- The types of activity included in the model are: home, work, shop, education, leisure and other.
- Four travel modes have been included: walk, cycle, car and public transport. The public transport mode includes buses, underground, rail, the Docklands Light Railway and the London Overground.
- The zones of analysis for the London model are the English Census 2011 Wards which we will refer to as wards from now on. Our case study is composed of 850 wards.

73.1 Supply

The assembly of the supply for our model includes the definition of the following three components:

- road network,
- public transport services, and
- land-use configuration

[1] see `http://eunoia-project.eu`

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The data used to build the road network is the Integrated Transport Network from the Ordnance Survey. The source network, which is defined at the navigation level, has been processed to remove some of the detail included. Decisions on the capacity of each road link has been based on the guidelines proposed by COBA Manual (2002)(Vol. 13),[2] by the UK's Department for Transport. This implies the usage of each road link's road type (Motorway or A road among others) and road nature (single carriageway, dual carriageway or slip road among others) to set the road capacity for each road link.

All the public transport services operating within the case study region have been obtained from timetable data held by the National Public Transport Data Repository from 2009[3]. This dataset, includes a very detailed account of all the services operating in the UK.

Finally, the land-use configuration for the London model has been produced using the Ordnance Survey `AddressBase` layer which keeps address records for all the United Kingdom with a definition of land-use for each one of them. We have processed the detailed spatial information in order to assign each address point to the nearest road link in the network; this means that after this process, each link in our network will contain a number of addresses which include the land-use associated to it. We have also mapped the wide categorization associated to each address point to the activity types from the model: home, work, shop, education, leisure and other.

73.2 Demand

In order to define the travel demand associated to London, we have followed the methodology adopted in TRANSIMS[4]. In this respect, we first generated a synthetic population representative of the case study area and then, we assigned the sequence of activities to each synthetic individual.

We created our synthetic population using a simulated annealing technique based on Metropolis et al. (1953). We have used the following two datasets: Census 2011 data for each of the 850 wards in London and the HSAR (Household Sample of Anonymised Records) for England in 2001. This technique is based on the selection of survey households from the HSAR which best match the overall socio-demographics from the Census 2011 for each of the 850 wards in London. The output of this technique includes a number of synthetic households associated to each ward and, correspondingly, the synthetic individuals which cohabitate within the household with very detailed socio-demographic information.

The assignment of each synthetic household to our network has been achieved using a probabilistic distribution based on the use of home-only activity locations within each ward.

The assignment of skeletal activity patterns for each synthetic individual has been executed using Classification and Regression Tree Algorithms much like in Speckman et al. (1998). More specifically, the multivariate regression tree algorithm. This technique aims to produce clusters of survey households whose activity patterns are similar through the use of socio-demographic data. Once the decision tree is built, it is used to assign each synthetic household to a given survey household through socio-demographic similarities between the two. In this case study, we have used the LTDS (London Travel Demand Survey) 2010/11 to generate the tree.

After assigning the skeletal activity patterns to each synthetic individual, the next step consists in assigning a location to each activity. In order to do this, we have used a multinomial logit choice model. This technique allows each synthetic individual to evaluate the benefit of performing a specific activity at a particular destination as a composite value based on objective metrics associated with this destination (e.g., number of relevant addresses), objective metrics associated with

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[2] retrieved from `https://www.gov.uk/government/publications/coba-11-user-manual`

[3] see `http://data.gov.uk/dataset/nptdr`

[4] We used v3.1, corresponding to that developed in Los Alamos National Laboratory.

traveling from origin to destination (e.g., travel time) and subjective components following a probability distribution. The area units being considered in London have been the wards again. And, in this respect, the attractiveness of each ward has been quantified by the number of addresses for each activity type, and the accessibility throughout the region as the travel time across all wards using the crow-fly distances and the average speed for each travel mode in the case study. The calibration for each travel mode and activity type pair has been performed, and those parameters have been used to calculate the new activity locations for each synthetic agent.

73.3 Calibration and Validation

In terms of the calibration, the multinomial logit choice model applied described in the previous section could also be included here. On top of this, activity-related time values have been set in MATSim's configuration file using typical duration values observed from the LTDS dataset. Finally, the parameter values set by default in MATSim taking have also been adopted here. This is a limitation as the modal split currently in place is the one provided by the MATSim corresponding module. The related parameters should be first adjusted so that the observed modal share is similar across modes to the observed modal shares.

In terms of the validation, traffic counts from around 600 sensors have been made available to us for London. We hold values for the AM peak (8-9 am), the inter-peak (9 am-5 pm) and the PM peak (5-6 pm). The former and the latter are hourly counts; the inter-peak is an average value. Those counts are organized into so-called cordons (3) and screenlines (3). Comparisons are currently in place and we are still not in a position to evaluate in detail how the model validates to the observed data.

73.4 More Information

More detailed information on the building of the model including some results from each module previously described can be found at: `http://eunoia-project.eu/publications/` (Report on Case Study 1: London).

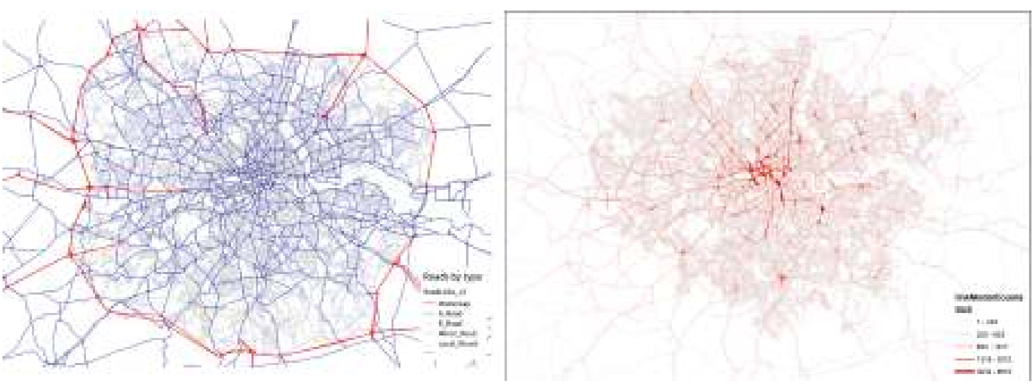

Figure 73.1: Snapshot of the road network for London's case study colored by road type (left) and map showing number of bus trips per road segment in London using timetable data (right).

Figure 73.2: Visual estimate of activities performed in London at 9 am using the Via software.

CHAPTER 74

Nelson Mandela Bay

Johan W. Joubert

The Nelson Mandela Bay metropolitan area is in the Eastern Cape province of South Africa and includes the cities of Port Elizabeth and Uitenhage, with a population of approximately 1.2 million inhabitants.

The issue of complexity drove the development of a scenario for this region. We needed an area where we could experiment with various modules and elements offered by MATSim, but one less complex than the mega-city region of Gauteng. The Nelson Mandela Bay case was attractive; it still had a substantial population, only one official bus operator (Algoa Bus Company) and one passenger rail operator (Metrorail). It also displayed the characteristic apartheid urban form of South African cities and towns, where many low-income commuters lived on the outskirts of spatially sprawled cities.

The population was, initially, generated from the 2001 census: later revised and updated to the 2011 census data. Travel demand was inferred from the 2006 travel diary conducted in the metro. The process of synthetic population generation is described in detail on the MATSim `https://matsim.atlassian.net/wiki/display/MATPUB/South+Africa` Confluence site. The population was generated as entire households, using MLIPF (Multi-Level Iterative Proportional Fitting) as published by Müller and Axhausen (2012). Households were also assigned to buildings, based on census description.

This was the first South African scenario to include private cars, freight and detailed public transport. The unique minibus taxis, a form of paratransit in South Africa and many developing countries, were incorporated in the Nelson Mandela Bay area and reported in Röder (2013) and Neumann et al. (2015).

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CHAPTER 75

New York City

Christoph Dobler

The MATSim New York model was an example of an agent-based model based on a given activity-based demand generation process outcome: in this case, the NYBPM (New York Best Practice Model) of Parson Brinkerhoff (Vovsha et al., 2002; Parsons Brinckerhoff, 2005, 2009). It produced persons with individual activity chains; MATSim was chosen as the simulation-based alternative to conventional assignment processes.

Activity locations were selected on zonal level (3 824 zones), timings (i.e., start time and duration) were chosen using given distributions. As part of the conversion process to MATSim, locations were distributed within the zones, according to land use and buildings. For the route assignment, transport modes were converted into those supported by MATSim. The resulting population contained 5.3 million persons (25 % sample).

A multimodal network was created, containing car and public transport links, for the MATSim model. Car links were derived from the aggregated model network data, including capacity, number of lanes and speed limits. For the public transport network, a shape file containing every lines' routes was available. After converting and cleaning the data, the final multimodal network contained 498 000 nodes and 541 000 links. Based on further public transport-related data, a full schedule was created, including different public transport modes (bus, train, etc.).

An example for final model outcomes was shown in Figure 75.1 and Figure 75.2, depicting the car share of all performed trips within a region. Red indicated a high share, blue a low. In Figure 75.1, trips were aggregated on zonal level. In Figure 75.2, the MATSim model high resolution is shown; there, the trips were aggregated using hexagons with a side length of 500 meters instead of a zonal level.

Finally, Figure 75.3 shows traffic flows in Lower Manhattan. Cars were represented by rectangulars, public transport vehicles by arrows. Further model outcomes were presented by Balmer (2014). An online movie can be found at `http://senozon.com/news/2014-05/z%C3%BCrich-meets-new-york`

How to cite this book chapter:

Dobler, C. 2016. New York City. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 453–456. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.75.

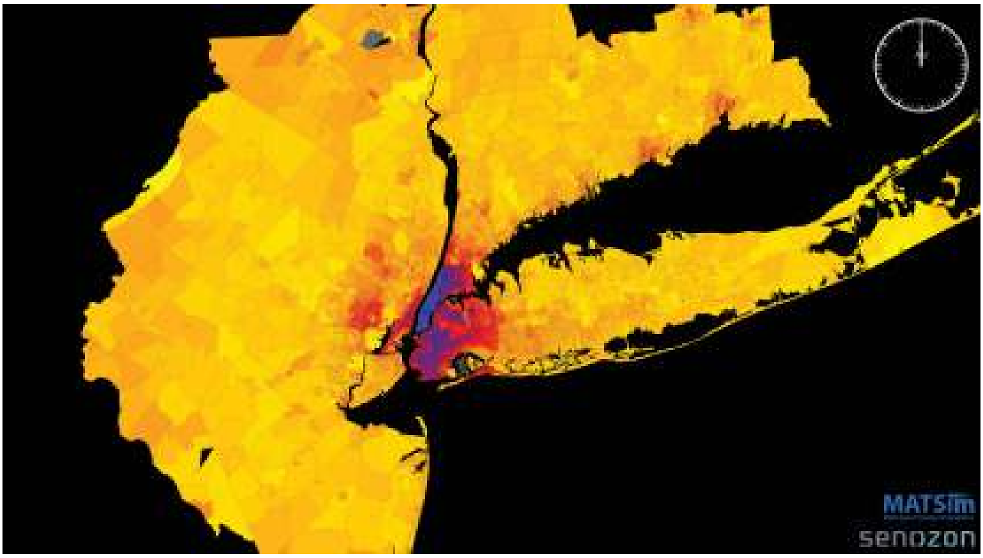

Figure 75.1: Car share (entire modeled area).

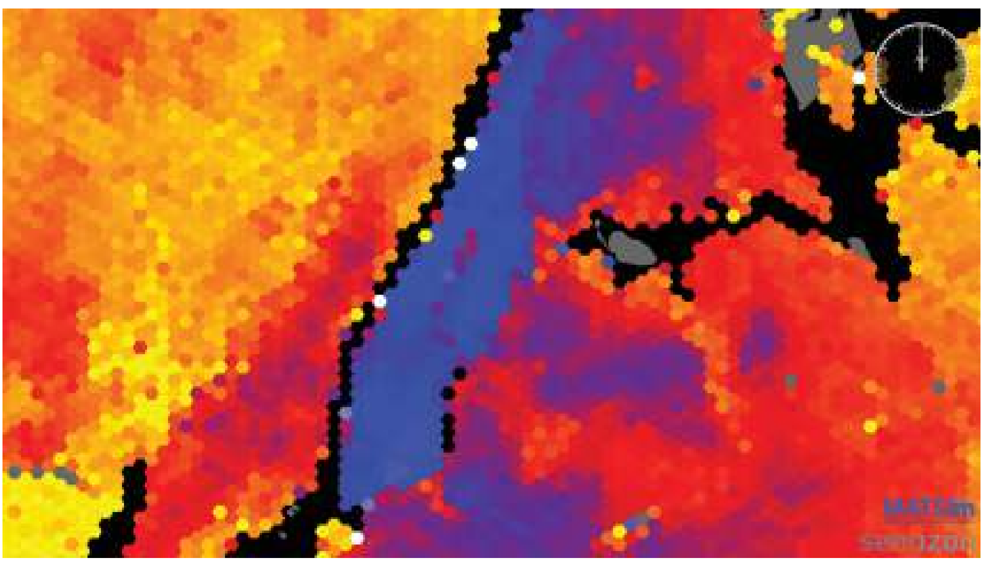

Figure 75.2: Car share (Manhattan).

Figure 75.3: Traffic flows in Lower Manhattan.

CHAPTER 76

Padang

Gregor Lämmel

The Padang scenario demonstrates the MATSim application to large-scale evacuation problems. The scenario has been created as part of the third party funded project "Last-Mile". Taubenböck et al. (2013) give a comprehensive overview. Padang is located on the west coast of Sumatra Island, Indonesia. In 2014, the city had a population of about 1 000 000 people. Because of its problematic location on the coast in a so-called "seismically locked" area (McCloskey et al., 2010), Padang is prone to earthquakes and subsequent tsunamis. In the "Last-Mile" project, a realistic tsunami scenario, triggered by an earthquake about 300 km off the coast, was identified (Goseberg and Schlurmann, 2009). The assumed tsunami would leave about 30 minutes for the evacuation. The flooding would reach as far as three kilometers inland, thus threatening up to 330 000 lives. Lämmel (2011) developed a MATSim scenario representing the city with its affected population. One unusual aspect of the Padang situation is the expected universal evacuation by foot; simulating pedestrians with MATSim was a novelty when this project started. The standard simulation model (see, e.g., Section 1.3) was thus adapted to deal with pedestrians. Details are discussed by Lämmel et al. (2009). Another important variation, contrary to most standard transport scenarios, is that network links would flood once the tsunami reached them. Thus, accessibility—flooded or not flooded—of the network links is time-dependent, which is modeled by a time-dependent network (Lämmel et al., 2010). In the time-dependent network concept, link attributes—like *freespeed*—can be changed, while the simulation is running, by precomputed network change events. For the Padang scenario, the network change events have been extracted from microscopic flooding simulation data.

Key Padang scenario facts:

- The network consists of about 6 000 nodes and 17 000 links.
- Synthetic populations for morning, afternoon, and night have been created, containing up to 330 000 agents.

How to cite this book chapter:

Lämmel, G. 2016. Padang. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 457–458. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.76.

Figure 76.1: Evacuation time analysis for downtown Padang. Numbers showing average evacuation time in minutes, which are also indicated by the colors green, yellow, red.

- The flooding is modeled by a set of 109 network change events (one per minute), affecting 7 609 links.
- A set of 42 shelter buildings, which could be used for vertical evacuation, is also part of the scenario.

Based on the Padang scenario, various evacuation strategies have been investigated:

- A seemingly obvious evacuation strategy is the shortest path solution, where everyone is on the shortest path. This solution, however, ignores possible congestion and lead to unfeasible results.
- Shorter evacuation times are achieved with a Nash equilibrium approach, where everyone tries to find an optimal evacuation route through iterative learning (Lämmel et al., 2009).
- While the Nash equilibrium reduces individual evacuation time, total evacuation time might not be minimal. The marginal social cost-based simulation approach tries to minimize the total evacuation time (Lämmel and Flötteröd, 2009; Dressler et al., 2011).
- These three basic evacuation approaches are investigated in combination with flooding (Lämmel et al., 2010; Lämmel, 2011).
- Further, an evacuation strategy to reduce the exposure to risk has been developed by Lämmel et al. (2011).
- And finally, Flötteröd and Lämmel (2010) propose a method to integrate shelter buildings, which are evacuation sinks (i.e., safe places) with limited capacity, into the simulation.

CHAPTER 77

Patna

Amit Agarwal

Patna is a medium-size city in eastern India. As in other developing nations, traffic conditions are heterogeneous, composed of: a large number of bikes (37 %, including 4 % cycle rickshaws) and motorbikes (14 %). When this scenario was composed, public transport accounted for 18 % and walk for 29 %; only 2 % of all trips were made by car. Therefore, the MATSim queue simulation was modified to simulate travel demand under mixed traffic conditions (Agarwal et al., 2015b).

A detailed Patna scenario description can be found in Agarwal et al. (2013). The scenario was created using household survey data from a comprehensive Patna mobility plan (TRIPP et al., 2009), using the area within the Patna Municipal Corporation. The scenario consisted of 72 zones, with a population of about 1.57 million (year 2008). MATSim demand was generated using trip diaries, with car, motorbike and bike used as main congested modes (Figure 77.1). PCU (Passenger Car Unit) factors for different vehicle types were derived using effective area occupied by vehicles. The effective area occupied by a vehicle is calculated, and the ratio of area occupied by this vehicle to the area occupied by a passenger car is taken as PCU factor for the respective vehicle. To allow overtaking of slower vehicles (bike), by faster vehicles (car and motorbike), pre-existing, state-of-the-art FIFO queue simulation was overridden, using earliest link exit time as shown in Figure 77.2. Traffic behavior in modified queue simulation was then analyzed by plotting fundamental diagrams and space time trajectories for car, motorbike and bike (Agarwal et al., 2015b).

To address some special factors of Patna's travel time distributions, MATSim utility function was calibrated so that a mode share from real world data was replicated in the model, performed by allowing agents to switch modes. The model was validated using traffic count data and modal travel time distributions. The model's main shortcoming seemed to be overly short average travel times for motorbikes. Although no specific experiment was performed to analyze computational performance, no noticeable loss of performance was found during simulations. Thus, the model seems to be useful for many areas where mixed traffic conditions predominate.

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Agarwal, A. 2016. Patna. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 459–460. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.77.

Figure 77.1: Patna: Various vehicles on network, car in red, motorbike in blue and bike in green.

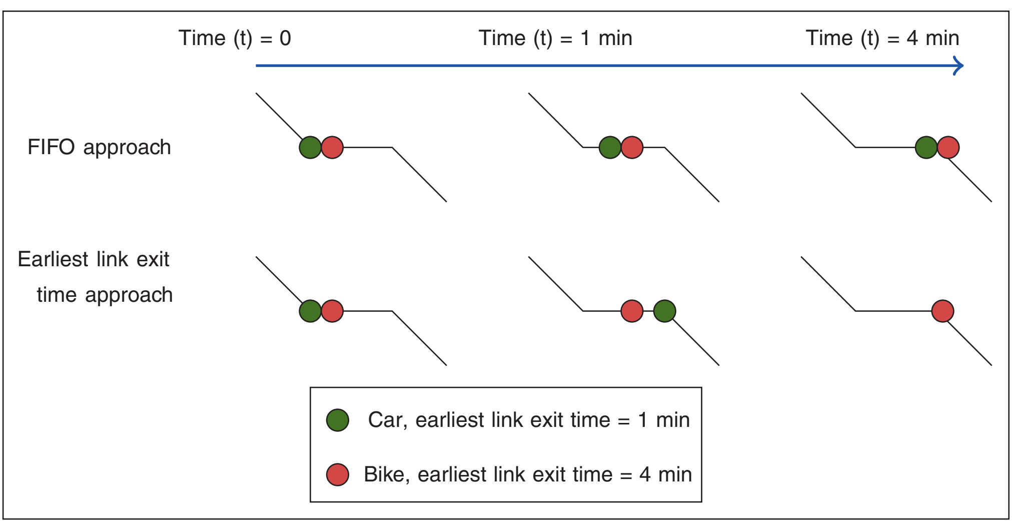

Figure 77.2: Patna: FIFO approach and passing of bicycle by car on a link (not to scale).

CHAPTER 78

The Philippines: Agent-Based Transport Simulation Model for Disaster Response Vehicles

Elvira B. Yaneza

This study's primary aim was adapting an agent-based traffic simulation model to assist planning agencies in determining road traffic routes for DRVs (Disaster Response Vehicles) in crises or disasters. After the initial disaster event period, road network management is crucial for disaster response operations, which must cope with travel demand increase. Depending on level of road damage, sections of the the road network may close. The degraded DRVs road traffic routes will result in longer travel times.

The model was developed using an agent-based simulation modeling paradigm implemented through MATSim. Road traffic routes were generated using Dijkstra's shortest path algorithm. MATSim output files stored each agent's routes, which represented traffic routes for DRVs; here, each route's calculated travel time was equivalent to each agent's running time (in actual motion, while using shortest paths from source to destination).

78.1 Literature Review

Road traffic routing studies generally use different modeling approaches and shortest path algorithms. In studies using modeling, Lefebvre and Balmer (2007) used MATSim for large-scale agent-based transport simulation, also investigating variations of Dijkstra's algorithm and A*-algorithm. Sumalee and Kurauchi (2006) used the Monte-Carlo simulation approach to approximate network capacity reliability, then evaluated traffic regulation policy performance, using the Kobe city (Japan) road network. Teknomo (2008) multi-agent simulation modeling approach considered route probability as a direct simulation output, rather than input, to the network. Sanders and Schultes (2017) outlined algorithms with faster run times than Dijkstra's algorithm for transportation network route planning. Their study focused on successful speedup techniques in static

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road networks with fixed edge cost. Elalouf (2012) model incorporated joint analysis of expected route time and its variance, using dynamic-programming, shortest path algorithm as a basis for a fully polynomial time approximation scheme.

78.2 Design Details and Specifications

Element 1: Study Area During Tropical Storm Washi (Sendong), areas most affected areas were those near the Cagayan de Oro river (Ramos, 2011). Landslides near river banks, flash floods, as well as the overflowing river and its tributaries, caused some barangays (barrios)—already damaged by Tropical Depression Shanshan (Crising)—to be swept away (Del Rosario, 2011). The five most affected major bridges cross along the Cagayan de Oro River, connecting its two main areas, District 1 (west) and District 2 (east), in Misamis Oriental province (see Figure 78.1). The designated road network coverage has a total area of approximately 73.2 square kilometers, including the riverside (see Figure 78.2).

Element 2: Road Network and Facilities The model involved three main entities: road network, facilities and population and is described by two variables: nodes and links. It used graphical representation and had 3 847 nodes and 9 630 directed links (see Figure 78.3). A specific stretch of street consisted of nodes and links, representing intersections and street sections, respectively. MATSim handles only one-way links; in this model, one-way attribute had a default value of 1 and modes attribute were assigned only as car. Facilities were represented by their geographical coordinate locations in the network, which involved 21 entities from the following agencies: 10 hospitals with ambulance services, 3 fire stations, 8 police stations and 2 evacuation centers. Facilities were mapped on nearest road network links.

Element 3: Population and Demand Generation The population was classified into different types of DRVs, representing major agents in the traffic simulation model: ambulances, fire trucks and police cars. The hospitals, fire stations and police stations were assigned as agents' origins,

Figure 78.1: Cagayan de Oro City, Philippines urban road network.
Source: GIS City Planning Office, 2012

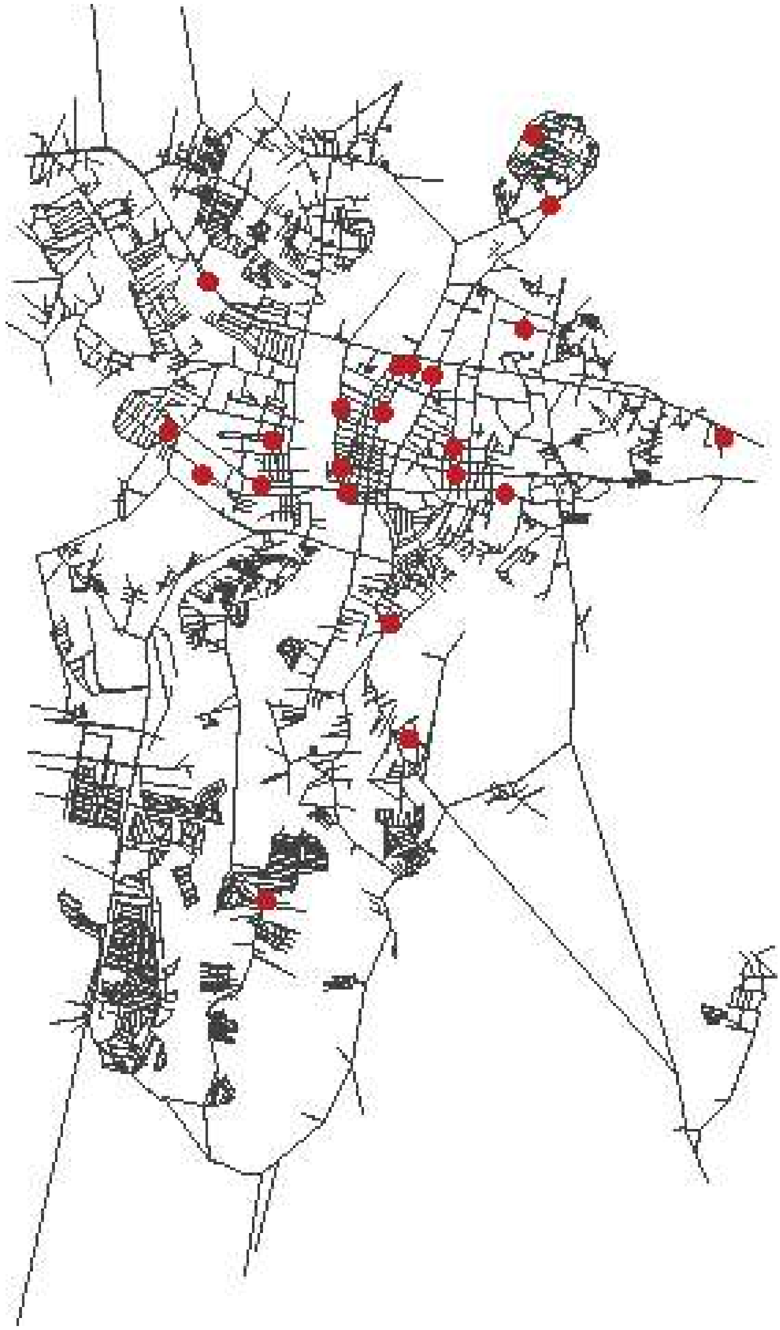

Figure 78.2: Spatial coverage of road network and locations of facilities in the network: it has 73.2 square kilometers including land and surrounding river and coastal areas. The facilities are mapped based on its actual geographical x and y coordinates in the road network. There are 23 facilities located in its nearest link in the network. These are: 10 hospitals, three fire stations, eight police stations and two evacuation centers.

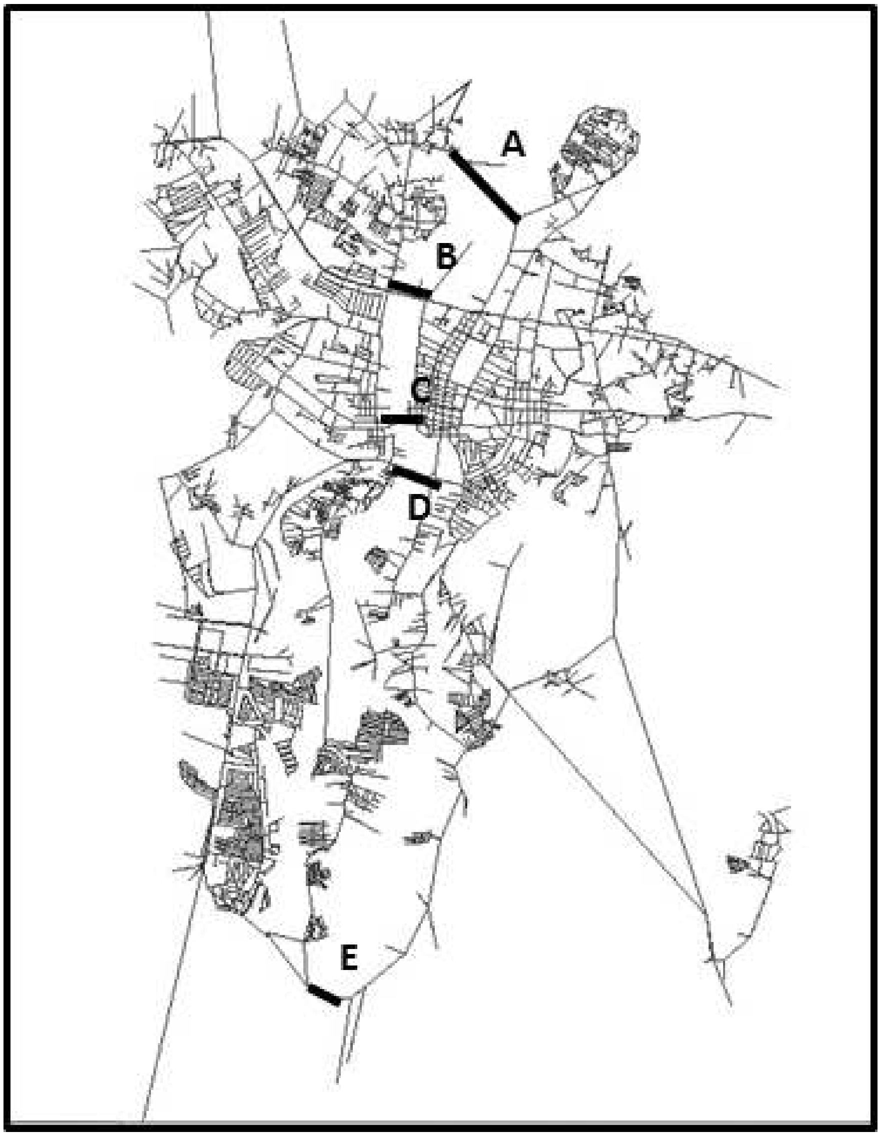

Figure 78.3: Nodes and links representation: Road Network has 3 837 nodes representing road intersections and 9 630 links representing the streets. It includes five major bridges along Cagayan River: (A) Kauswagan-Puntod Bridge, (B) Maharlika Bridge (formerly known as Marcos Bridge), (C) Gov. Ysalina Bridge (formerly known as Carmen Bridge), (D) Kagay-an Bridge (Rotunda Bridge) and (E) Emmanuel Pelaez Bridge.

where vehicles start and end their activities; evacuation centers were assigned as agent destinations. Population was characterized by four variables: person, plan, act and leg. The leg variable used a mode defining vehicle type, assigned as car. The model advanced by performing traffic routing activities. Each traffic routing activity, seven events, was processed in the following sequence: end activity event, agent departure event, wait to link event, enter link event, leave link event, agent arrival event and start activity event. The end activity event prompted the agent to depart from the origin facility and begin again in the same flow of events.

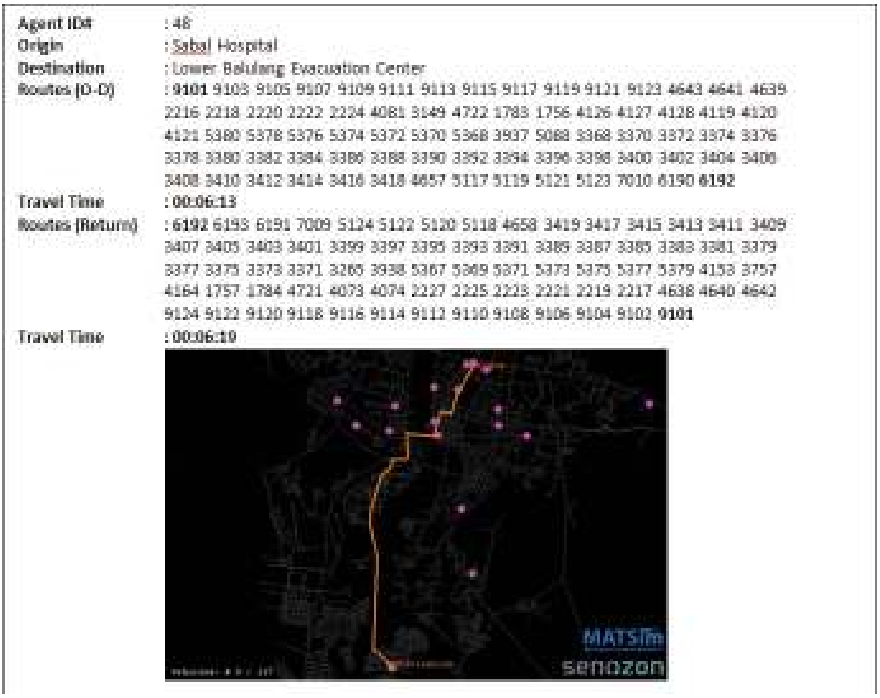

Figure 78.4: Screenshot of SCENARIO 1 (without bridge closures) using agent ID#4. DRVs trip starting from the Sabal Hospital (Origin) passing Carmen Bridge (Gov. Ysalina Bridge) going to Balulang Evacuation Center dropping point (destination) then back to its origin.

78.3 Model Scenarios

The simulation model was applied to the network of Cagayan de Oro City in Philippines. Two scenarios were assumed.

Scenario 1: No Bridge Closures The scenario was based on disaster response operations right after the disaster occurred; operations took place in Cagayan de Oro City. The scenario had two evacuation centers identified, (1) Balulang Elementary School Evacuation Area, located at the west side of Cagayan de Oro and (2) Burgos Barangay Hall Area, located on the east side of the city. The road network had 21 facilities as agents' origins, with 3 to 4 DRVs in each, dividing the network into 2 different evacuation centers. A total of 67 DRVs joined operations over time, as well as 50 additional vehicles from private institutions, traveling on their own rescue operations with different origins and destinations. No road obstructions were considered; traffic could access all five bridges defined in the network (see Figure 78.4). During the simulation run, DRVs were expected to cross the nearest bridge on their trips to destinations or evacuation areas: thus, using only shortest time traveled routes.

Scenario 2: With Bridge Closures In this scenario, road obstructions were represented as bridge closures in the network. The link IDs of bridges expected to close were required in data needed to run the java class for road closure generation. In the experiment performed, the link IDs for three bridges were entered; Carmen Bridge, Rotunda Bridge and Marcos Bridge. The same two evacuation areas and fifty additional vehicles were considered in the experiment and this time, only three bridges constituted road obstructions. The DRVs and other vehicles were expected to cross only the two remaining bridges (not included in the road closure generation): Taguanao Bridge and

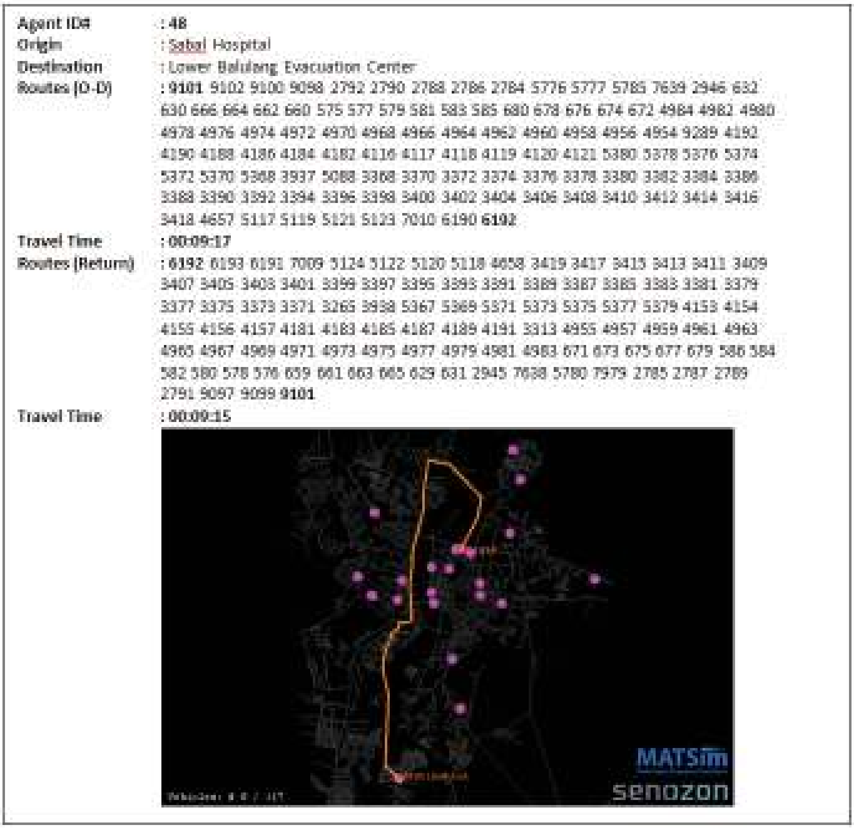

Figure 78.5: Screenshot of SCENARIO 2 (with bridge closures) using agent ID#48. DRVs trip starting from the Sabal Hospital (Origin) passing Kauswagan-Puntod Bridge going to Balulang Evacuation Center dropping point (destination) then back to its origin.

Kauswagan-Puntod Bridge. Expected vehicle flow occurred, as seen during visualization output; see Figure 78.5.

78.4 Validation

Face Validation from Field Experts The goal was to verify and validate whether the simulation model reasonably represented the real-world system and its conformance to design and operational behavior specifications. Four domain experts were invited from the fields of: traffic engineering, computing, planning and management for face validation. Two evaluators were invited from the academy; one was a transportation engineering and built-environment specialist, the other a computer scientist. The other two evaluators were from local government units: one handled management and administration as a technical supervisor from the Road and Traffic Administration Office and the second was a planning coordinator with the Cagayan de Oro City Planning Office. Whether accepting or rejecting, the field experts evaluated the simulation model based on their areas of expertise. Generally, the four evaluators verified and accepted the simulation model design specifications, as well as validating and accepting its operational behavior.

Travel Time Validation Using Test Car Technique and Simulation Model Results When the plans file was scrutinized, from both scenarios, calculated travel time resulting from the simulation was actually equal to the running time when the vehicle was in motion. Running time was computed as equal to the difference between travel time and stopped time delay. Actual measurement of travel time and delay, using test car technique (Sigua, 2008) and travel time, using the simulation model, were compared. Delay time was the time lost by traffic due to traffic friction, traffic control devices and geometric designs. The actual running time computed was only 36 % of actual total travel time measured, due to of travel time delay. The difference between actual running time computed and running time from the simulation model was mostly caused by vehicle speed ranges.

78.5 Achieved Results

Scenario 1: No Bridge Closures Based on the generated events file, there were 667 directed links used by agents representing the DRVs, about 6.9 % of the total 9 630 directed links in the network. The events file stored all activities of 117 agents, 67 agents represented the DRVs and 50 agents represented the other vehicles. Finally, when no bridge obstruction occurred, the DRVs coming from 86 % of the entities crossed the Carmen Bridge. For faster road traffic access, it was suggested that the Carmen Bridge be restricted to DRVs during disaster response, together with the 667 directed links.

Scenario 2: With Bridge Closures Results showed that there were 841 directed links used by agents representing the DRVs, about 8.7 % of the total 9 630 directed links in the network. Note that three bridges (i.e., Marcos Bridge, Carmen Bridge and Rotunda Bridge) were considered for road closures. DRVs originated from 90 % of entities who crossed Kauswagan-Puntod Bridge. It was thus suggested that this bridge, and the 841 directed links, would be in the running when restricting routes for exclusive use of DRVs.

78.6 Conclusions

This study showed that the simulation model reasonably represented of the real-world system, as verified and validated by the four field domain experts and results confirmed the exclusive traffic routing system through the shortest path routes generated by Dijkstra's algorithm. The results were useful tools for traffic management decision-makers when determining traffic routes for exclusive use of disaster response vehicles.

Acknowledgements The author wishes to acknowledge the guidance and information received from the developers of MATSim, Prof. Dr. Kai Nagel of VSP at the ILS, in Berlin, Germany and Dr. Marcel Rieser of Senozon AG in Switzerland. The author would also like to thank Engr. Gerardo S. Doroja for several discussions we had when implementing this model.

CHAPTER 79

Poznan

Michal Maciejewski and Waldemar Walerjanczyk

At the time of the initial scenario, Poznan (population of over 550 000), was the fifth largest city in Poland; together with the neighboring suburban area, it made up an agglomeration inhabited by nearly one million people. The MATSim scenario development for the Poznan agglomeration began in 2012, and the model has been continuously extended and improved. Currently, it is a 24-hour microscopic model of private transport, with a goal of creating a 24-hour, multi-agent activity-based simulation of the Poznan agglomeration, combining both private and public transport.

The road network model was extracted from OSM and included all roads and link roads (such as entrances or exits from motorways). The final result was a high-detail road network model consisting of 17 026 nodes and 40 129 links. This model was calibrated to determine traffic flow parameters for links (e.g., flow capacity, storage capacity, free-flow speed) for each of the 13 modeled road classes (Piatkowski and Maciejewski, 2012).

The travel demand model was derived from the official trip-based 4-stage model used by the Poznan city planning department; this model dates back to 2000, but has been frequently updated since then. Since the official model was originally designed for morning and afternoon peak hours, it had to be extended to describe travel demand throughout the day, hour after hour. As a result, demand for private transport is represented by 24 sets of hourly O-D matrices, each set consisting of nine different matrices, one for each of nine travel motivations, namely home → work/education/shopping/other, work/education/shopping/other → home, and not related to home. This adds up to 216 O-D matrices (Piatkowski et al., 2014; Maciejewski et al., 2014).

The official model divided the agglomeration into less than 400 zones, insufficient for activity locations to be accurately modeled at the microscopic level. To increase accuracy, OSM land use data was used. Six types of land use—residential, industrial, green, commercial, schools and unclassified—were used to subdivide zones into homogenous subzones. As a result, home activities were located in residential subzones, education activities at schools, shopping in residential or commercial subzones, and so on. Figure 79.1 illustrates the distribution of *home* locations when land use was taken into account Piatkowski and Maciejewski (2013).

How to cite this book chapter:

Maciejewski, M and Walerjanczyk, W. 2016. Poznan. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 469–472. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.79.

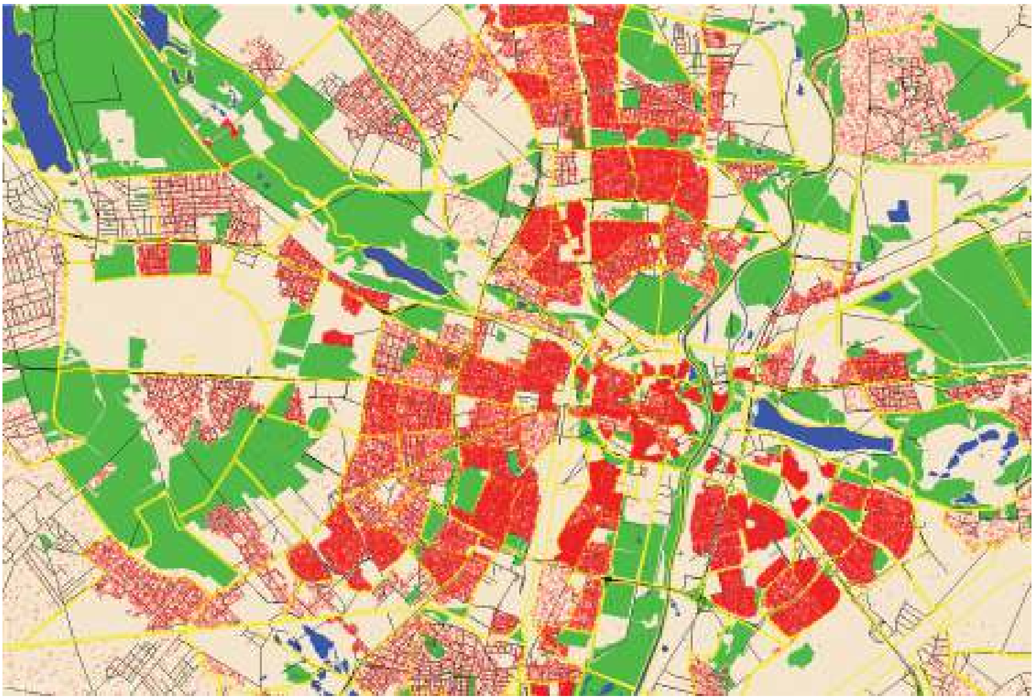

Figure 79.1: Distribution of home activities based on land use.

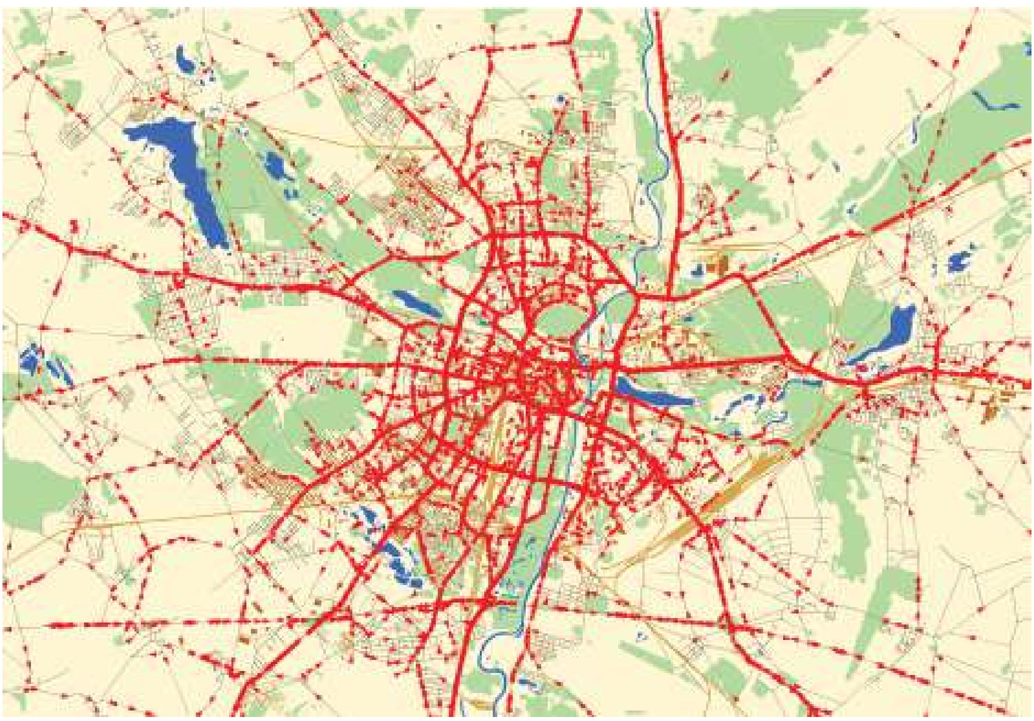

Figure 79.2: Road traffic in the Poznan agglomeration at 7 am.

Having calculated the O-D matrices for private transport and subdivided the area into homogenous subzones, the next step was to generate agents population. In the first attempt, it was assumed that each agent performed only one trip, so the number of agents equaled the demand represented by the O-D matrices, which was almost 840 000. Departure times were randomly distributed (uniform distribution) over each hour, and therefore, the only decision made by each agent during the replanning phase concerned the route choice for the preselected pair of locations. The whole simulation consisted of 120 iterations, yet it usually takes about 60 iterations to achieve a relaxed state. Figure 79.2 shows the state of traffic at 7 am.

Currently, the model is being updated according to a comprehensive travel study carried out in 2014. At the same time, the public transport system is being added, allowing for simulation of both private and public transport. The Poznan model has been used for simulation of real-time electric taxi dispatching, done through the DVRP contribution (see Chapter 23).

CHAPTER 80

Quito Metropolitan District

Rolando Armas and Hernán Aguirre

DMQ (Quito Metropolitan District, Ecuador) has grown rapidly in recent years, with increasing traffic congestion, gas emissions, pollution and energy use. Our research integrated evolutionary computation, traffic simulation, emission models and data mining tools to gain a better understanding of DMQ's complex mobility and transportation system and propose sustainable solutions.

As a first case study (Armas et al., 2014), we implemented a mobility scenario to optimize traffic lights under congested conditions. We focused on the DMQ's business district, an area covering 7x3 square kilometers, as shown in Figure 80.1. The area included only the primary and secondary pathways, where free speeds ranged from 30 to 80 kilometers per hour. The network had approximately 1 000 links and was derived from Geofabrik and OSM. 20 000 agents were simulated, each with a mobility plan consisting of three main trips: (1) home to work, (2) work to leisure and (3) leisure to home (see Figure 80.2). The plans were designed so that all agents moved first from south to north, completely crossing the geographical area of study. In their second trip, the agents moved from north to the central zone of the area under study and in their last trip, from the central zone to the south. Eleven signal lights were located on a main two-way street with flows in south-north and north-south directions (see Figure 80.1).

The evolutionary algorithm (the SOP (Signal Optimizer)) together with MATSim found optimal signal settings of the DMQ scenario, minimizing average travel time. First, we ran MATSim for 500 iterations, to ensure it reached a user equilibrium state without setting any traffic signals. After that, the SOP evolved a candidate solution population for a number of generations. Each solution represented a configuration of signals (signal control) for the transportation system. At each generation, the SOP called MATSim for each candidate solution to evaluate it. MATSim started from the equilibrium state, setting its signals controls with the tentative solution provided by the SOP and ran one additional iteration. This iteration's output was used to calculate travel time, which converted and feed back to the SOP as the fitness value. Figure 80.2 illustrates the

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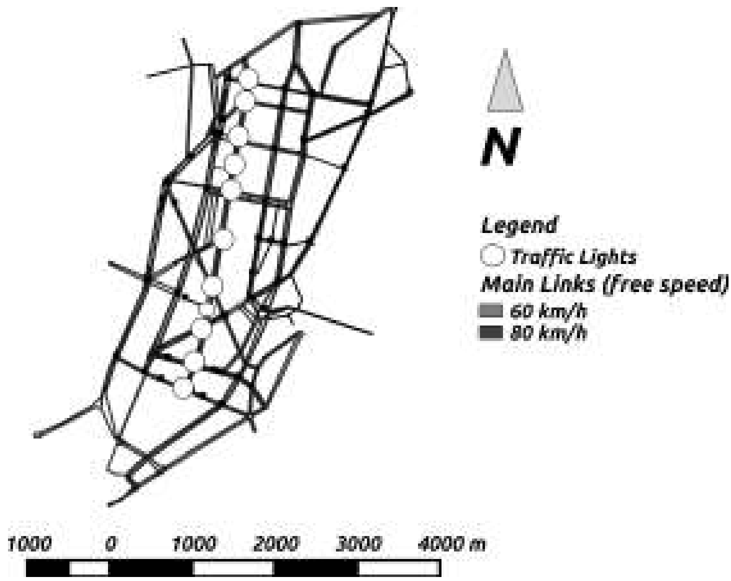

Figure 80.1: Study area.

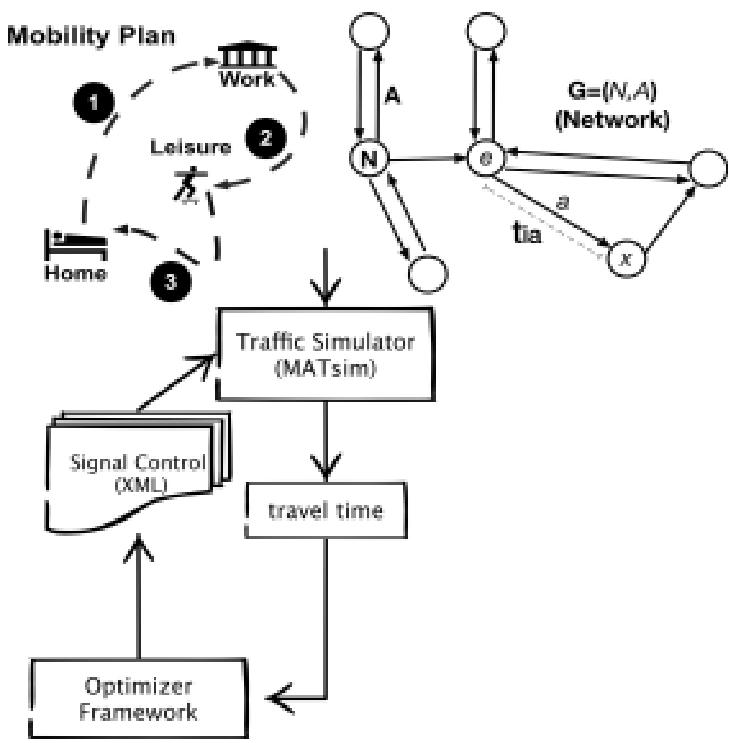

Figure 80.2: Optimization system.

interaction of MATSim and the SOP. The first case study (Armas et al., 2014) provided valuable insights into optimal traffic light setting in the business district of DMQ under congested conditions. This allowed us to validate problem representation used in the SOP and effectiveness of the mutation and recombination operators implemented to search solutions.

Currently, we are scaling up the number of traffic signals to be optimized and testing other mobility scenarios in the same area of study. Our next step is to incorporate an emissions model and use multi-objective evolutionary algorithms (Aguirre et al., 2013) to evolve optimal transportation and mobility system designs of the DMQ, satisfying multiple criteria for sustainability. These criteria include transportation and mobility policies, accessibility, reduction of emissions, reduction of energy use, as well as social and economic benefit.

CHAPTER 81

Rotterdam: Revenue Management in Public Transportation with Smart-Card Data Enabled Agent-Based Simulations

Paul Bouman and Milan Lovric

In Lovric et al. (2013) and Bouman et al. (2012), we proposed two scenarios for studying public transportation revenue management via time-based pricing strategies, like peak markups and off-peak discounts, currently being used by various transit agencies. To evaluate this approach, we developed agent-based simulations using MATSim and a transportation demand generated from smart-card data collected in a Dutch urban area. In the first scenario, we simulated only a metro network, while in the second scenario we considered a multimodal network, consisting of metro, tram and bus.[1]

In Lovric et al. (2013), we designed and implemented a decision support system for sustainable revenue management to evaluate the impact of various revenue management strategies on economic, social, and environmental performance. Figure 81.1 shows the decision support system structure built on top of the MATSim framework. Smart card transactions (individual check-in and check-out transactions made at stations' entrance and exit gates) were used to reconstruct individual passenger's daily tours. These were inputted into MATSim as initial demand; information about the transit network and vehicle schedule was extracted from the OSM data and the public transit operator's web site, respectively. Revenue management experiments were then

[1] This research was conducted at Rotterdam School of Management and supported by Netherlands Organisation for Scientific Research (NWO) Complexity Grant No. 645.000.001 awarded to Dr. Ting Li and Prof.mr.dr. Peter Vervest from Rotterdam School of Management. It was presented at MATSim User Meetings in 2011 and 2012, INFORMS International 2012 Beijing, the 7th Workshop on Agents in Traffic and Transportation at AAMAS 2012 Valencia, Erasmus University Rotterdam, Berlin Institute of Technology, Tsinghua University and Beijing Jiaotong University.

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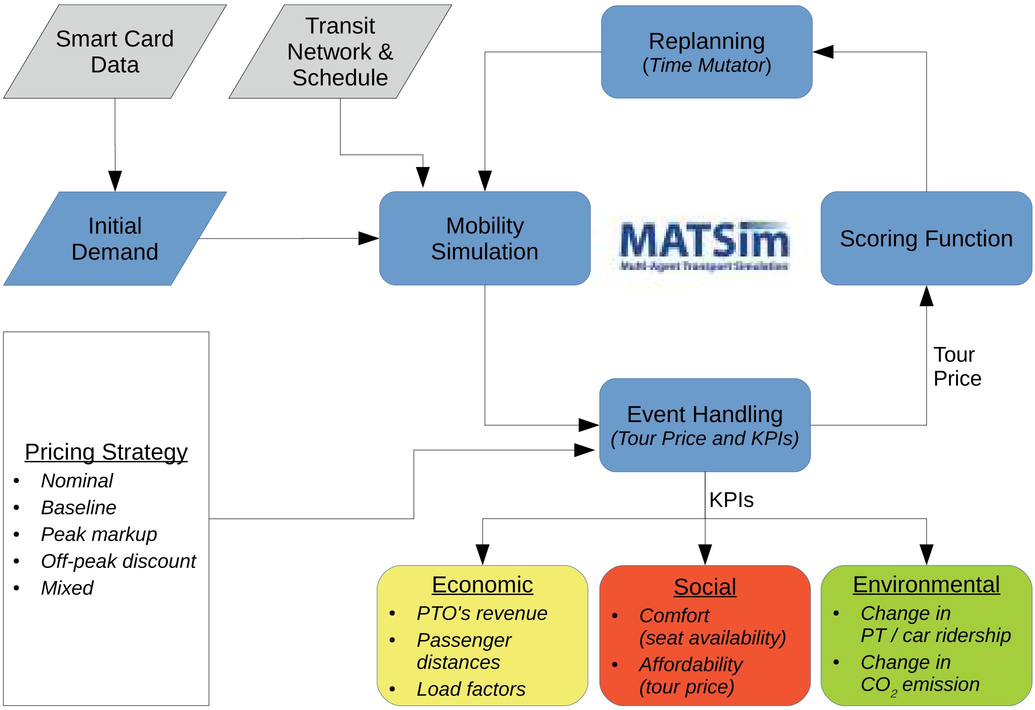

Figure 81.1: Rotterdam scenario: Decision support system for sustainable revenue management in public transportation.

conducted by applying various time-based pricing strategies defined as percentage-wise discounts or markups (applied on top of the nominal price) during specific periods of the day.

MATSim's loop (Section 1.2) was adapted for studying time-based pricing. First, an event handler was created to calculate whole daily tour travel fare for each individual (this was implemented using the real-life pricing scheme: a fixed fee applied at check-in, plus a variable distance-based fee applied at check-out). Second, we adapted the original Charypar-Nagel scoring function (Charypar and Nagel, 2005), by adding travel fare disutility. The existing MATSim's time mutator was used as a replanning strategy, allowing passengers to discover more affordable travel times when pricing strategies were enforced (however, a trade-off was introduced by applying a penalty for arriving outside the expected arrival window, based on the observed smart card data check-out times).

To capture revenue management impact on the three sustainability dimensions, we added event handlers to produce a number of relevant KPIs (Key Performance Indicators). The economic performance was measured by PTO (Public Transit Operator), passenger kilometers revenue and vehicle load factors. Social performance was measured by seat availability (a proxy for passenger comfort), calculated from vehicle loadings after the mobility simulation. We also looked at average tour price as the measure of public transportation affordability. Impact of a pricing policy on the environment was expressed as the change in carbon footprint occurring through a demand shift between public transportation and private cars (calculated from average tour price change and demand elasticity).

Our results showed that, by using a smart-card enabled decision support system and taking a customer-centric view, PTOs can better explore feasible solutions in a broader policy-making context that includes three dimensions of people-profit-planet sustainability. We validated our approach by comparing the simulation-generated travel fares in the nominal scenario with actual fares recorded in the smart card transactional database (see Lovric et al., 2013).

To further study smart card data opportunities in demand generation, Bouman et al. (2012), we introduced a pattern-based demand generation method using three different modalities' (metro, tram and bus) smart card transactions in a Netherlands urban area as input. In addition to using single day observations to generate activity-based demand, daily commuting patterns detected from longitudinal observations for a single smart card were generated. In this study, generated demands were utilized to analyze time-shifting behavior under two different revenue management policies: a plain tariff (with a fixed price per journey and a price per unit of traveled distance) and an off-peak discount. The experiment was repeated for different levels of pattern-based demand, where the varied parameter was the number of observed samples required for a smart card to be included.

In generated demand, agents not generated using pattern-based demand had to replicate their observed tour or trip within 15 minute windows of observed arrival and departure times. Pattern-based agents had time windows dependent on observed standard deviations in passengers' actual commuting travel patterns, which were used as a proxy for their time flexibility. This aspect of demand modeling was more detailed than Lovric et al. (2013), where agents were assumed to be homogeneous about their time flexibility. This flexibility was exploited by the time shift mutator, made available in MATSim as one of the replanning strategies. In future work, improvements in scoring function and use of more sophisticated pattern-based demand generation approach must be considered to create more realistic scenarios for a study of time-shifting behavior under revenue management policies.

CHAPTER 82

Samara

Oleg Saprykin, Olga Saprykina and Tatyana Mikheeva

82.1 Study Area

Samara is a major Russian city, regional capital of the Samara region, situated on the left bank of the Volga River between the mouths of the Samara and Sok rivers. The area is 466 square kilometers, made up of nine administrative districts, with a city population of 1 172 348 people (year 2014). There are more than 2.7 million people living within the city agglomeration (GKS, 2010).

Personal and public transportation are developed to varying degrees in Samara city. Automobilization of the population is 286 vehicles per 1 000 people (year 2014) (Gradoteka, 2015). Public transport consists of trams, buses, trolleybuses and subway. Transit of freight through the city is prohibited.

Samara is a major economic, transport, scientific, educational and cultural center. However, despite this, the city's street and road network is insufficiently developed, leading to the following problems.

- The street and road network has only two highways, which are connected by narrow streets; there are no transverse highways, resulting in traffic congestion. According to research from the Yandex company, Samara city was in fourth place for number of traffic jams in Russian cities (Yandex Company, 2013).
- Lack of sufficient parking areas leads to parking along city roads, creating additional traffic congestion.
- Active construction development in 2000, characterized by absence of an overall city building strategy, led to obvious violations in transport planning and significantly degraded transport infrastructure quality.
- Samara is located opposite the Samarskay Luka National Park, a region of unique natural beauty, but a destination for a huge number of summer weekend recreational trips, leading to uneven traffic flow distribution in the region.

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In addition to these problems, Samara city is currently attempting to move toward more sustainable development, which raises new challenges:

- rapid growth of residential development within the city boundaries requires transport infrastructure modification,
- formation of new neighborhoods and new cottage villages within the urban agglomeration involves the construction of new roads, bridges and interchanges,
- hosting the FIFA-2018 World Cup requires traffic management organization in the downtown, stadium and festival/fans areas.

These issues and developments require street and road network modernization, impossible without traffic flow simulation modeling to support the projects.

82.2 Transport Demand

Population residence coordinates were taken from anonymized city population spatial distribution information provided by the National Population Census 2010 (GKS, 2010). Place of employment coordinates about Samara region companies and organizations were based on data from address directories.

Statistic package R was used for O-D matrices calculation; initial data relied on collected information about population distribution and employment locations. The estimation of O-D matrices was performed by the entropy model using the Shelehovsky-Shtskiy balance method (Nurminski et al., 2014; Autodor, 2013; Shvetsov, 2003). This approach is applicable for estimation of the O-D matrices values in case worker, business or recreation trips for private vehicles or freight transport. The O-D matrix was then obtained, which showed number of agents moving from one transport zone to another.

Activity chains were calculated for define path of each MATSim agent. Activity chains calculation was performed by a custom-developed method, using the author's algorithm described in Saprykina and T. Mikheeva (2012). Activity chains calculation uses O-D matrices as source data and resulting data was kept in the plans file and used in MATSim.

82.3 Transport Supply

As shown in Figure 82.1, the road network was extracted from OSM and saved to the MATSim network format, using the `NetworkEditor` module presented in Chapter 10. Detailed verification of the obtained network model revealed that some roads have incorrect number of lanes, requiring the writing of a utility that semi-automatically allowed for adjustment of the street and road network model according to the actual transportation planning scheme. Minor model inaccuracies were corrected manually in the `NetworkEditor`. The final network model consists of 4 365 nodes and 11 178 links.

The network model should contain transport infrastructure elements for adequate transportation planning reflection. The model takes into account certain traffic signs: speed limit, traffic lanes, movement on the interceptions and "no entry". Addition of traffic lights to the model is under development now. At this point, traffic light regulation schemes at specific intersections have been developed; work on their integration into the general city model is underway.

Transport simulation was performed only for private vehicles; Inclusion of public transport to the model is in process. Bicycle paths are still poorly developed in the city; therefore, their simulation is ow-priority.

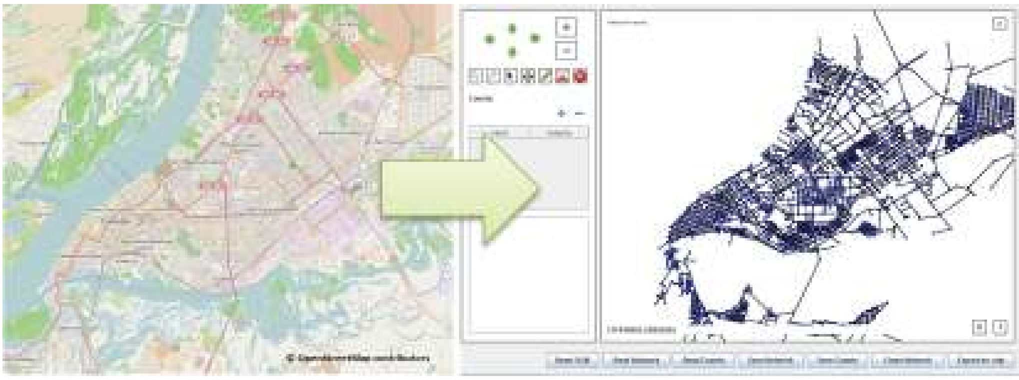

Figure 82.1: The transport network extraction process.

82.4 Calibration and Validation

For calibration purposes, information about traffic flows at all intersections of Krasnoglinskoye highway and Voljskoe highway, as well as the intersections of central (historical) part of the city, was used. Traffic flow intensity data was received for the period from 19th to 24th of May 2009. Source data required pre-processing, which consisted of vehicle number alignment according to their type and calculation of total intensity in the target area. Maximum intensity requirement was utilized because intensity measurements were performed during "rush hours" from 8 am to 11 am and from 4 pm to 7 pm (Mikheeva, 2008).

For transport infrastructure mode validation and verification of its accuracy vs. real traffic conditions in the city, the following steps were completed:

- traffic flow parameters field measurements,
- data gathered from different traffic Web-services (Yandex Maps, Google Maps, etc.),
- comparative analysis of results obtained from the simulation, field explorations and Web-services (Saprykina and Saprykin, 2014).

82.5 Intelligent Traffic Analysis

The simulation results analysis is especially valuable to solve the relevant problems. With MATSim's tools Senozon Via (Chapter 33) and OTFVis (Chapter 34), visual analysis of the model can be performed. However, a deeper understanding of the model can be achieved by applying data mining tools to simulation results to identify hidden patterns and correlations, supplying more information to address applied problems.

At this point, the simulation output folder contains files with events and actual plans, containing all actions performed by agents. For loading the data to the mathematical package R, they were converted into `.csv` format through specially designed utility and MS Excel applications. Transport infrastructure information from external sources was also imported to R as a table, containing the coordinates and types of the object. This made it possible to process the MATSim output using all power of the programming language R.

The search for hidden patterns was performed using the `NeuralNet` package installed in R. One of the goals was finding dependencies of tension at transport flows' gravity points from transport infrastructure spatio-temporal parameters. To solve this problem, a feed-forward neural network was used, trained by resilient back-propagation with weight backtracking algorithm. Source data was split into training and test sets in a 70/30 ratio. Verification was carried out by the regularity criterion (Mikheeva et al., 2012).

The study produced a trained neural network, able to predict gravity points' tension during changing transport infrastructure parameters. This eliminates the need to restart the simulation to test the hypotheses for city transport infrastructure changes, allowing an overview of changes on the fly. Figure 82.2 shows how the trained neural network displays the tension calculation process at the intersection.

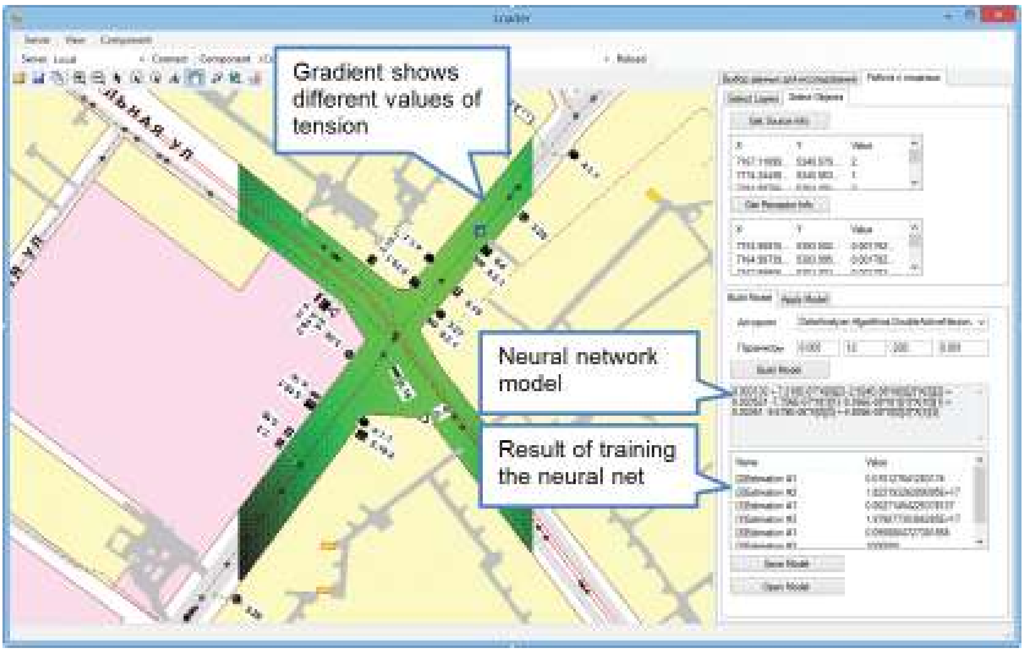

Figure 82.2: The tension calculation process by the trained neural network.

CHAPTER 83

San Francisco Bay Area: The SmartBay Project - Connected Mobility

Alexei Pozdnoukhov, Andrew Campbell, Sidney Feygin, Mogeng Yin and Sudatta Mohanty

83.1 Introduction

Novel mobility-as-a-service paradigm, enabled by ICT and mobile computing, is changing the transportation landscape faster than traditional data sources, such as travel surveys, are able to reflect. The development of on-demand transportation, the rising popularity of car- and ride-sharing services and the growing tendencies towards multi-modality pose new challenges for supply side modeling. This is particularly true in the San Francisco Bay Area (California, USA) as the influx of people and businesses to the city, volatility of job markets, evolving demographics and internal migration further increase the variability of mobility patterns evolution. It is more important than ever to be able to measure, realistically model and forecast travel demand in near real-time. The baseline scenario of the SmartBay project spans the nine counties in the area and is designed to extend the state-of-the-art in activity-based simulations in two respects. First, the SmartBay's demand model is based on the anonymized cellular network infrastructure data stream. Second, agents' population is connected to a social network and their scoring functions are tailored to study the implications social influence exerts, particularly in mode and secondary destinations locations choice.

83.2 The Study Area and Networks

The baseline SmartBay simulation implements a typical working day scenario within the nine San Francisco Bay area counties. As of 2015, total area population is 7.5 M people, with an estimated 3.4 M commuters, of whom 350 K use public transport as their only commute mode. Driving is the major mode for home to work trips, with 75 % of trips made by a driver alone. While average commute duration is estimated to be 28 minutes, severe congestion at peak hours is widespread.

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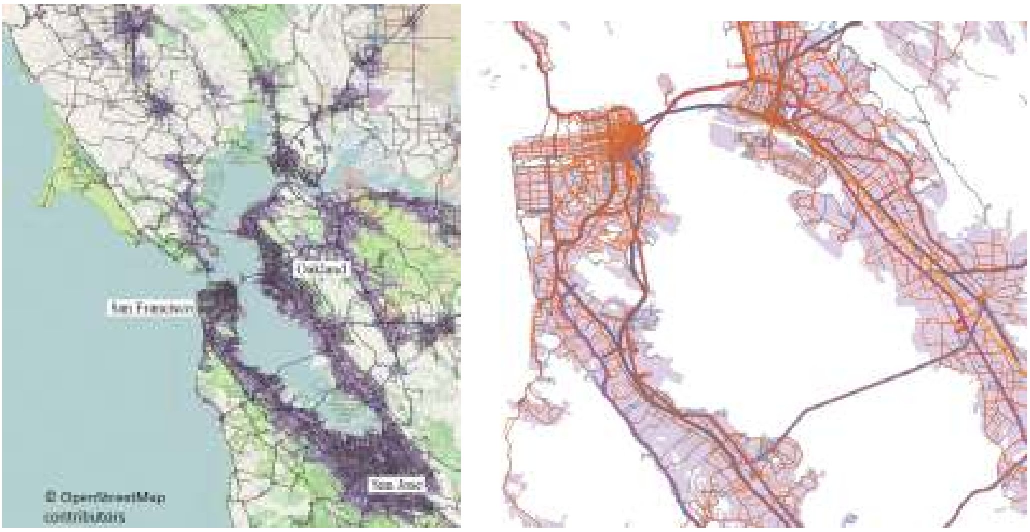

(a) (b)

Figure 83.1: The geographical extent of the SmartBay simulation (left) and a close-up view on the multimodal network spanning San Francisco-Oakland area (right).

The road network used in the scenario consists of a total of 96 000 links, with a mix of freeways, state routes, all major arterial and countryside roads. Road network geometries were extracted from the OSM data: then verified and augmented with the speed limits, capacities and number of lanes. The network was extended with all major public transit lines available through GTFS, provided by the respective agencies. There are 9 major bus agencies, several minor bus line operators, a light rail system, and commuter trains. The major rapid rail carrier is a Bay Area Rapid Transit system that serves 400 K daily trips over four inter-connected lines. GTFS includes schedules and capacities of transit vehicles.

83.3 Population and Demand Generation

There are 1454 TAZs in the area developed by the MTC (Metropolitan Transportation Commission), used as origin and destination units of a demand model developed and supported by the MTC, as well as for population and workplace projections made on a regular basis for different time horizons. The MTC model adopts the activity-based approach, with a tour-trip hierarchy of mandatory (home, work, school trips) and secondary trips, with the respective mode choices, composition of tours and departure times governed by a rich set of discrete choice models calibrated from recent California Household Travel Survey data (CHTS, 2010-2012) and inherited from other California agencies' relevant studies.

SmartBay scenarios use the anonymized cell phone data logs to adjust MTC demand models. Cell phone data are routinely collected and managed by AT&T Inc., the second largest nationwide telecom operator in the United States with 120 M users nationwide (which translates to a sample size of more than 1 M commuters in the SF Bay Area). Data used for mobility modeling originates from anonymized CDRs, recorded at the spatial resolution of the deployed cell phone towers (or antennas) and is usually available with a time latency of several minutes. Historical CDRs analysis allows detection of important places for each user based on frequency of calls, texts or data packets sent through a given cell tower (Isaacman et al., 2011; Becker et al., 2013). This approach is most robust in identifying primary locations of frequent and recurrent visits, such as home, work or school. The data is stored and processed internally at secure AT&T servers. A rescaling procedure, based on area-to-point pycnophylactic interpolation (Kaiser and Pozdnouhkov, 2013) and a variant of iterative proportional fitting was used to project aggregates from cell tower level to areal units defined by the TAZs. Population census data were used to estimate correction coefficients and adjust cell phone user counts for the total population. This adjustment resulted in an up-to-date and more accurate representation of mandatory trip O-D flows related. When compared with the MTC demand models, notable discrepancies detected include new urban developments, as well as major shifts in employment re-distribution due to the fast IT sector evolution in Silicon Valley.

83.4 Work Commute Model Evaluation

MATSim instance was deployed on AT&T servers to simulate the home-to-work commute scenario for a typical weekday. Scenario runs with 15 % to 30 % commuting population sample were evaluated (550 K to 1.1 M agents). Driving and public transit were set as the only modes; mode share at the beginning of the mode re-planning in MATSim was set according to MTC findings from CHTS. Resulting link volumes were validated based on hourly traffic counts collected by California Department of PEMS (Transportation Performance Management System) inductive loop detectors, deployed on all major freeways. Sample count histograms are presented in Figure 83.2. The model met the Federal Highway Authorities accuracy specifications.

83.5 Extensions and Work in Progress

Main extensions developed in the SmartBay project are related to simulating a population explicitly connected to a social network; current work is directed toward two domains. First, an extension of location choice is approached with machine learning tools that model social influences in destination choices for secondary activities and the second extension introduces social connections to scoring functions and aims to capture peer pressure effects in mode choices.

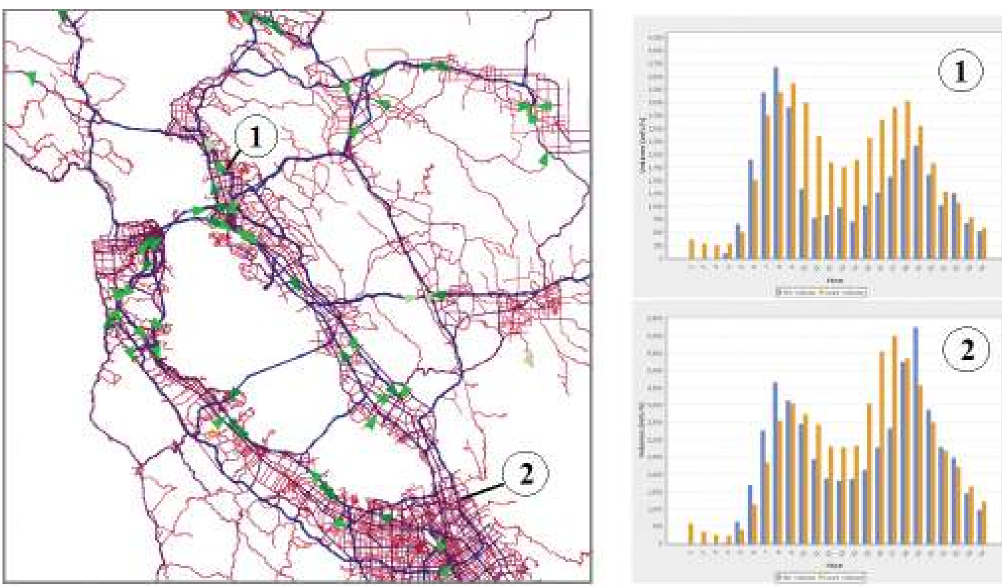

Figure 83.2: A sample of the simulated vehicles and the examples of the observed (light/orange) and simulated (dark/blue) counts at two particular validation locations. Secondary trips, mainly occurring at midday, were not included in this scenario.

Social Influence in Destination Choice There is evidence that population social network geography in an area is a strong predictor of destination choice for secondary trips. This is valid both for trips directly related to social activities, as well as when destination choice was conditioned by recommendations received from peers in the past. As such, this provides a way to use machine learning-based approaches for predicting destination choice from historical data and social ties. This approach requires building a social connections model for the virtual agent population, i.e., defining a weighted graph with edges P_{ij} for each pair of agents i and j. Our preliminary work is based on the model proposed in McGrath and Pozdnoukhov (2014) and is applied at the home level TAZs, instead of an individual. This approach requires a seed network to be derived from the cell phone CDRs, with the weights P_{ij} emphasizing recurrent reciprocal calls, as evidence of a social tie between i and j. The seed network is then removed from the model, resulting in a connected virtual population with similar network statistics that replicates the geographical community's real social network structure in the area.

SmartBay currently adopts the MTC secondary activities classification that includes eight categories for non-mandatory trips. There are 120 K venues derived from the `Factual.com` API, introduced to the simulation as destinations for secondary trips. Hierarchical spatial clustering was applied to the venues set to reduce the number of venues to 1 200. This approach is justified both by the need to reduce computational expenses in the re-planning stage, as well as evidence of spatial hierarchies in human spatial cognition and decision making. A spatial choice model for the secondary home- and work-based trips is calibrated from the CDRs, using the McArdle et al. (2014) approach. A key parameter set in this model is the attractiveness of agent venues, which is assumed to be proportional to the number of peers who also visit the venue. A thorough experimental validation of the full-scale scenario, with secondary trips, is computationally expensive and is ongoing.

Social Influence in Mode Choice The following extension to the conventional Charypar-Nagel scoring function is considered:

$$U_i = U_i^{CN} - \gamma \sum_{j=1}^{N} P_{ij} \left\| a_i - a_i^0 \right\| + \theta \sum_{j=1}^{N} P_{ij} \left\| a_i - a_j \right\|$$

Here, an agent specification is extended with an attribute vector a_i, describing an agent's profile as it relates to membership in a particular group (such as drivers or transit users). We define attribute components as continuous within [0, 1] interval, corresponding to an agent's tendency to drive or take transit as his/her primary commute mode. This attribute value is also used to define the probability of the current plan's primary mode choice to be selected for mutation in the evolutionary optimization re-planning step. U_i^{CN} represents the Charypar-Nagel score of the daily plan, augmented with two terms. The first term describes peer pressure effect toward a pre-specified "socially-responsible" choice a_i^o. The second term describes an agent's tendency to behave similarly to his/her immediate peers in regard to choice attributes. As these two effects appear only with evidence of a social tie, both terms include a summation over the agent peers, with connection strength P_{ij} defined as described in the previous subsection. The resulting mode choice sensitivity to parameter values γ and θ is determined through currently ongoing computational experimentation.

83.6 Conclusions and Acknowledgments

An increasing pace of urbanization severely tests city infrastructure systems. The transportation field is responding to these global challenges by evolving at an ever-increasing pace. More flexible and powerful tools are required to support decision making in planning, operations, and policy regulation applied to emerging mobility technologies. SmartBay project has developed a MATSim-based platform capable of ingesting demand models based on big data and extending the utility functions specifications to study social influence on mobility behaviors. It also incorporates semi-parametric machine learning models applied to destination location choice predictions for socially-related secondary trips. With encouraging results obtained in baseline scenario simulations, these advanced developments are currently ongoing.

The authors acknowledge the contributions from our collaborators at AT&T Research: Dr. J.-F. Paiement, Dr. J. Pang, Dr. A. Skudlark, Dr. C. Volinsky. Funding support from State of California Department of Transportation (CalTrans) through UCCONNECT faculty research grant program, agreement 65A0529, is also acknowledged.

CHAPTER 84

Santiago de Chile

Benjamin Kickhöfer and Alejandro Tirachini

84.1 Introduction

This section describes the creation process of the freely available MATSim scenario of Santiago de Chile. The first version of a calibrated scenario is available online[1] and is documented in Kickhöfer et al. (2016). For the scenario setup, three open data sources are used: (i) car network information from OSM (OpenStreetMap), (ii) PT (Public Transport) supply data from GTFS (General Transit Feed Specification), and (iii) travel diaries from Santiago's 2012 Origin-Destination Survey.

Multiple interventions in Santiago's transport system in the past 20 years make this city an interesting case study for the analysis of alternative transport policies. Santiago has a Metro (subway) network of five lines over 104 kilometers, with two new lines to be launched in 2017 and 2018, adding 37 kilometers to the network. In the city, there is a full-scale integrated public transport system launched in February 2007—the Transantiago system (Muñoz et al., 2014), which has fare integration between all urban buses and the Metro through the use of a single prepaid (smartcard) payment method. There also exists a network of 200 kilometers of tolled urban highways. In winter, the air pollution problem is tackled, in part, by introducing plate-number based car driving bans on the most polluted days. All these elements make Santiago an appealing case study for the application of a metropolitan-scale transport and activity simulator.

[1] See https://svn.vsp.tu-berlin.de/repos/public-svn/matsim/scenarios/countries/cl/santiago/ or search from http://matsim.org/datasets.

How to cite this book chapter:

Kickhöfer, B and Tirachini, A. 2016. Santiago de Chile. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 491–494. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.84.

Figure 84.1: 2012 ODS study area and zones, adapted from SECTRA (2014).

84.2 Data

84.2.1 The 2012 origin-destination survey

The travel demand and activity patterns of the MATSim Santiago scenario are based on the travel and activity data collected in the 2012 Origin-Destination Survey (ODS), whose database and results were released to the public in March 2015.[2] The surveyed area encompasses 45 *comunas* (municipalities) of the Santiago Metropolitan Region, with an estimated population of 6.65 million people. The survey goes beyond the Great Santiago Area to include the neighboring municipalities of Colina, Lampa, Pirque, Calera de Tango and Melipilla. The total area has 2 million households with an average of 3.24 persons per household. The sample size is 18 000 randomly chosen households along 866 zones that were defined for the survey. Figure 84.1 shows a map of the survey area and zones. The Great Santiago Area is highlighted by an ellipse, in which 91 % of the population is concentrated.

It is estimated that, on a normal working day, there are 18.5 million trips, from which 38.5 % are by non-motorized means (walking and cycling). Around 25 % of the total trips are made using the Transantiago public transport system, out of which 52.4 % are bus-only trips, 22.2 % are metro-only trips and 25.4 % are combined bus-metro trips. Car travel has a modal share of approximately 26 % of the total trips.

In total, 60 054 individuals were interviewed in the 2012 ODS, with a total of 113 591 trips. Omitting all individuals that do not have two activities plus one connecting trip reduces the sample size to 42 459 synthetic agents (70.7 % of all interviewees). Therefore, considering the population of the whole metropolitan area of the sample (6.65 million), the MATSim synthetic population represents

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[2] The survey form, reports and full database are available at the website of Chile's Transport Planning Office (SECTRA), `http://www.sectra.gob.cl/biblioteca/detalle1.asp?mfn=3253`, accessed 16 August 2015.

approximately a 0.65 % sample, with agents performing activities of the following types: home, at work, work-related, education, health-related, visit someone, shopping, leisure and other.

84.2.2 Road network and public transport supply

The source data for the MATSim Santiago road network is taken from OSM. The source data for the Transantiago PT routes and departure times/service frequencies at the stops over time-of-day is a GTFS file[3], published and continuously updated by Santiago's Metropolitan Public Transport Authority (Directorio de Transporte Público Metropolitano, DTPM). The GTFS file includes all bus and Metro services.

From the MATSim transit schedule, a pseudo transit network is created along with the transit vehicles. This transit network connects—for each transit line—the stops directly to each other. It is not connected to the car network, and only follows the car network's geometry where the resolution of transit stops is high (i.e., where a transit line has a stop at every corner). In consequence, cars and buses run in separate networks; as a result it is currently not possible to analyze, for example, cross-congestion effects between modes. Nonetheless, current congestion patterns of PT are exogenously included, since bus travel times are set to be larger in peak periods, calibrated using historical data from buses that are equipped with GPS devices.

84.3 Setting up the Open Scenario

84.3.1 Scenario specifications

By converting the input data into MATSim format, several files are generated to run the simulation. Since there are no data restrictions, these files are provided as an open scenario.[4] The code for obtaining this data from the input data is also publicly available.[5] Behavioral parameters are taken from a study by Munizaga et al. (2008) and converted into MATSim parameters (Kickhöfer et al., 2016). When performing mode choice, in the present version of the model, agents are only allowed to switch between the transport modes car, PT and walk. Trips performed by any other mode (bike, colectivo, other, ride, taxi, train) remain fixed but can be included in the choice set in future versions. PT captive users are taken into account since agents are only allowed to use a car if they have access to a car according to the survey data. Otherwise their only options are PT and walk. The attributes of the three different modes considered in the present study are travel time (car, PT, walk) and monetary costs (car, PT). Travel time for car trips is a direct output of the simulation where vehicles interact on the road network. Hence, the car travel time also includes road congestion. Travel times for PT results from the GTFS data (station-to-station travel times including transfer time) plus access and egress times done by the walk mode. Hence, the PT travel times do only partly include road congestion, i.e., as long as it is approximated correctly by the schedule, which uses longer travel times in peak periods. Travel times for walk are approximated by teleporting agents between their activities q and $q+1$ with a travel time of $t_{trav,q} = \frac{1.3 \cdot d_{trav,q}}{4.0\ km/h}$, where $d_{trav,q}$ is the beeline distance between the two activities.

Travel times for all other transport modes are approximated by congested car travel times (for colectivo, other, ride, taxi) or by teleportation similar to the walk mode (bike, train) with different

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[3] See http://datos.gob.cl/dataset/1587, accessed 13 August 2015.

[4] See https://svn.vsp.tu-berlin.de/repos/public-svn/matsim/scenarios/countries/cl/santiago/ or search from http://matsim.org/datasets.

[5] Currently, see https://github.com/matsim-org/matsim/tree/master/playgrounds/santiago/src/main/java/playground/santiago.

teleportation speeds (10.0 and 50.0 km/h, respectively). Monetary costs are also approximated. However, as long as switching from/to these modes is not allowed (see next paragraph), this essentially has no effect on simulation results.

84.3.2 Calibration/validation

The Alternative Specific Constants of the different modes are determined in the calibration process. The procedure to run the first simulation with 200 iterations, together with the calibration of the constants is explained in Kickhöfer et al. (2016).

Another standard verification of MATSim simulation output is the comparison of traffic flows to data from real-world counting stations. 49 counting stations are available within the Santiago greater area, 40 on major roads, 9 on (parallel) local roads. The counts data is recorded in July 2011. After cleaning the data, 36 counting stations remain with data from 6:00 am to 11:30 pm in 15 minutes time bins. MATSim traffic output versus observed traffic is analyzed in Kickhöfer et al. (2016), which indicates the need for further calibration efforts once the population is expanded to a 10 % or 100 % sample.

84.4 Conclusion and Outlook

This section summarized a MATSim scenario set up from input data that is open and publicly available. This makes the scenario an interesting tool for transparent decision making of public administrations, for advancing transport modeling and policy research as well as for stimulating innovation activity of the private sector. Possible applications include the (economic) evaluation of planned transport policies and projects and the development of business ideas based on the simulated mobility of individuals in Santiago. A number of future model improvements to be implemented in the scenario are provided in Kickhöfer et al. (2016). A non-exhaustive list of potential research problems to be analyzed with the MATSim Santiago scenario is the following:

- the effects of road pricing strategies on travel times, traffic volumes, public transport and demand for non-motorized mobility, air pollution, noise levels, etc.,
- the introduction of alternative interventions such as (full or partial) pedestrianization of the city center, speed limitations, roads with exclusive right-of-way for public transport, plate-number based car driving restrictions, parking restrictions, road closures and road openings, restrictions on truck traffic, new cycleways and new Metro lines, and
- the extraction of accessibility measures to study the land use impacts of transport interventions.

CHAPTER 85

Seattle Region

Kai Nagel

A MATSim model of the Seattle region—more precisely the PSRC (Puget Sound Regional Council) area—was developed during K. Nagel's sabbatical stay with the UrbanSim team in Seattle in 2008. The model resulted from a prototypical integration of the UrbanSim software (e.g., Waddell et al., 2003) with MATSim.

The base was an existing PSRC UrbanSim model, which used an established EMME/2 model as a travel model. The investigation centered around how difficult it would be to replace the EMME/2 model with MATSim.

The network was taken, by conversion, from the existing EMME network, resulting in 15 478 links and 5 025 nodes with attributes length, free speed, and capacity.

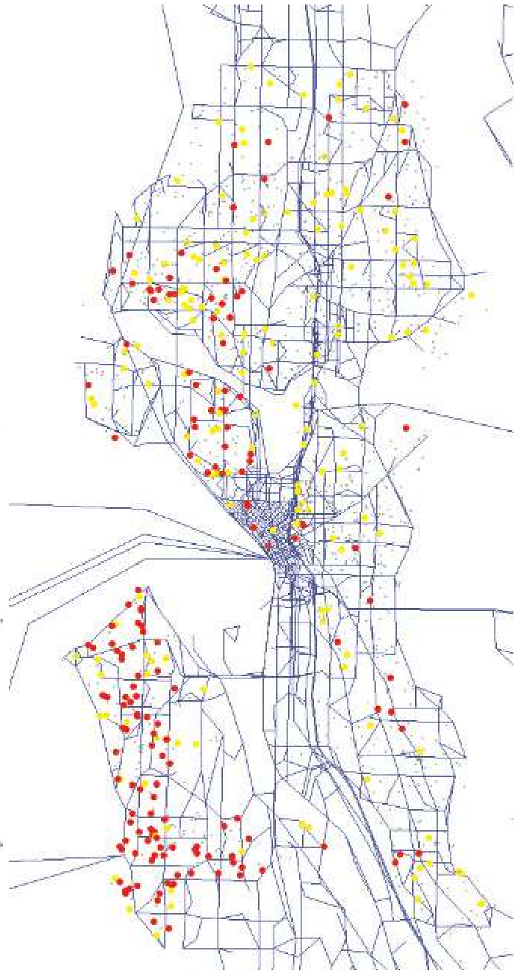
Demand was generated as output from UrbanSim. Evidently, the UrbanSim simulation already contained a full synthetic population. The UrbanSim model was also set up with workplace choice, so that each synthetic person with "working" status had a workplace assigned. Since that version of UrbanSim worked on the parcel level, this meant that home-to-work trips could be extracted directly, with coordinates, from the model. As so often for initial MATSim studies, this home-to-work demand was then extended to home-work-home plans.

The configuration used standard MATSim scoring parameters: a 7 am workplace opening time and latest work start time of 9 am. The iterations were run with re-routing and time mutation enabled until convergence. Since this was an exercise in rapid prototyping, only a 1 % sample of the full synthetic population was used; road network flow and storage capacities were scaled down accordingly. Figure 85.1(a) shows a result. Figure 85.1(b) shows households most affected by a hypothetical closure of the Alaskan Way viaduct, which traverses the Seattle downtown area on the waterfront side to the west.

How to cite this book chapter:

Nagel, K. 2016. Seattle Region. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 495–496. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.85.

(a) Simulated congestion patterns in Seattle at 7:30 am



(b) 10 % households most affected by closure of the so-called Alaskan Way Viaduct (in red)

Figure 85.1: Seattle region scenario.

CHAPTER 86

Seoul

Seungjae Lee and Atizaz Ali

The MATSim model of SMA was developed in 2012, as a result of long-term research collaboration between the University of Seoul (Prof. Seungjae Lee) & ETH Zürich (Prof. Kay W. Axhausen). The model was updated yearly and demand was generated based on 2012 HHTSD. Demand statistics (input) are summarized as follows.

Study area was the SMA (Gyeonggi-do province, with emphasis on the Seoul Metro, comprised of 25 main administrative districts). A population synthesizer was developed to generate the MATSim input demand, based on HHTSD 2012. Total population of SMA was 21.5 million; therefore, a 10 % sample was generated and simulated (2.15 million agents). A detailed nodes and links network was generated, capturing all details (16 384 nodes and 32 768 links) for railways, highways, arterials, pedestrians, expressways and bus-only lanes. EMME/2 network was converted to MATSim format. The 2012 Korean Transport Database was utilized to generate transit schedules and vehicle definitions, according to bus types, railway and metro lines. Total number of routes was 1 317 (contained regional buses, inter-city buses, feeder line buses and metro lines, etc.). In collaboration with Senozon AG, a more realistic door-door demand was generated in Seoul City in July, 2014. Data source was the Korean GIS department.

In Seoul, MATSim has been widely used for various research purposes to aid policy evaluation Kim et al. (e.g., 2012); Lee and Ali (e.g., 2014).

A master's thesis on transit demand generation and calibration using smart card data in SMA is currently underway by this chapter's second author, sequenced as follows. A video is available from the authors on request:

- data mining (trimming off non-useful data),
- converting disaggregate transactions (O-D) to individual trips and trip segments based on user ID,
- activities inference and assignment in SPSS (Statistical Package for the Social Sciences) database,

How to cite this book chapter:

Lee, A and Ali, A. 2016. Seoul. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 497–500. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.86.

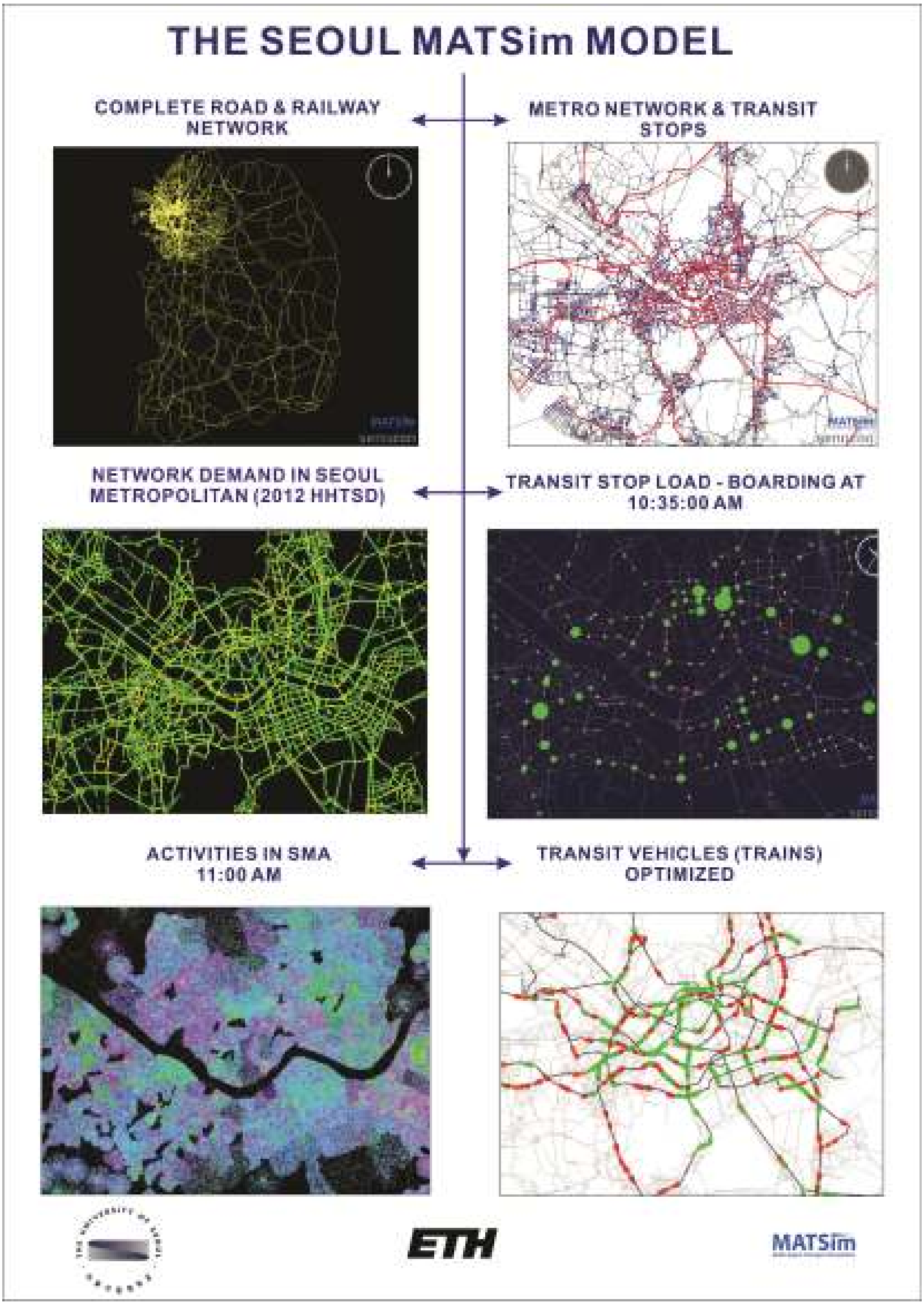


Figure 86.1: Seoul scenario.

- generating transit demand (MATSim input format),
- updated transit network & schedule for running the simulation, and
- model calibration (in process).

MATSim tutorials were also presented during the fall semester 2014 to help Department of Transportation Engineering undergrad and grad students gain a thorough working knowledge of MATSim.

CHAPTER 87

Shanghai

Lun Zhang

Shanghai, with a population of about 20 million and 6 073 square kilometers land area, is the biggest metropolis in China. To fully integrate activity-based demand modeling and further public transport models, the full implementation of MATSim for Shanghai was built to forecast precise traffic demand on network, as well as scientific policy evaluation. The scenario contained 200 000 synthetic persons, simulated on a network with 50 000 links. Shanghai scenario key features are as follows.

A 1 % sample of the actual population, about 0.2 million agents, was used. To generate the population individual with personal attributes, the Monte Carlo method was used to disaggregate available census data from the 4th Travel Survey of Residents.

Demand generation was based on 24 hour O-D matrices generated from the GPS data and synthetic population; the O-D were then disaggregated into individual trips. The activity-based modeling was used to generate initial population plans in five steps: activity chain choice, duration choice, mode choice, destination choice and route choice, where the MNL model was used to estimate and serialize choices of agents. During the simulation, activity replanning were introduced to discern better travel plans; while scoring for a plan was modeled using a utility-based approach.

The Shanghai street network was extracted from the overall OSM network and then merged with the Shanghai expressway network. Road attributes, such as number of lanes per direction, or flow capacities, were set through road classification specification. To simplify the original network, optimization rules were designed to remove unneeded information that increased computational burden.

All facilities from O-D pairs were classified into particular zones using their geographical coordinates. Three main facilities types, home, work/education and leisure, are used. Origin and destination facilities' names were obtained via reverse geocoding; these facilities are classified by their names. The unit resolution of facilities was the hectare, in which facilities and types are randomly created according to their coordinates.

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Simulated modes were as follows. A public transport system, subways and buses, was integrated with both motor traffic and non-motorized traffic. Transit schedules were considered for public transport. A travel time based transport mode choice model—between car and public transport—was developed.

Activity replanning was used to optimize activity plans of agents; stable simulation system state was reached after 100 replanning procedures iterations. The effectiveness of the Shanghai MATSim transport simulation model was validated against observed counts from vehicle detectors and mode split from travel surveys. Extensive simulation results indicate that most traffic simulation volumes matched quite well with observed counts, which demonstrated MATSim's potential for large-scale dynamic transport simulation. It provides researchers and policy makers with a useful tool to evaluate traffic policies.

Specific algorithms integrating new data in Shanghai with MATSim inputs, such as synthetic population, facilities and network, were separately designed according to data characteristics. To see more detailed work about the Shanghai scenario, please see Zhang et al. (2014).

CHAPTER 88

Sochi

Marcel Rieser

Major sport events usually attract huge crowds of spectators, as well as media reporters, necessitating numerous official helpers in various locations to guide and support attendants; naturally, all athletes must also be at the right place at the right time. For large, international contests like Olympic games or soccer championships, accommodations are rarely close to the event facilities, making it necessary to transport spectators, media, helpers and athletes efficiently over long distances. As such events typically run for multiple days, or even weeks, with ever-changing combinations of locations and times where actual competitions take place, substantial planning is required to ensure that all attendants and participants reach their event locations in time.

Masterconcept Consulting GmbH (Gesellschaft mit beschränkter Haftung), an Austrian consulting company, has positioned itself to provide high-level concepts for large sport events. To better serve its clients, it developed ITSOS (Intermodal Transport Simulation & Operation System), a GIS-based system to support its transport planners in the creation of mobility concepts for major events, as well as regional planning. When simulating the planned events, ITSOS depends heavily on MATSim to verify that special infrastructure at major events can handle transport within required time frames, to and from specific event locations.

Senozon AG was responsible for integrating MATSim with ITSOS and adding ITSOS-specific functionality to MATSim. Together, they created a test scenario depicting the 2014 Olympic winter games in Sochi.

88.1 System Overview

ITSOS used ArchGIS for storing and editing infrastructure data, like road and train networks and event facilities. A custom plug-in also provided a graphical user interface inside ArchGIS to specify transit routes and schedules, vehicle types and their assignments to lines and departures, as well as methods describing expected travel demand. Transport planners could create and manage scenarios and scenario variants directly from the custom user interface available inside ArchGIS.

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After successful modeling of a scenario in ArchGIS, a planner could export the network and transit schedule in MATSim's XML format directly from ITSOS to a local directory. The travel demand information, consisting of activity-chains, with zone- or facility-references and number of persons having such a chain, was exported as tabular information. A special program created a MATSim population file from this tabular data, along with a default config file.

The user could then start the MATSim simulation, using a simple bat-file on Windows. After the simulation ended, events were preprocessed and imported into a database, from which they could be queried and used within ArchGIS for analysis and visualization purposes.

88.2 Extensions to MATSim

The various groups at major sport events require different handling; in addition to athletes, there are media reporters, officials, helpers, caterers, and, of course, many spectators. Persons from different groups attending the same event will have different requirements about when to be at the event location, what entrance to use for the event location and the kind of transport necessary to reach the location. For this reason, supporting sub-populations for replanning and scoring was an important issue. Different transit offerings were also defined for different agent groups, because spectator mass transport must usually be separate from athlete and official transport.

To facilitate transport planners' work, transit lines in ITSOS were defined with adaptive schedules; given a base headway, additional departures were scheduled between iterations, if high occupancy was expected to occur on a line during specific hours. This adjustment was based on a rule set that ensured a minimum duration for the shorter headway, as well as a minimum duration for the base headway between the shorter headways. Figure 88.1 shows the graphical schedule of an adaptive transit line after 80 iterations.

In addition to private car traffic and schedule-based public transport, athletes, media and officials also use special transportation offerings: shuttle buses, or even limousine services operating on demand, between only two or more fixed locations. Termed "transit on demand" in ITSOS, transit lines with stops along a route were defined, but without scheduled departures. Instead, a within-day-like operator was implemented, scheduling vehicles whenever someone from an agent group wished to depart. The rule-based operator had additional constraints, like minimum occupancy of on-demand vehicles before departure (to prevent every on-demand vehicle transporting only

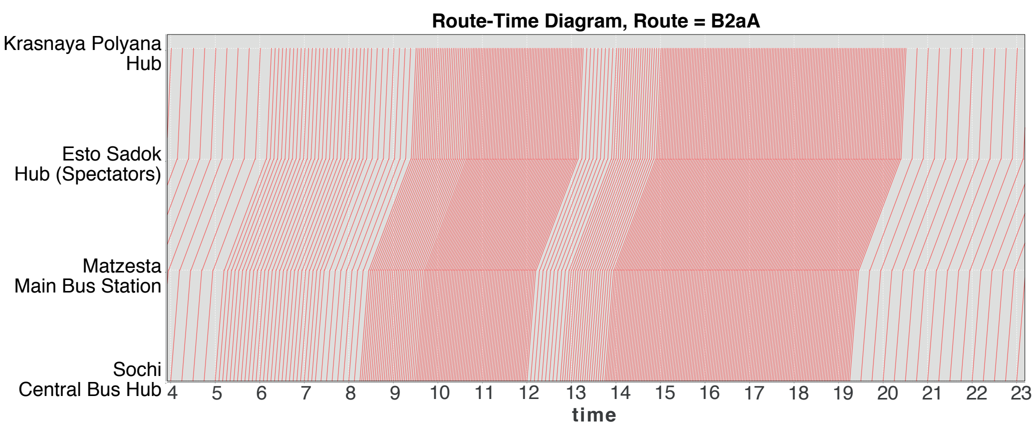

Figure 88.1: Bus schedule with automatically adapted headways based on simulated demand for bus line from Sochi (Central Bus Hub) to Krasnaya Polyana (Hub).

Figure 88.2: Simulated pedestrians (red circles) at Krasnaya Polyana hub. Transit vehicles (incl. cable cars) shown as green boxes, transit stops as blue circles.

a single agent), as well as a maximum waiting time before departure for such vehicles (to prevent agents in remote locations having to wait forever).

At sport events, large number of spectators have to share both common entrances to event facilities and common access paths to those facilities. This made it necessary to simulate more detailed pedestrian flows (in certain places) than just the default teleportation approach typically used by MATSim. For Olympic games, this was even more crucial because, in several locations, security checks created additional bottlenecks. This requirement was solved by implementing a special router for the walk mode, along with a custom departure handler. The router tried to find a path on the network for walk legs, assessing distance from the closest walk link to/from a facility to decide if the link functions as an access to the facility or not. If no nearby link was found, or no route found between two access links, an empty route was stored in the leg. The departure handler checked whether the route was empty or not, either teleporting the agent or putting it on a walk link in the network. Walk links are regular queue-based network links with capacity and free-speed set, according to the simplified physics of directed pedestrian flows. This approach readily allowed modeling of security screening gates' bottleneck effects and considered essential walk path locations where necessary. These were modeled, omitting them on non-critical routes. Figure 88.2 shows an example of simulated pedestrian movements at Krasnaya Polyana, the mountain area near Sochi where numerous events took place.

88.3 Simulation of Sochi

To test ITSOS applicability for major events transportation planning, a model of the 2014 Olympic winter games in Sochi (Russia) was built. Data was either collected either by Masterconcept employees or cooperating companies, or received from Russian governmental institutions.

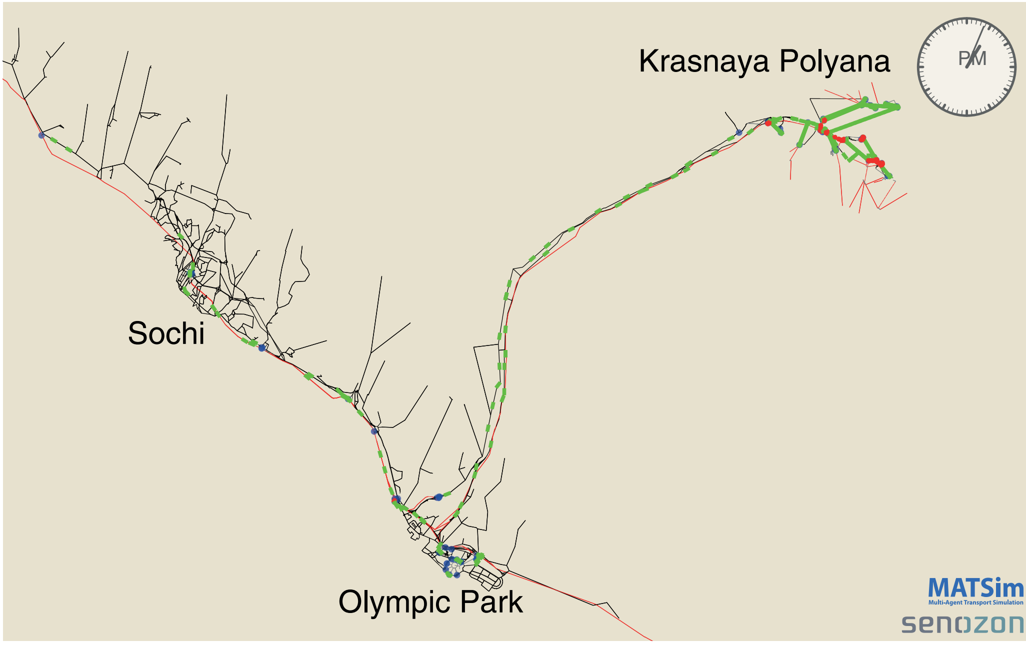

Figure 88.3: Overview of the Sochi model.

Road and train networks were modeled in ArchGIS, using the ITSOS extensions. The transit schedule included 55 transit lines, a mix of bus lines, train lines, and cable cars, going up into the mountain areas. 24 of those lines were defined to be adaptive, 19 lines operated on-demand as shuttle services.

Travel demand was defined for each day of the games, based on the actual schedules, making assumptions about how many spectators would visit each different competition during the day. While size of event facilities can be used as a upper limit for number of spectators, substantial experience and knowledge from Masterconcept was used to define actual numbers of people expected at each event.

Events often start and end at different times of day, because many event locations share, at least partially, a common route to reach them; it was important to simulate whether the transport services offered could cope with the combined travel demand generated by multiple, separate events.

A typical simulation run of Sochi included about 150 000 agents. To speed up simulations, parallel events handling and parallel qsim was used. The simulation generated around 15 million events per iteration. Figure 88.3 shows a screenshot of the Sochi scenario, visualized in Via.

88.4 Outlook

In addition to the test case of the 2014 Olympic winter games in Sochi, ITSOS/MATSim was also used to simulate traffic in St. Johann (Pongau, Austria), with particular emphasis on pupils, who often must take a combination of buses and trains to get to school.

A new company, Masterconcept Mobility GmbH, was split off from Masterconcept Consulting GmbH in 2014; this new firm offers major event transportation planning services, as well as regional planning services based on the combination of ITSOS and MATSim.

CHAPTER 89

Stockholm

Joschka Bischoff

The Stockholm scenario was created as a student project at TU Berlin in summer, 2014. Because several groups worked on the project, the common base was a census data synthetic population, an OSM-based network and counts data.

The network was taken from OSM 2013 data. Within the city, all roads were used; in outlying regions, only mayor roads were included in the network. Demand consisted of home-work-home-plans only. The population sample size was—depending on the student group—between 1 and 5 %. Agents used car and (pseudo) public transit.

Count data for the morning peak along a mayor road, the E4, was used to calibrate the scenario. This calibration was handled differently by the groups; some just added traffic, others tried to imitate the Stockholm toll. Further scenario documentation is available in German.

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Bischoff, J. 2016. Stockholm. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 507–508. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.89.

CHAPTER 90

Tampa, Florida: High-Resolution Simulation of Urban Travel and Network Performance for Estimating Mobile Source Emissions

Sashikanth Gurram, Abdul R. Pinjari and Amy L. Stuart

90.1 Introduction

Mobile sources are significant contributors to ambient traffic-related air pollution associated with adverse health impacts in urban areas. Thus, it is important to accurately characterize mobile source emissions and population exposure to those emissions; this requires a high-resolution simulation of urban travel. In this study, using activity-based travel demand modeling and MATSim-based dynamic traffic assignment modeling, we demonstrate a large-scale, high-resolution simulation of resident population travel activity and highway network performance in Tampa, Florida. Such high resolution simulation outcomes are useful in estimating mobile source emissions and human exposure to those emissions.

90.2 Study Area

Hillsborough County, a large section of the Tampa Bay region in Florida, is our study area. The county's geographic context is presented in Figure 90.1. The freeway road I-275, acts as a major commuter corridor connecting the area north of Tampa to the central business district to the south. The freeway roads I-75 and I-4 run north-south and east-west, respectively, and serve as major highways for intra-city, inter-city and inter-state travel. The county has a diverse mix of air pollution sources and population demographics, few public transportation options, an unsatisfactory air quality record and a sprawling urban form. These make it an interesting test case from an air pollution perspective.

How to cite this book chapter:

Gurram, S, Pinjari, A R and Stuart, A L. 2016. Tampa, Florida: High-Resolution Simulation of Urban Travel and Network Performance for Estimating Mobile Source Emissions. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 509–514. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.90.

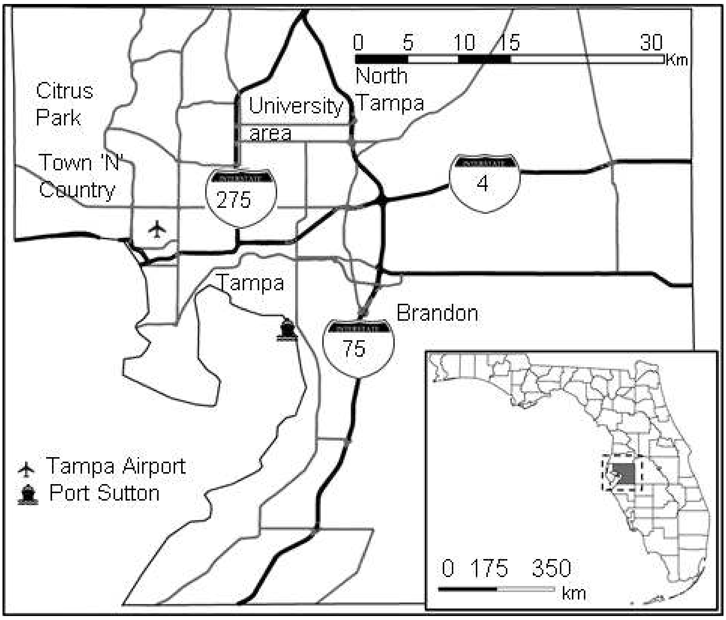

Figure 90.1: The study area of Hillsborough County, Florida.
Source: Gurram et al. (2015)

90.3 Modeling Framework

Figure 90.2 depicts the modeling framework used to simulate urban population activity and transportation network performance for the study region. An activity-based model (ABM) of travel demand (DaySim) is coupled with MATSim, here applied as a dynamic traffic assignment (DTA) model. The DaySim framework was originally developed for the Sacramento region (Bradley et al., 2010) and calibrated for the Tampa Bay region, using local household travel data (Gliebe et al., 2014). An appealing feature of DaySim is its use of fine, parcel-level representation of space, which leads to high spatial resolution in the simulated activity locations. Similar to other ABMs (Activity-Based Models), inputs to DaySim include detailed population demographics, land-use patterns and transportation system characteristics in the study region. The demographic inputs come from a population synthesizer called PopGen (Pendyala et al., 2011) that generates a synthetic population of individuals and households to match aggregate-level distributions of both household- and person-level characteristics from the U.S. Census. Demographic variables not controlled in PopGen (e.g., household car ownership and individual employment characteristics), were estimated using econometric models based on local data. Taking all the above as inputs, DaySim simulates the daily activity and travel patterns of all residents in the study region, including the timing, duration and location of activities and the mode of travel between different activity locations. We ran the model on an eight-core Windows machine with a 2.8 GHz Intel Xeon processor and 24 GB RAM. The run time was approximately 5 hours for the entire Tampa Bay population of about 3 million individuals.

DaySim does not simulate travel route information between different activity locations. However, information on travel routes and network performance (i.e., link speeds and volumes) is essential for estimating emissions and human exposure to those emissions. Therefore, MATSim was used to simulate travel routes and network performance (Balmer et al., 2008). To do so, outputs from the Tampa ABM were processed using SPSS and Java programming to provide the initial set of plans for

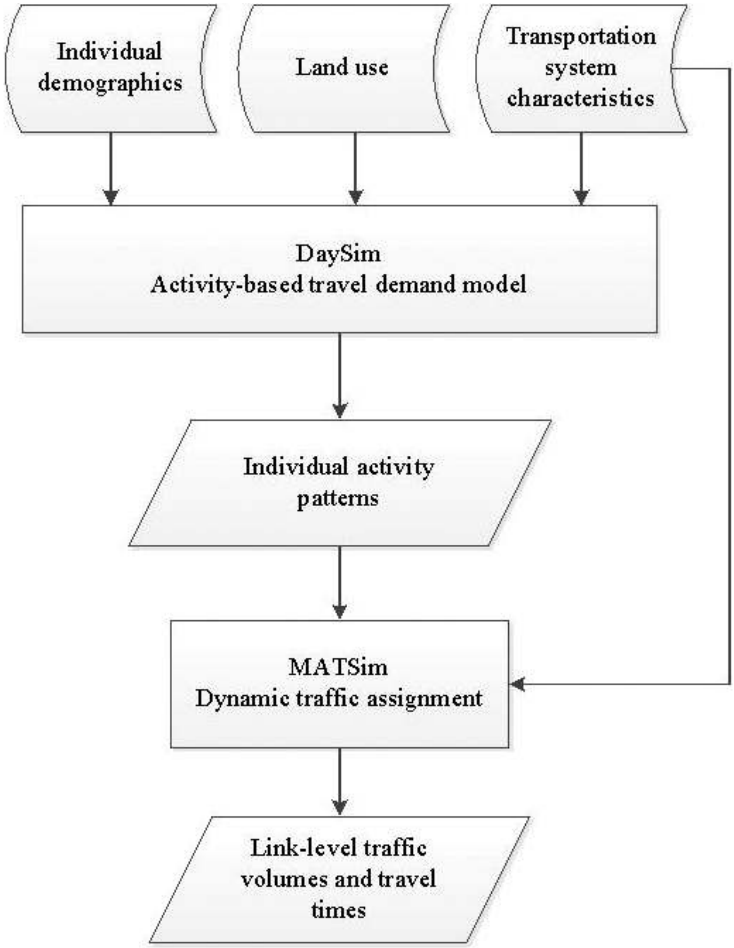

Figure 90.2: The transportation modeling framework.

MATSim. Similarly, the ArcGIS road network file for the Tampa Bay area was processed to create network inputs for MATSim. Since most travel in Tampa is by automobile (with close to 90 % mode share), only these trips were simulated in MATSim. It is worth noting, however, that a large number of automobile trips were simulated. Specifically, 9.7 million trips made by approximately 2.3 million residents of the study region during a 24 hour period were simulated. The simulation was run for 300 iterations, with the storage capacity factor for the links set to 3. Additionally, maximum plan memory size for each agent was set to 3. The `BestScore` and `ReRoute` replanning modules were used with a probability of 0.9 and 0.1, respectively. To undertake this large-scale and computationally intensive simulation, 48 parallel processors each with 25 GB of RAM from a university research computing cluster setup were utilized, requiring 5.2 days total run time. Link-level outputs from the simulation, including hourly traffic volumes and travel times, were written to a `linkstats` file; trip-level route information was written to a `plans` file.

90.4 Results

Diurnal patterns of link-level passenger car volumes and travel speeds for Hillsborough County are presented in Figure 90.3 (in the form of bi-hourly averages). As expected, traffic volumes, shown in

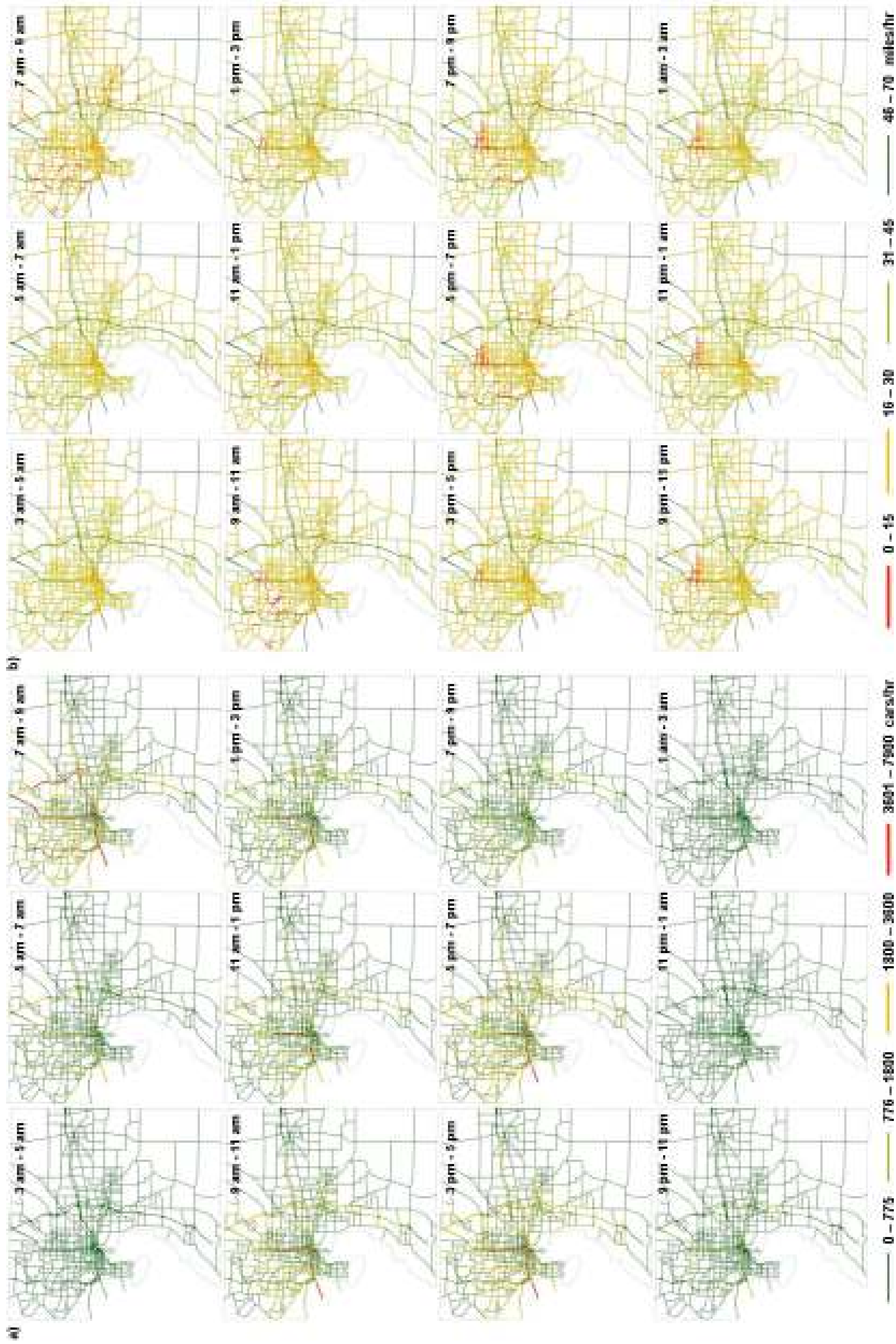

Figure 90.3: Simulated bi-hourly varying a) passenger car volumes and b) travel speeds (mph) for Hillsborough County on a typical weekday.

Figure 90.3 a), are higher during the morning (7 to 9 am) and the evening (4 to 7 pm) peak hours than the rest of the day. Additionally, traffic volumes during evening peak hours are higher than volumes during morning peak hours, perhaps partly because the evening commute has a higher propensity for trip chaining compared to the morning commute (Chu, 2003). Travel speeds shown in Figure 90.3 b) correspond to the diurnal pattern of traffic volumes, with lower speeds during the morning and evening peak hours.

Spatially, higher volumes are observed along major freeway corridors—I-75, I-275, and I-4 as expected. High traffic volumes are also observed along the road network near suburban locations, including Brandon, Citrus Park and Town 'N' Country. Accordingly, travel speeds are lower in these suburban locations along with the North Tampa area, University area and a few sections of the freeway corridors.

The root mean squared error between the estimated traffic volumes and observed traffic volumes at eight different traffic counting stations is 0.41. Further, the error between estimated and observed traffic flows for inter-city roads was higher than those for intra-city roads, presumably because the current model system does not consider long-distance (or inter-city) travel, visitors' travel and freight movement in detail. Nevertheless, the high temporal and spatial resolution of the population activity (including individuals' travel routes) and network performance (i.e., link volumes and speeds) simulated using the model system is promising for future detailed estimation of traffic pollutant emissions and human exposures to those emissions.

90.5 Future Work

The next steps of this study include addition of inter-city, visitor and freight travel to the model system. Utilizing the fine-resolution, link-level traffic volume and speed outputs from MATSim, EPA's MOVES software is being used to estimate mobile source emissions. Mobile source emissions can be combined with other sources of emission and meteorological data, using a pollutant dispersion model, to estimate diurnal cycles of hourly varying pollutant concentrations. The resulting pollutant concentrations will be combined with the diurnal locations of individuals (obtained from the ABM and MATSim) to estimate individual-level exposure to traffic-related pollutants, such as nitrogen oxides. Such individual-level exposure measures will be utilized to estimate demographic group-level exposures for assessment of inequality in exposure to traffic-related air pollution, as we have done previously using travel survey data (Gurram et al., 2015). The model system described above will be used to obtain estimates of population exposure, for alternative scenarios of urban land-use design and transport policies.

90.6 Conclusion

In this study, we simulated urban travel using activity-based travel demand modeling and dynamic traffic assignment, to obtain network performance measures, including link-level traffic volumes and speeds, at a high spatial and temporal resolution for Hillsborough County in Florida. As expected, simulated traffic volumes are higher and travel speeds lower during morning and evening peak hours. Spatially, higher volumes and lower speeds are observed along the freeway corridors and suburban locations than other locations. Model performance (vis-à-vis observed traffic patterns) is better for inter-city roads than intra-city roads, highlighting the need for better modeling of long distance passenger travel and freight movement. When the ABM-DTA framework built in this study is expanded to consider mobile source emissions and pollutant dispersion, the resulting transportation and air pollution modeling system will be useful for understanding interactions between urban transportation design, air pollution and population exposure to pollution.

CHAPTER 91

Tel Aviv

Christoph Dobler

The initial Tel Aviv MATSim scenario (Bekhor et al., 2011) was recently extended by adding destination choice to the MATSim iterations (Dobler et al., 2014).

The modeled area was divided into 1 219 TAZ (Figure 91.1(a)); geometry was provided as a ESRI shape file (ESRI, 1998). Zonal attributes contained information on the population living in the zone, as well as types of activities that can be performed.

The population was created using population generator outcomes from the Tel Aviv activity-based model, containing socio-demographic attributes and daily schedules with up to six activities. This kept computational effort manageable; a 10 % population sample was simulated. Additional data was provided for external trips; for each of the three types (car, truck, commercial), O-D matrices for three different time periods were available.

Network input data was taken from the EMME/2 model (see INRO, 2015), also used by the Assignment Unit of the existing Tel Aviv Model. Conversion process details can be found in Gao et al. (2010). Turning restrictions were handled by adapting the network structure, resulting in a network containing 9 474 nodes and 18 570 links (Figure 91.1(b)). Some major road capacities were obviously too low (e.g., noticeably lower than traffic counts indicated) and were corrected manually.

The Tel Aviv scenario contained road pricing for two arterial highways; count data for validation was available for three arterial roads.

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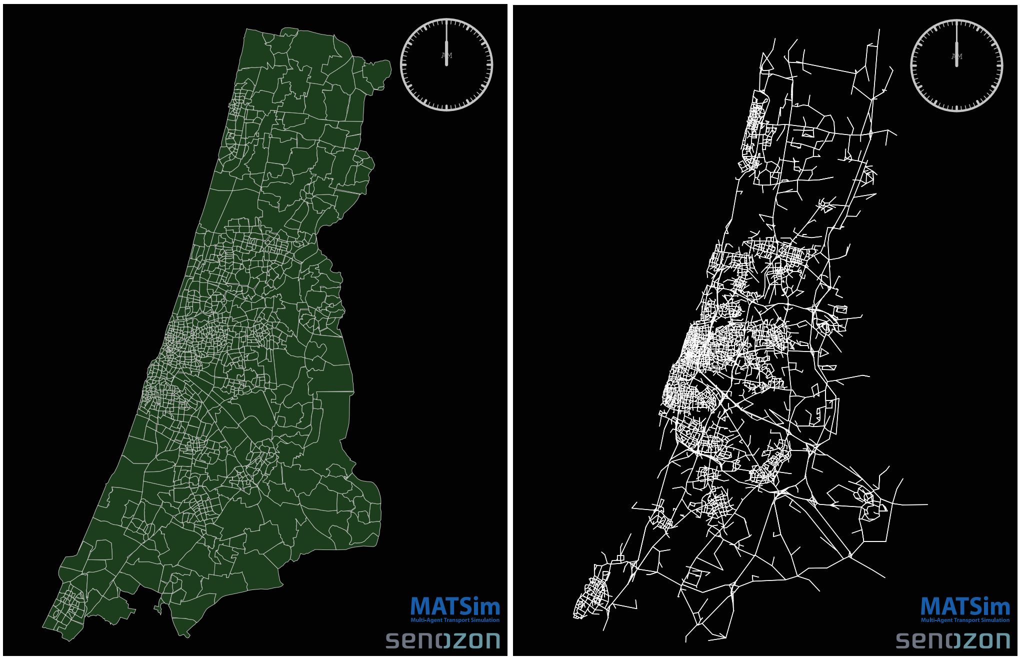

(a) TAZ (b) Network

Figure 91.1: Tel Aviv scenario.

CHAPTER 92

Tokyo: Simulating Hyperpath-Based Vehicle Navigations and its Impact on Travel Time Reliability

Daisuke Fukuda, Jiangshan Ma, Kaoru Yamada and Norihito Shinkai

92.1 Introduction

Most standard commercial vehicle navigation systems usually rely on fixed travel times as link weights; sophisticated algorithms deal mainly with stochastic travel time. Reliable routing incorporating such travel time variability could provide extra benefits to drivers. However, implementations of many reliable routing algorithms might become impractical, mostly due to heavy computational loads. The hyperpath-based navigation demonstrated in this chapter would consider only lower and upper bounds travel times for each link as inputs and produce a set of potentially optimal links with recommended link choice possibilities.

The basic concept of hyperpath is: "Don't put all your eggs in one basket in an uncertain environment". In literal terms, actual routes are more widely distributed as congestion increases. Thus, delay risk due to induced congestion would be reduced and the network burden—congested links—would be lightened (Figure 92.1). Based on the idea of "Optimal strategy", widely employed in frequency-based transit assignment (see Spiess and Florian, 1989), Bell (2009) proposed the shortest hyperpath search algorithm called "Hyperstar". Algorithm variations under various conditions have been further developed in Bell et al. (2012) and Ma et al. (2013) for risk-averse vehicle navigation.

Hyperpath-based navigation can be beneficial in at least three ways:

1. The concept of hyperpath could benefit drivers by helping reduce travel time unreliability; it provides an 'adaptive choice opportunity' to potentially avoid stops at intersections, or long delays on links. For example, other than typical navigation systems, the turn notification

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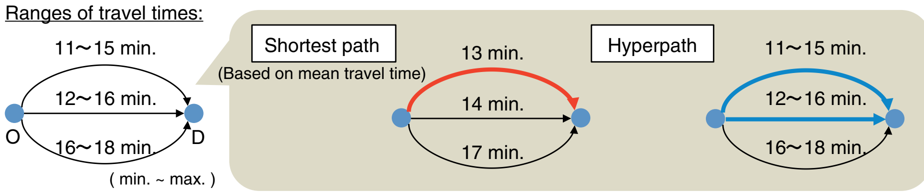

Figure 92.1: Concept of hyperpath under travel time uncertainty (1 O-D - 3 routes example).

received by drivers before entering intersections could be "go straight or turn right". In this case, drivers may decide to turn right when encountering a red light for going straight. Even if the final experienced travel time is slightly longer than the non-adaptive drive, driving experience could be better (say, eight minutes driving plus two minutes waiting versus ten minutes non-stop driving).

2. For drivers, hyperpath also could cater more to individual tastes without pre-defining drivers' actual route choice preferences. Comparatively, shortest path (SP), or multiple shortest paths with different criterion, would require modelers' definition of "shortest". In the long run, the hyperpath model has the potential to evolve with reinforcement learning technologies and provide more customized adaptive route guidance.
3. Existing commercial navigation systems seldom take their effect on networks into consideration; sometimes congestion is actually produced by navigation systems. Thus, DTA, along with route guidance, might be still be mostly academic or hypothetical. Classical DTA are largely based on time-dependent K-shortest paths and aim to analyze equilibrium conditions as ideal states. For example, Dynamic User Equilibrium defines the equilibrium where drivers cannot change their trip plans to reduce actual experienced travel time. However, experienced travel time can never be known beforehand, since real-life transportation is much more complicated than laboratory DTA settings. Hyperpath-based route choice does not search for equilibrium, but it might be equilibrium-like to some extent, as it is strategically reactive to delay changes.

The hyperpath-based route recommendation could thus reduce overall network congestion, because it recommends a potential optimal set of paths instead of the shortest (single) path and leads to appropriate dispersion of traffic. However, its impact on the entire traffic networks has not been well analyzed. In this chapter, we demonstrate—using MATSim—how hyperpath-based vehicle navigation market penetration would affect overall network performance. Though development of real-time traffic information for navigating vehicles has benefited drivers, to some extent, market diffusion of these technologies may not lead to the reduction of traffic congestion, mainly due to the concentration of traffic into particular paths or links in the traffic networks. Certain unexpected phenomena, such as "Hunting (e.g., Oguchi et al., 2003)", might occur. We changed the ratio of vehicles with risk-averse route guidance, conducted traffic simulation and then checked traffic performance.

92.2 A Small-Sized Network Case

MATSim was utilized as the simulation tool. In the early stage, we conducted such simulations on the Sioux Falls network (see also Chapter 59) with synthetic O-D demands (see (Yamada et al., 2013) for details). Hyperpath algorithm was initially written as an external route planning module in Python and the market share can be configured by setting the "ModuleProbability" item. Figure 92.2 illustrates the configuration sample for hyperpath with 20 % market share. Figure 92.3

```
<param name="ModuleProbability_1" value="0.2" />
<param name="Module_1" value="ExternalModule" />
<param name="ModuleExePath_1" value="python &INBASE;/external_parallel_v5.py" />
<param name="ModuleProbability_2" value="0.8" />
<param name="Module_2" value="ReRoute" />
```

Figure 92.2: Setting for the case that 20 % of vehicles follow hyperpath-based vehicle navigation.

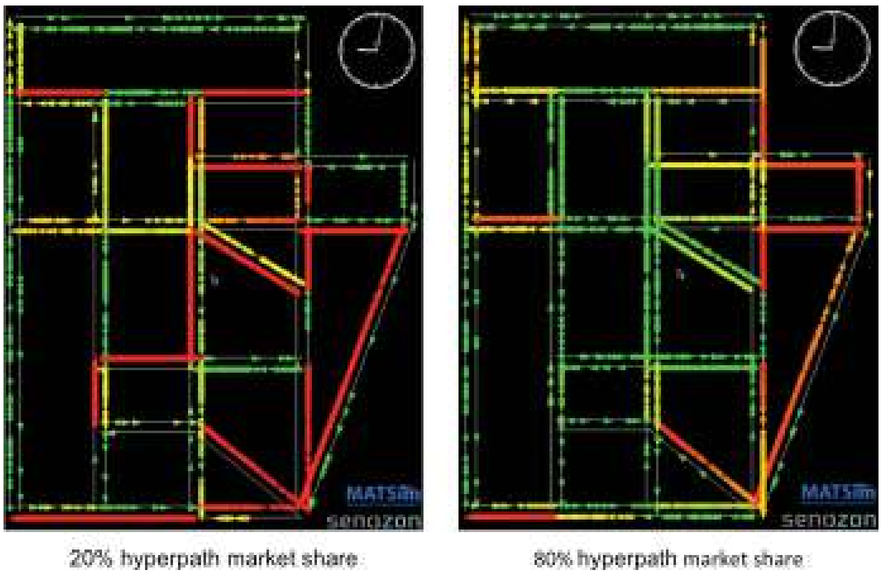

Figure 92.3: Link travel speeds for different levels of market penetrations.

also shows the network state (in terms of link speed) improvement with increase in the market share of hyperpath from 20 % to 80 %.

92.3 Simulation in Tokyo's Arterial Road Network

Based on early-stage experiments on the Sioux Falls network, we were interested in a similar simulation in Tokyo's large-scale arterial network with actual traffic data.

92.3.1 Network and Travel Demand

The arterial road network, including the whole Tokyo Metropolitan Area (Figure 92.4), was prepared from Digital Road Map version 2011 (DRM2403) in a radius of about 70–80 kilometer from downtown. The traffic network consisted of 444 220 nodes and 177 971 links after being cleaned using the "networkcleaner" API in MATSim. Capacity and free flow speed of each link were set up considering road hierarchy information, type of links and their corresponding speed limits.

We analyzed car traffic during morning rush hours and the O-D table was subtracted from a large-scale travel survey (Person Trip Survey 2007) to create agents' plans. The total number of the O-D pairs was 17 186 and there were about 2 307 000 vehicular trips during the target time period within the whole area. From the data, 219 642 agents (approximately 10 % sampling rate) were randomly created and each agent had only one activity, commuting from his/her home to the

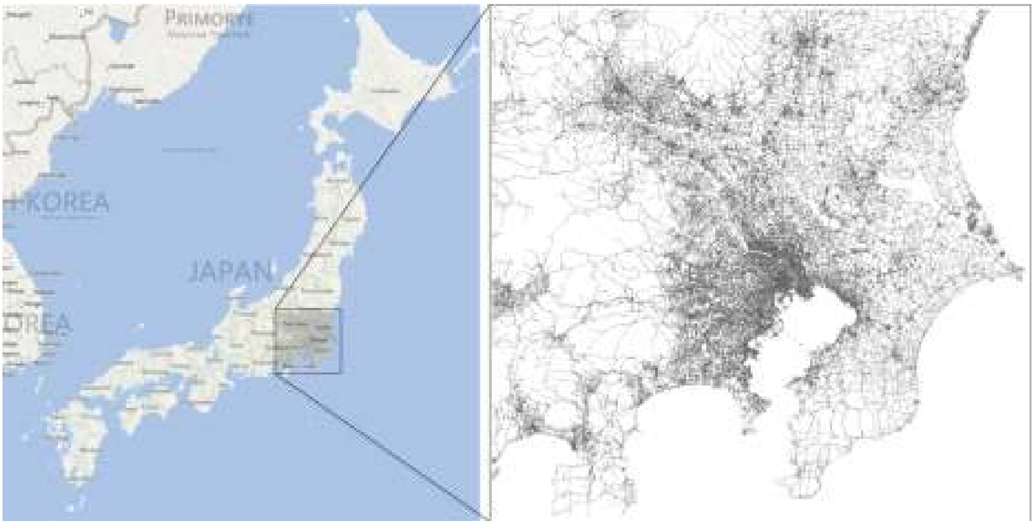

Figure 92.4: Arterial road network in Tokyo Metropolitan Area.

workplace. For drivers' departure time from home, a normal distribution with the mean of 7 am and the standard deviation of 1 hour was assumed.

92.3.2 Setup of Day-to-Day Simulation Experiments

Although the Logit-based route planning module had already been employed as one of the MATSim routing strategies, it may have had less supportive route guidance explanations. We thus focused on the combination of "re-route" and "best-score" planning modules, which meant that some drivers adjusted their daily travel plan according to yesterday's experience, while the others simply chose the most positive route from their past choices.

To get travel time data for creating hyperpaths, simulation runs for 30 iterations (i.e., 30 days) were firstly performed with no HP-based drivers (i.e., 100 % of SP-based drivers) to obtain travel time distribution. Then, maximum delays in each during these 30 days were computed and used in the following main simulation, with the market diffusion of HP-based navigated drivers. Figure 92.5 illustrates a simulation with MATSim for the downtown Tokyo.

92.3.3 Results

We conducted five different cases of traffic simulation by changing the shares of HP-based drivers from 0% to 80% by 20%. The simulation runs were conducted for 30 days for each case to evaluate network-level travel-time savings, as well as reliability.

Average travel time per unit length of all agents in each one day was plotted for different cases in Figure 92.6. Since the traffic network in Tokyo is quite large and drivers' trip lengths are diverse, we plotted the average travel time per unit length (shortly ATTPUL) for a fair comparison. Apparently, there were high levels and large fluctuations in ATTPUL when there were no HP-based drivers (HP %, that is SP 100 %). But it is obvious that, as the market diffusion rate of HP-based drivers increased, fluctuation and levels of ATTPUL would be significantly reduced.

Table 92.1 summarizes the result of Figure 92.6 by computing the ATTPUL ($\bar{t}_{unit}$) average, as well as the ATTPUL (σ_{unit}) standard deviation over the 30 days. It is clear from this table that

Figure 92.5: Snapshot of the hyperpath-based traffic simulation in Tokyo.

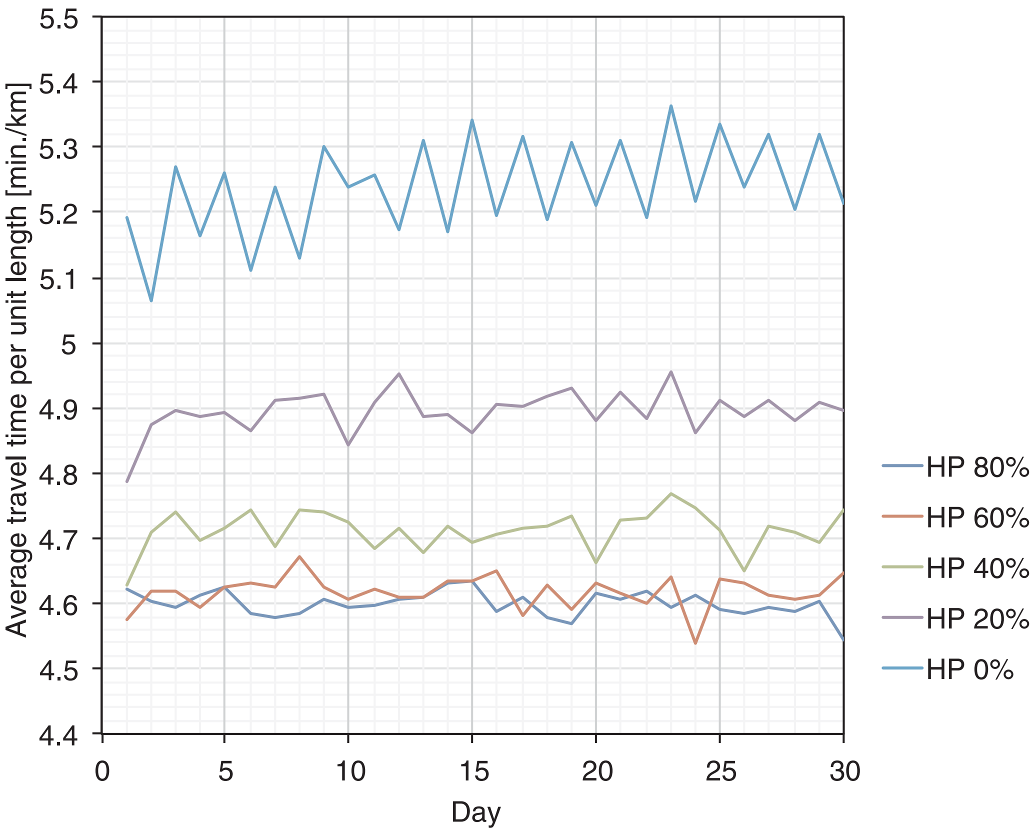

Figure 92.6: Average travel time per unit length for all vehicles.

Case	$\bar{t}_{unit}$ [min./km]	σ_{unit} [min./km]
HP 80%	4.60	0.02
HP 60%	4.62	0.02
HP 40%	4.71	0.03
HP 20%	4.90	0.03
HP 0%	5.24	0.07

Table 92.1: Summary of the network perfomance.

both average and standard deviation of travel time tended to decrease when the mixing ratio of HP-based route guidance was increased. This result indicates that HP-based route guidance would be superior in terms of of travel time reduction and reliability given day-to-day patterns of average travel time for heavy Tokyo traffic.

92.4 Validation of Hyperpath-Based Navigation

A field experiment was conducted to verify the benefits of travel time reliability improvement for drivers by Ito et al. (2015) in Tokyo. Drivers equipped with the time-dependent shortest path and those equipped with the time-dependent hyperpath navigation systems were compared. Both navigation systems use the same historical travel time sourced from probe vehicle data. Based on results collected from two weeks of experimental driving by different drivers, the hyperpath produced a significantly better result, especially when the network was congested.

CHAPTER 93

Toronto

Adam Weiss, Peter Kucireck and Khandker Nurul Habib

93.1 Study Area

The GTHA (Greater Toronto and Hamilton Area) is located northwest of Lake Ontario, in the province of Ontario, forming Canada's largest urban region. The GTHA's current population is over 6.5 million, with projected growth to approximately 8.6 million by 2031.

93.2 Population, Demand Generation and Activity Locations

The TTS (Transportation Tomorrow Survey) was the basis for travel demand used for the multi-modal assignment simulation. TTS was a retrospective telephone survey, conducted in the GTHA every five years. The TTS sampled just over 5 % of GTHA households; the survey collected household socioeconomic and geographical data, characteristics of each household member and a full 24 hours travel diary for each household member. Current MATSim models use the TTS travel diary records to generate the plans file. Integration of the TASHA activity based model, developed for the glsgtha, was also investigated. Irrespective of the demand data source, both sources provided the traffic zone location for all activities. The Toronto implementation then randomly distributed activities around the traffic zone, which resulted in unique x-y coordinates for each activity. Within the current MATSim implementation in Toronto, no MATSim facilities development has been attempted.

93.3 Network Development and Simulated Modes

The GTHA MATSim implementation used a pre-existing planning level network for static user equilibrium assignment,employing the EMME traffic assignment software. This network was converted to a MATSim network, using a conversion tool found in the MATSim Toronto playground.

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More recently, this network was merged with GTFS data for five of the eight major regional transit agencies to allow for multimodal demand assignment.

93.4 Calibration, Validation, Results

The Toronto MATSim implementation was compared to more conventional, large-scale assignment models with varying success. The work of Gao et al. (2010) found that travel time, travel distance, link flows and speeds were reasonably comparable, in fact more plausible, than those achieved through the EMME assignment. Conversely, work on transit assignment, first done by Kucirek (2012) and then by Weiss et al. (2014), found limitations associated with predicting line boarding figures; these were based on different transit technologies and agencies and utilized different fare structures, suggesting that further work to calibrate the multimodal assignment model is required. These issues are exacerbated by the current implementation's inability to distinguish between in-vehicle dwell times and out-of-vehicle wait times; these should ideally be weighted differently, particularly given the climate and predominance of outdoor bus stops in the region.

CHAPTER 94

Trondheim

Stefan Flügel, Julia Kern and Frederik Bockemühl

The Institute of Transport Economics (TØI), in cooperation with Julia Kern from TU-Berlin and Frederik Bockemühl from Hasselts University, built a first prototype model for the region of Trondheim (Norway) (Flügel and Kern, 2014).

The road network data was imported from a publicly accessible data base (Elveg). Figure 94.1 illustrates the network. Most required link information could be directly inferred from the data base. The lane capacity (vehicles per hour) was assumed to be a flat 1 800 per lane. Existing toll stations, with their current toll structures, were coded manually in the network file. The public transport, walk and cycle networks had not been implemented at this time. Agents using one of these modes were teleported; travel times were calculated with predefined speeds per transport mode. Initial demand was derived from the National Travel Survey (NTS 2009) travel diaries. 4 453 respondents were simply scaled up to 191 676 agents; activity locations and departure times were slightly randomized to avoid clusters. This model differentiated only between work and "other" activities. Desirable working hours were specified as eight hours; demand consisted only of private cars (no trucks).

Standard utility functions were applied, but in the calibration process, default values for travel time disutility in different transport modes were adjusted so that the model would reproduce observed market shares. The simulated traffic fit (in the reference scenario) against real-world counts was deemed satisfactory for a first implementation (Bockemühl, 2014).

Standard behavioral modules in MATSim were included in the Trondheim model. Agent could react to policy measures through three choice dimensions: changing route, changing transport mode and changing departure time. To test whether MATSim predicted reasonable behavioral changes, a small case study was performed. Additional tolls on streets (bridges and tunnels) to Trondheim city center were coded in the network and three congestion price structure were tested. Figure 94.2 illustrates the effects on the simulated cars entering and leaving Trondheim city center. Compared to the reference scenario without tolls, total number of cars was reduced in

How to cite this book chapter:

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all toll scenarios. Some agents changed transport modes; others, who would have driven through Trondheim center, changed their route. Comparing the three different congestion-pricing structures, it was also evident that agents changed departure time. The difference between the 15 NOKs flat scenario and the 10/20 NOKs scenario was small; the effect in the 50 NOKs rush scenario was substantial. Actually, in this scenario, traffic was heavier before 3 pm and after 5 pm implying that many agents changed departure time to avoid high congestion pricing.

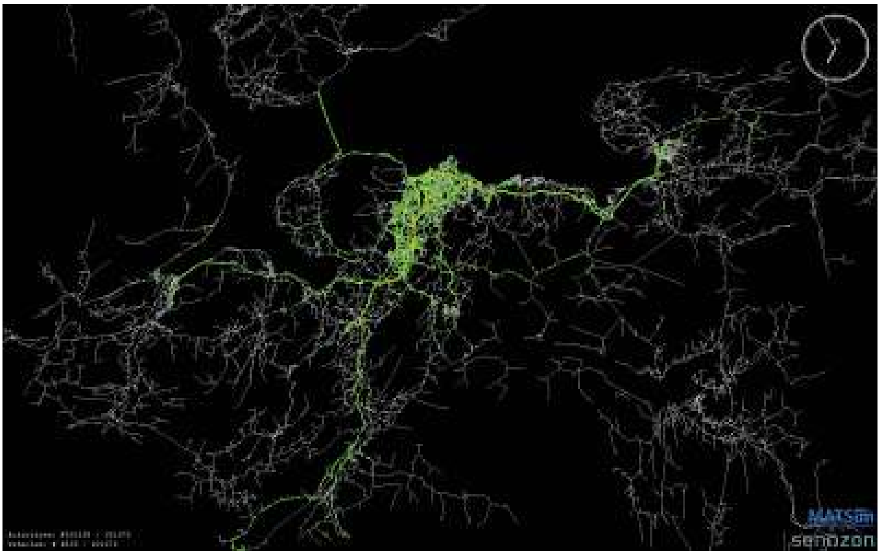

Figure 94.1: Network and simulated traffic in Trondheim and surroundings for 6:55 am (source Flügel et al., 2014) (visualized with Via).

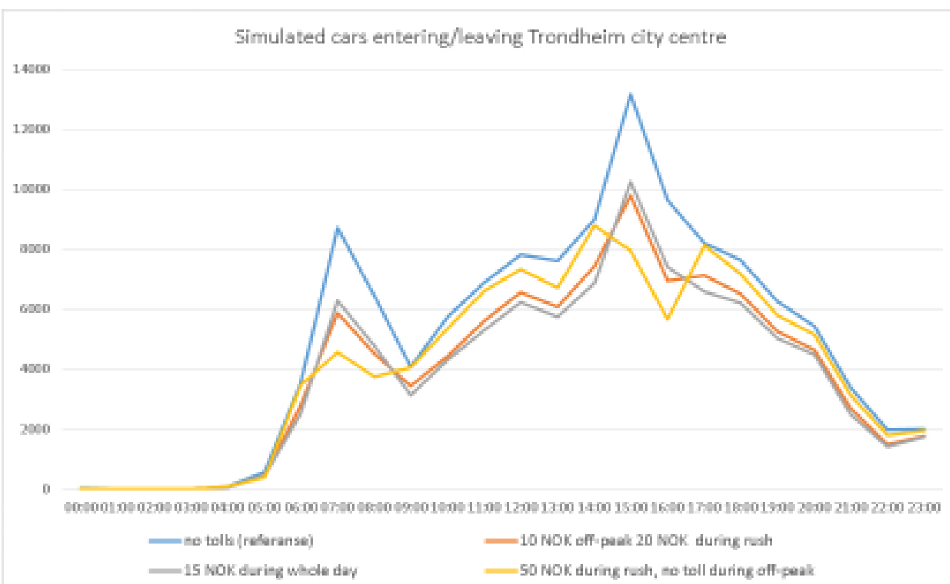

Figure 94.2: Cars entering/leaving Trondheim city center in reference scenario and three congestion pricing scenarios (source Bockemühl, 2014).

CHAPTER 95

Yarrawonga and Mulwala: Demand-Responsive Transportation in Regional Victoria, Australia

Nicole Ronald

In November 2013, Public Transport Victoria implemented a service called Flexiride in twin regional Victoria towns, consisting of an on-demand public transport service using taxis. This service replaced an existing fixed-route bus service, which was poorly patronized.

This scenario was designed to investigate operational performance change between two different DRT schemes: Flexiride and a completely ad-hoc scheme. More details can be found in (Ronald et al., 2015). This work was a first step in developing a decision-support tool to evaluate different DRT schemes, particularly when integrated with other transport modes.

The scenario was part of a larger project exploring the viability of mobility-on-demand, focusing on ridesharing and DRT services (Ronald, 2014).

The scenario covered twin towns on the border of Victoria and New South Wales, Australia, separated by the Murray River. Yarrawonga (Victoria) has a population of 7 057 and an area of 95.0 square kilometers, while Mulwala (New South Wales) has a population of 1 904 and an area of 18.6 square kilometers.

The Flexiride scheme delivered six services on weekdays and three services on Saturday, leaving Yarrawonga center (Orr St) at fixed times. The local taxi operator was paid a holding fee by Public Transport Victoria to have a taxi available at Orr St at the nominated time. The taxi returned to normal service when there were no bookings or passengers waiting.

Passengers could ride either by starting their trip at Orr St, or by phone booking, at least 10 minutes before a scheduled departure from Orr St. Existing bus stops were used as pickup and drop-off points.

Flexiride drivers recorded pickup and drop-off locations for each service. Using this data, probabilities of trips occurring between two zones were developed, using the process in Deflorio (2011). A continuous departure time distribution was derived from evenly spreading demand for particular services to either side of that service.

How to cite this book chapter:

Ronald, N. 2016. Yarrawonga and Mulwala: Demand-Responsive Transportation in Regional Victoria, Australia. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 527–528. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.95. License: CC-BY 4.0

The network was extracted from OSM. Some bus stops were removed if they were assigned to the same link in MATSim, e.g., stops on the same road between intersections.

Only passengers for the demand-responsive service were included. However, the use of MATSim for this initial model means that other modes could be added in later versions.

This was an exploratory simulation that demonstrated how DRT could be modeled for exploring viability and comparison of different schemes.

Using MATSim, experimentation with varying demands, two different scheduling algorithms and an altered Flexiride service, with more services, were carried out. Outcomes like drive time, vehicle-kilometers traveled and passenger wait time could be measured.

Results showed that the two schemes performed differently for operators and passengers. Optimization schemes had little effect in low demand situations, while seating requirements showed more variability in the ad-hoc scheme, as demand increased. Future work involves estimating both schemes' costs for further comparison.

This work was supported by a grant from the Australian Research Council (LP120200130). We are also grateful to Michal Maciejewski for his assistance with the DVRP contribution (see Chapter 23).

CHAPTER 96

Yokohama: MATSim Application for Resilient Urban Design

Yoshiki Yamagata, Hajime Seya and Daisuke Murakami

96.1 Introduction

In Yamagata and Seya (2015), we proposed the concept of a resilient local electricity-sharing system as a complement, or alternative, to a FIT (feed-in tariff) to achieve CO_2-neutral transportation in cities. In our proposed system, electricity generated from widely introduced solar PVs (Photovoltaic Panels) is stored in cars "not in use" in a city. In Japan, almost half the central Tokyo metropolitan area cars are used only on weekends and thus are kept parked weekdays. These cars could represent a huge new storage potential if they were replaced by EVs; that is, they could be used as storage batteries in a V2C (Vehicle to Community) system.

This study analyzed the potential of EVs as storage batteries in emergency cases. Specifically, we focused on the following three questions:

1. How much residential demand can be met (in each 24 hour) by electricity from just PVs, which are installed on the roofs of all detached houses in the study area?
2. How many EVs are needed to store all surplus electricity (PV supply minus demand)?
3. How does EVs driving change the load curve and how can mass-adopted PVs fulfill total demand?

To answer our second and third questions, we needed to know (a) the number of cars parked at home during each hour (that is, the time each car arrived at home after use) and (b) the amount of battery charge consumed by each driver during his/her daily trips (that is, trip duration). For this simulation, we used MATSim. In this chapter, we briefly introduce our MATSim application for a local electricity-sharing system in Yokohama city, based on Yamagata and Seya (2013); Yamagata et al. (2014, 2015).

How to cite this book chapter:

Yamagata, Y, Seya, H and Murakami, D. 2016. Yokohama: MATSim Application for Resilient Urban Design. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) *The Multi-Agent Transport Simulation MATSim*, Pp. 529–532. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw.96.

96.2 Results

We assumed that PV was installed on the roof of each detached house in Yokohama city. Then, we calculated the amount of electricity supplied each hour throughout the whole day by employing simple intensity method. The O-D trip data used are from the Fourth Person Trip Survey in Tokyo Metropolitan Area, implemented in 1998. The data are available through the People Flow Project (`http://pflow.csis.u-tokyo.ac.jp`) on request (application) and include the O-D trips by traffic mode, time of day, purpose, etc. for each micro district, called *cho-cho-moku*. The Person Trip survey is a national survey that focuses on people's travel behavior during a given few days of each month, from October to December. Because the number of cars in Yokohama for each cho-cho-moku was unknown, the city-level value was allocated to the cho-cho-moku (areal weighting) and adjusted for the size of the population. The road-network information was taken from the National Digital Road Map Database and included sufficient data on road capacity, width classification, link length, number of lanes and travel speed to perform traffic simulations in MATSim. MATSim requires a daily "plan file" for each agent (car driver); we prepared these files by using the Fourth Person Trip Survey, which captured the daily movements of 722 000 people. Because the Fourth Person Trip Survey sampled approximately 2 % of the population of the Tokyo metropolitan area, the plan file was replicated according to the intensity factor provided by the People Flow Project, resulting in 505 335 agents. From the MATSim simulation, we had obtained each agent's trip duration and arrival time.

Considering load curve changes due to the EVs driving, we then asked if massively adopted PVs would be enough to satisfy total energy demand in Yokohama. In Figure 96.1, the solid and dashed lines represent electricity surplus cumulative distribution, charged to or discharged from the batteries of EVs, not in use and used only for charging the EVs in use, during May and August (solid line, maximum; dashed line, average). The dotted line in the figure represents the scenario where electricity surplus was both charging EVs and satisfying households' typical electricity demand

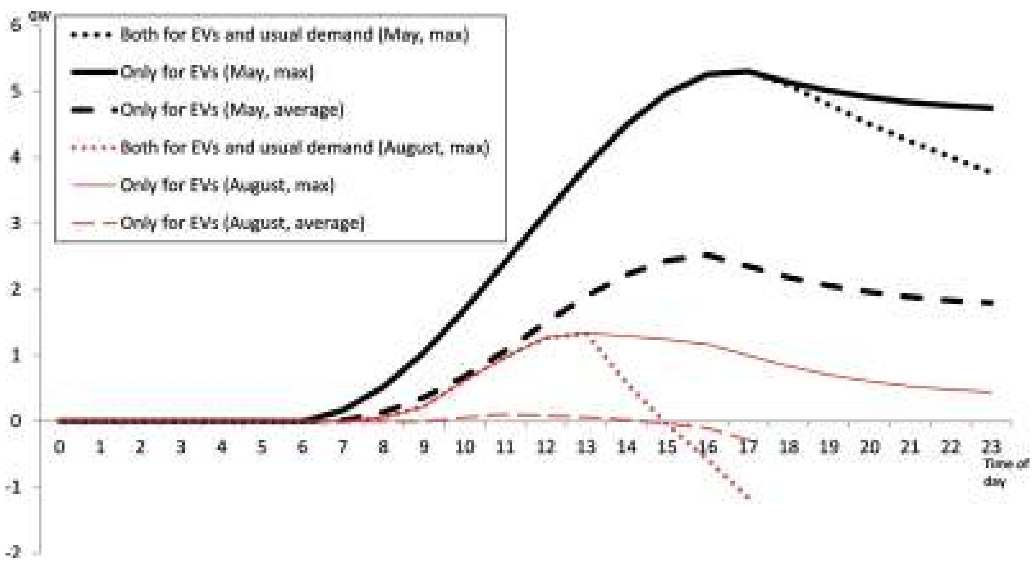

Figure 96.1: Cumulative distribution of electricity surplus charged to or discharged for electricity demand (y axis denotes the cumulative distribution of electricity surplus).

Source: Reproduced by permission of the Institution of Engineering & Technology: published in Yamagata and Seya (2015, Figure 6) under maximal/average solar irradiance. However, in August (high demand, high PV supply), the electricity surplus was sufficient for charging EVs, but not enough to meet the households' huge electricity demand due to evening use of air-conditioning.

To meet household electricity demand, PV electricity needs be efficiently stored in EVs and locally shared. For example, if a high-affordability zone (storage capacity is greater than electricity surplus) is adjacent to a low-affordability zone (storage capacity is smaller than electricity surplus), then the share of their EV capacity increases the ratio of stored PV electricity. Because storage affordability (storage capacity minus electricity surplus) is significantly different regionally (see Figure 96.2), clustering of community-based local sharing must be carefully designed. In this study, we attempted to optimize community clusters using several different algorithms. Firstly, the number of clusters was assumed 18 to be the same as the number of Yokohama city wards. Then, cluster optimization was performed by minimizing (the sum of storage affordability in the 18 clusters) plus *k* (minimum circularity in these clusters), where *k* was the weight for the circularity. The first term balanced storage capacity and electricity surplus to increases the rate of stored PV electricity; the second term decreased inter-point distance within each cluster, as well as electricity sharing (transmission) cost. The minimization was conducted in every month through a simulated annealing algorithm to find optimal spatially clustered communities.

Figure 96.3 shows four-month clustering results; all clusters indicate positive storage affordability in April, May, June, July, September, and October. In other words, PV electricity covers whole household electricity demands, if EV capacities are shared with these optimized clusters.

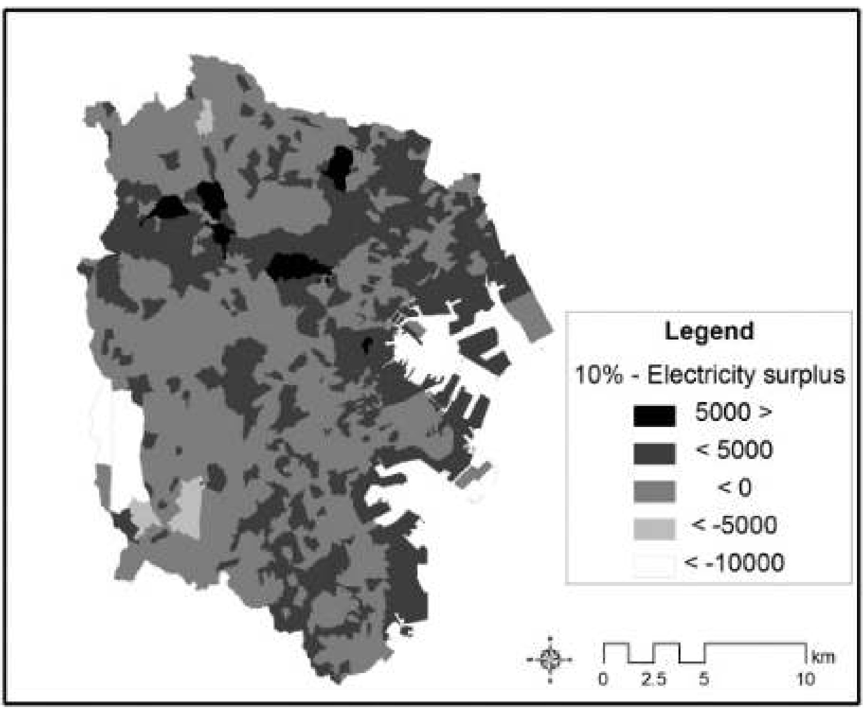

Figure 96.2: Storage affordability: Storage capacity minus electricity surplus in kWh/day (10 % of EVs not in use being used as battery).

Source: Reproduced by permission of the Institution of Engineering & Technology: published in Yamagata and Seya (2015, Figure 10.a)

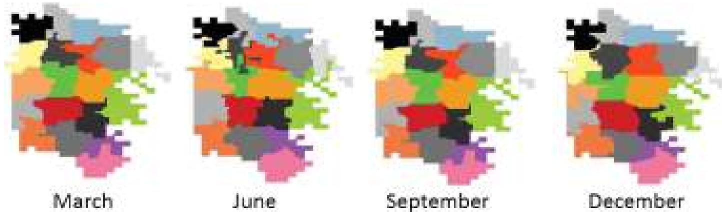

Figure 96.3: Monthly clustering results.

In summary, we applied MATSim to analyze the potential of EVs in a V2C system and found that EVs can cover typical household electricity demands in some months and the cover ratio can be increased by community clustering for local electricity sharing. In the future study, we plan to use MATSim to simulate mobility behavior for electricity sharing community scenarios and extend our clustering analysis utilizing simulated behavior. Finally, development of community level mobility sharing service would be a very important topic to integrate MATSim simulations with our land use and transportation scenarios, such as compact and dispersion scenarios (see Yamagata et al., 2013).

CHAPTER 97

Research Avenues

Kai Nagel, Kay W. Axhausen, Benjamin Kickhöfer and Andreas Horni

The on-going work documented and interest expressed in the various scenarios proves that this system has not at all exhausted its possibilities as a platform for research both on and with it. This chapter highlights chances for further discussion and action.

97.1 MATSim and Agents

97.1.1 Complex Adaptive Systems

The core MATSim architecture, where agents learn utilities for plans, was originally derived from the field of Complex Adaptive Systems (CAS; e.g., Axelrod, 1984; Holland, 1992; Hraber et al., 1994; Palmer et al., 1994) (also see Section 46.1 of this book). Arthur (1994) addresses a coordination problem where agents receive a payoff only when less than 60 out of 100 go to an event. He addresses this by first generating a large number of heuristic predictors for the next round's attendance, such as "same as in last round" or "trend from last four rounds". He next gives each agent a randomly selected handful of these strategies, so that agents have different sets of predictors. Then, many rounds of the game are played, where the score of each predictor is updated based on its prediction quality, and agents act based on their currently best predictor. Simulations demonstrate that the approach leads to successful coordination, i.e., around 60 agents show up in every round. That approach, in turn, builds on work by Palmer et al. (1994), who simulate a stock market, Holland (1992), whose classifier systems have more structure than Arthur's model, but a similar model of performance learning, or Axelrod (1984), who investigates adaptive agents in the face of repeated non-cooperative games.

Arthur (1994) keeps each agent's predictors fixed after initialization. In contrast, Hraber et al. (1994) simulate an artificial ecosystem, where individual agent strategies are based on so-called genes, adapted over the rounds/iterations by genetic algorithms (Goldberg, 1989).

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97.1.2 Artificial Intelligence

CAS focuses on many agents, agent interaction and emergence. Artificial Intelligence (AI) in contrast, concentrates on single agents. In AI terms, the original MATSim agents (those doing day-to-day learning) are very simple reinforcement learning agents (Russel and Norvig, 2010, Chapter 21.3). Since these MATSim agents have only one state (the initial/nightly state) and each action is simply a plan, the distinction between Q-learning and utility learning (as defined by Russel and Norvig, 2010) actually collapses; what remains is the temporal difference learning (again as defined by Russel and Norvig, 2010) scheme for the utility, which translates to the MATSim situation by updating the score/performance/utility value of each plan every time it is selected.

97.1.3 Synthesis

The original MATSim system thus took the focus on large systems, interaction, emergence, and strategy innovation from CAS, while the score updating comes from the AI field. In consequence, a clear path to move on is the inclusion of more modern AI aspects into the MATSim agents. Examples include:

- Extend MATSim to agents that can react immediately, rather than having to wait for the next iteration or round. In transport, this is sometimes called en-route or within-day replanning (e.g., Emmerink et al., 1995; Balijepalli et al., 2007; Axhausen, 1990). See Chapters 30 and 23 as well as Section 97.2.
- Improve the MATSim agents with respect to choice set generation. This may include both better creative capability for the agents to come up with innovative new strategies to handle their virtual lives, as well as consistency considerations between choice set generation and estimated choice models. See Sections 49.2 and 97.3.

97.2 Within-Day Replanning and the User Equilibrium

Within-day replanning, i.e., the ability of the agents to respond to the immediate context, is the standard mode of operation for simulation models. In the transport domain, note the traffic flow models as an example, where aspects such as acceleration/braking, or lane changing, are (obviously) computed reactively, while the simulation is running and not before the simulation starts (e.g. Wiedemann, 1974). Many traveler-oriented or agent-based models of travel demand adopt the same approach, cf. ORIENT (Sparmann and Leutzbach, 1980), ORIENT/RV (Axhausen and Herz, 1989), MobiTOPP (Schnittger and Zumkeller, 2004). For many aspects of Intelligent Transport Systems (ITS) systems, within-day replanning is indispensable (e.g., Hall, 1993; Emmerink et al., 1995; Dobler, 2013). None of these systems aim for equilibrium in the same way as MATSim, carried forward from TRANSIMS and originally inherited from static assignment.

One may argue that, if supplied with a learning approach, these within-day models should approach equilibrium after many iterations, as agents with a suitable memory structure would avoid plans that could put them at a disadvantage. This memory, which would need to be agent-specific and covering the very large set of choice options, makes the approach costly to implement. Importantly, the solutions may be different: when faced with a stochastic environment, an agent able to react within-day could be better off than an agent following a pre-computed plan. This is important: finding a plan with the highest expected score is not the same as finding a conditional strategy with the highest expected score.

Still, there are contexts where this immediate response ability can be used within MATSim to explore the choice set more effectively, especially if the choice alternatives are limited and within geographic reach. Waraich et al. (2013a) proposes within-trip replanning to find the best parking space near a destination. This localized search reduces the need for full iterations considerably and allows addition of behavioral detail at this point (here the type of parking), walking distance to final destination, and parking fee trade-off.

While within-day replanning can be used as described above within the framework equilibrium search, it can also be added to open up the MATSim framework to contexts where such an equilibrium is inappropriate. Dobler (2013) uses the MATSim calculated equilibrium as the starting point for his model of evacuations and the behavior of evacuees. He also explains that his approach finds a set of executed plans close to the MATSim equilibrium, but for much lower computing cost. While the benefits of an equilibrium solution in comparison with an approximation have been extensively discussed for aggregate assignment models, for MATSim the issue is whether these fast approximations could be used to speed up the overall equilibrium search; similar to starting a Frank-Wolfe search based on four or five incremental loadings of the network (Jourquin and Limbourg, 2006).

While aggregate assignment can identify the routes chosen as belonging to the equilibrium, research in the agent-based context is needed to see: a) if the approach is indeed faster and b) if the resulting set of plans is unbiased by the fast initialization.

97.3 Choice Set Generation

As described at several places in this book (e.g. Sections/Chapters 3.1, 4.5.1, 49.2, 27, 47, 49), the MATSim iterative process in its standard version modifies each agent's choice set (= each agent's set of plans) over the iterations. Clearly, an agent can only select a plan generated by this process. Thus, search space definition is important.

97.3.1 The Statistical Weight of Each Plan

Econometric research (e.g., Ben-Akiva and Lerman, 1985, Chapter 8 and 9) points out that it is not sufficient if certain alternatives are eventually discovered by the search process; rather, it is important that they are generated with probabilities consistent with the choice model. This, however, is at odds with the CAS approach, where solutions are generated rather arbitrarily. For example, Arthur (1994) "create[s] 'an alphabet soup' of predictors" that are "randomly ladle[d] out".[1] Research is needed to clarify when statistical properties of the choice set need to be tightly consistent with the choice model and when not.

As a result, in the MATSim context, it is important to look not only at plans generation/innovation (e.g., Section 4.5.1.1), but also at plans removal. The default MATSim approach is to remove the plan with the worst score. This is, however, problematic both from a CAS and an econometric perspective. From a CAS perspective, such an approach simply does not generate enough diversity, since similar scores rather often mean similar plans; thus, the approach has a tendency to remove the most different plan, typically leading to a set of plans that are all quite similar. From an econometric/discrete choice perspective (cf. Section 49.2), the combination of plans generation and plans removal needs to ensure that each plan's probability of being in the choice set corresponds to its weight used in the choice model estimation.

Section 49.2 discusses a version of the plans' generation/removal process, but makes rather strong assumptions about the capability to compute best-response plans. Here, let us instead consider a heuristic argument. Assume that plans i for a person n are created with a certain probability $p_{n,i}^{create}$; the person index n will be dropped in the following. Also assume that plans are removed with probability p_i^{remove}. The master equation for the probability q_i of plan i to be contained in the choice

[1] To be precise, Arthur uses strategies that eventually *generate* choices.

set becomes in leading order[2]

$$\frac{dq_i}{dt} = -q_i \cdot p_i^{remove} + p_i^{create} \; .$$

The steady state solution, obtained from $dq_i/dt = 0$, is given by

$$q_i = \frac{p_i^{create}}{p_i^{remove}} \; . \tag{97.1}$$

That is, quite obviously, if one wants to control the statistical distribution q_i within the MATSim process, one needs to look not only at plans generation, but also at plans removal.

MATSim's plans generation model can be approximately described by a creation probability of $p_i^{create} \sim \exp(\beta^{create} S_i)$, with relative large β^{create}, corresponding to an approximate best-response model.[3] At the same time, removal of the worst plan corresponds to $p_i^{remove} \sim \exp(-\beta^{remove} S_i)$ with a very large β^{remove}. Overall, thus

$$q_i \sim \exp((\beta^{create} + \beta^{remove}) \, S_i) \; .$$

Combining this with a choice model that selects with $\sim \exp(\beta^{choice} S_i)$ from the set of plans, i.e. `ChangeExpBeta` or `SelectExpBeta`, leads to

$$p_i \sim \exp(\beta^{choice} S_i) \cdot q_i \sim \exp((\beta^{choice} + \beta^{create} + \beta^{remove}) \, S_i) \; . \tag{97.2}$$

Let us again stress that this is not an exact statistical analysis of the MATSim dynamics, but instead an illustrative approximation to gain insight. From this approximation, it becomes clear that MATSim in its current form, because of the strong additional effects of plans generation, expressed through β^{create}, and plans removal, expressed through β^{remove}, strongly over-weighs plans with high scores. *It is thus important to include plans removal in all considerations,* since otherwise the very large β^{remove} in Equation (97.2), coming from always removing the worst plan, will dominate the statistical distribution.

97.3.2 Heterogeneity in Plans Removal

Clearly, removing not the worst plan, but instead according to some logit model with a smaller β^{remove} would improve the situation. In addition, to increase diversity and simultaneously correct for correlations between alternatives, one could use an (inverse) path-size logit (e.g., Frejinger and Bierlaire, 2007; Prato, 2009; Schüssler, 2010) model, i.e.,

$$p_i^{remove} \sim \exp(-\beta^{remove} S_i + \alpha \, PS_i)$$

where PS_i would be an index of similarity of plan i to all other plans in the plans set. As a result, plans very similar to other plans in the set would have a greater chance of being removed. The last of such similar plans would no longer be similar to any other plan, thus PS_i would be small; that plan would be less likely to be removed.

Such an approach is experimentally available as `PathSizeLogitSelectorForRemoval`. It possesses an ad-hoc similarity computation of one plan to all other plans in the set (Grether, 2014). Further investigations using this approach should be performed.

---

[2] In higher order, one would have to correct for the possibility that a plan may appear more than once in the choice set.

[3] The operator $\sim$ means "proportional to in leading order". It neglects, for example, the effect of the denominator in a logit model.

97.3.3 Heterogeneity in Plans Generation

No extended research has yet been undertaken to see whether MATSim could adopt the strategy of regularly introducing new random starting solutions to avoid local minima. One challenge: the generation of such random plans would result—in most cases—in nonsensical plans, which would need to be removed through computationally expensive iterations. See Feil (2010) for difficulties in constructing optimal alternative plans for the number and sequence of activities. One possibility is to initially allocate a small set of randomly chosen alternative day plans and measure their similarity throughout the simulation. There is no research on a replanning technique involving switching of the day plan activity order, which again would produce more dissimilar plans than currently possible.

Moyo Oliveros and Nagel (in press) and Nagel et al. (2014) report computational experiments where a randomized Pareto router is used to generate a different route every time it is called. The Pareto router randomly draws a trade-off between different utility function contributions, such as fare/toll, travel time, access/egress time, then computes an optimal route based on the resulting generalized cost. The randomized approach considerably reduces the requirement that the router be consistent with the scoring function. The randomized Pareto router generates a collection of possible routing solutions; each agent then can select one that best suits its own trade-off between monetary budget and time pressure. Heterogeneity is generated by each synthetic traveler having a different trade-off.

The approach of Horni (2013, also see Chapter 27 of this book) can also be seen in this sense: attaching a random error term to each location-person-pair means that two persons—at exactly the same home location with exactly the same activity pattern—will select different locations for their activities. So far, this describes heterogeneity between persons. However, the approach also generates more heterogeneity per person, since the destinations attractive to each synthetic person will be spatially more spread out than they might otherwise be.

97.3.4 Deliberate Search Strategies

The need for a strategies meta-search, as sketched by Arthur (1994), remains an open question. In the MATSim context, all decisions, based on explicit search for alternatives, can be studied to see how far apart choice set generation strategies of discrete choice modeling (which draw from the universal choice sets), are from explicit construction strategies. One idea would be to observe the second step to see what impact these would have on the results and the policy conclusions.

A good example is parking search (Waraich et al., 2012), for which multiple strategies have been documented and which explains the empirical observations (Shoup, 2005). In a discrete choice model context, distribution of parking preferences can mimic choice strategies, but the approach could not capture the context-specific strategy choice. In MATSim, this set of strategies could become the object of a meta-search to see which agents would retain which strategies and how these would be used by the agents. Empirical work could be conducted to see whether these sets and their distributions match travelers' practices.

In the same vein, one could look at the leisure destination choice, where different strategies can be observed, although they have not yet been subject of empirical study. If longer-term choices were added to the MATSim framework, residential and workplace choice could also be considered.

MATSim plans' convergence towards a single optimal structure can be seen as the absence of search strategies on the plan level. This overlaps strongly with the question of number choice and activities sequence, where these alternative plans are needed.

97.3.5 Transients Versus the Notion of "Learning"

As in other similar simulations, interpretation of the relaxation procedure (iterations) of MATSim is unclear. Sometimes, the relaxation process is ascribed a behavioral interpretation: for example, day-to-day learning, where the transition process, as well as the final equilibrium, has a meaning (Liu et al., 2006, p.128), (Nagel and Barrett, 1997, p.523). An opposite viewpoint exists, where the relaxation procedure is just a numerical method to compute the equilibrium state, or states, without a behavioral basis of the transitions. Although this interpretation ambiguity has not hampered development process so far—also because, in discrete choice modeling, the same ambiguity exists—it is obvious that future questions about adoption of behavioral versus statistical methods require MATSim interpretation.

97.4 Scoring/Utility Function and Choice

97.4.1 Discussion of the Present Scoring Function Mathematical Form

The current logarithmic MATSim activity scoring function,

$$S_{act,q} = \beta_{dur} \cdot t_{typ,q} \cdot \ln(t_{dur,q}/t_{0,q})$$

(cf. Equation (3.2), with $t_{0,q}$ as defined by Equation (3.7), is not suitable for modeling activity addition and dropping (Feil, 2010, p.127f). As already stated in Section 3.3.1, the problem is that, at the typical duration, i.e., at $t_{dur,q} = t_{typ,q}$, all activities generate the same score, independent of their actual duration; thus, it makes sense to first drop the longest activity, since that generates the least amount of utility *per time unit*. This is typically the home or work activity; dropping this first clearly is nonsensical.

The property that all activities have the same utility at their typical duration is obtained by computing the value of the parameter $t_{0,q}$ from the condition[4]

$$const \cdot \beta_{dur} \stackrel{!}{=} S_{act,q}\Big|_{t_{dur,q}=t_{typ,q}} = \beta_{dur} \cdot t_{typ,q} \cdot \ln(t_{typ,q}/t_{0,q}) \tag{97.3}$$

and therefore

$$t_{0,q} = t_{typ,q} \cdot \exp\left(-\frac{const}{t_{typ,q}}\right) \tag{97.4}$$

(cf. Equation (3.7) with $10h \rightarrow const$ and $prio \rightarrow 1$).

97.4.2 Utility at Typical Duration Proportional to Typical Duration

As an alternative, Equation (97.3) could be replaced by the requirement that all activities at their typical durations yield a score proportional to their typical duration, i.e.,

$$const \cdot \beta_{dur} \cdot t_{typ,q} \stackrel{!}{=} S_{act,q}\Big|_{t_{dur,q}=t_{typ,q}} = \beta_{dur} \cdot t_{typ,q} \cdot \ln(t_{typ,q}/\tilde{t}_{0,q}) \ , \tag{97.5}$$

leading to

$$\tilde{t}_{0,q} = t_{typ,q} \cdot \exp(-const) \ . \tag{97.6}$$

That is, replacing Equation (97.4) by Equation (97.6) in the MATSim scoring function would make, in first order, all activities equally likely to drop. Starting with MATSim release 0.8.x, there will be a config switch

[4] The notation $S\Big|_{x=a}$ means that the expression S shall be evaluated at $x = a$.

```
<param name="typicalDurationScoreComputation" value="..." />
```

where `uniform` will mean the old behavior and `relative` the behavior suggested in this section. Consequences of this still need to be investigated.

97.4.3 S-Shaped Function

A new S-shaped function, proposed by Joh (2004), was tested by Feil (2010, p.129ff). It starts horizontally at zero duration, bends upwards with a positive second derivative and then changes curvature to the normal negative second derivative at longer durations. The function was motivated by the observation that utility functions with infinite (i.e., diverging) first derivative at duration zero lead to "doing a little bit of everything". This is also known from regular consumer theory, with activities replaced by goods. The S-shaped function avoids that problem, instead implying that activities below a certain duration should instead be dropped completely.

Estimates of the new function, based on the Swiss microcensus, were provided; this estimation, however, was difficult, which was attributed to the non-linearities of the function, and to the difficulty in generating sufficiently large choice sets. In addition, many daily activities and their durations were not chosen freely by the individual. Consequently, it is currently *not* advisable to replace the MATSim default scoring function with the Joh/Feil approach.

97.4.4 Heterogeneity of Alternatives and Challenges of Estimation

It is normal to differentiate between types of alternatives in the average; for example, trips by different modes, or with different purposes, are commonly assigned different time values. However, there are also large deviations from those averages between travelers. A possible approach to address this are so-called taste variations, i.e., to make some parameters of the utility function random, but fixed per agent; parameters of this randomness are made part of the choice model estimation. However, some of this apparent randomness may, in fact, be causal. For example, higher values of time for commuting than for leisure may be caused by the more crowded daily schedule on working days. Similarly, the strength of a preference for public transit may be caused by the walking distance to that transit stop serving the desired destination.

Simulation systems such as MATSim should be able to explicitly integrate alternatives' heterogeneity. Besides the aspects discussed in Section 97.4, it is desirable to know how the following aspects influence the scoring function:

- access/egress times to/from public transit,
- transfers between public transit lines,
- crowding in public transit vehicles,
- parking search,
- types of parking (on-street, guarded, sheltered, etc.), and
- personal or household income.

Clearly, this list is not complete.

For most of these aspects, initial studies within the MATSim context are available, see, e.g., Moyo Oliveros and Nagel (2012, in press) for access/egress times and transfers to PT (Public Transport), Bouman et al. (2013), Sun et al. (2014a) or Erath et al. (in preparation) for crowdedness, Waraich et al. (2013b) for parking search, or Kickhöfer et al. (2011) for income. In some cases, it is even possible to configure these elements through the standard config file, completely without Java programming. It is also quite clear that these issues were addressed outside the MATSim context.

A challenge, however, is that it is normally not possible to just collect and combine results from different studies, for the following reasons:

- It is not correct to take an estimated utility function and then change the list of attributes. For example, if walking access/egress to/from PT is not included in the estimation, then its effect may be partially be included in the alternative-specific constant, or in the population density (which may serve as a proxy for the density of PT access points). Just adding the effect of walking access/egress from some other study is thus incorrect.
- Even when MATSim is able *in principle* to add these elements, doing so in practice poses a considerable statistical challenge. For example, one may assume that households inside a zone self-select their precise residential location based on the PT accessibility of their regular destinations. In contrast, a typical MATSim initial demand generation process will first assign residential locations, then generate their destinations, e.g., their workplaces. Thus, persons who might reach their destinations easily by PT might have their MATSim residences far away from the relevant PT stop.

Therefore, it is necessary to estimate the scoring function with exactly those attributes available in the simulation with sufficient precision. Kickhöfer (2009) has, in consequence, re-estimated his scoring function based on data from Vrtic et al. (2008). For the same reasons, it is not possible to combine functions independently estimated for different choice dimensions. This is not even possible when they all contain monetary units. For example, assume that one has

$$\ldots + \beta_t \, t_{trav} + \beta_m \, \Delta m + \ldots$$

for mode choice, and

$$\ldots + \beta_r \, \rho + \tilde{\beta}_m \, \Delta m + \ldots$$

for parking, where t_{trav} is the travel time, ρ is congestion in a parking lot, and Δm is, in all cases, the change in the monetary budget, e.g., cost for gas, PT fare, or parking. Even then, it is not possible to say

$$\ldots + \beta_t \, t_{trav} + \beta_m \, \Delta m + \beta_r \, \frac{\beta_m}{\tilde{\beta}_m} \, \rho + \ldots \, ,$$

since that confuses the scale parameters of the two separate estimations.[5] If only travel time is available as common attribute, the situation deteriorates, since time valuation in MATSim is non-linear; thus, operating points for linearization need to be defined, or found by iterative procedures (Horni, 2013, p.75ff).

As a long-term perspective, one could also imagine estimating choice models directly inside MATSim, possibly taking hints from UrbanSim which has such an approach at its core. An early step in this direction within MATSim using Cadyts (see Chapter 32), is described by Flötteröd et al. (2012).

97.4.5 Agent-Specific Preferences

MATSim scenarios so far consider a relatively small set of agent attributes, essentially because of missing data suitable for deriving detailed large population attributes (Müller and Flötteröd, 2014). Some studies, however, used larger sets of attributes. Grether et al. (2010); Kickhöfer et al. (2011) estimated individual income-contingent utility functions. Horni and Axhausen (2012b,a)

[5] Realistically, combining separate estimations via their conversion in monetary terms may be the best one can do in many situations.

incorporated agent-specific travel preferences and individual income-dependent marginal utilities of money; preference values, however, were assigned randomly. Because consideration of agent-specific preferences is one of the cornerstones of agent-based microsimulations, future work should exploit this avenue.

97.4.6 Frozen Randomness for Choice Dimensions Other Than Destination Choice

For destination choice, an iteration-stable random error term has been successfully applied to incorporate unobserved heterogeneity not included by the stochasticity of the co-evolutionary process (see Chapter 27). Other choice dimensions might also benefit from explicit agent-specific error terms. This could incorporate a mechanism to generate the error terms with the correct correlation structures.

More formally: The current MATSim choice process can be interpreted as maximizing, for each agent n,

$$U_{ni} = V_i + \tilde{V}_{ni} + \boldsymbol{\beta}^T \boldsymbol{\eta}_{\mathbf{ni}} + \tilde{\varepsilon}_{ni} \,, \tag{97.7}$$

where V_i is the systematic utility of alternative i, $\tilde{V}_{ni}$ is an agent-specific addition, $\boldsymbol{\beta}^T \boldsymbol{\eta}_{\mathbf{ni}}$ describes randomness inserted by the network loading model (see Equations (49.4) and (49.5)), and $\tilde{\varepsilon}_{ni}$ is remaining (unexplained) noise. Two challenges are:

- $\tilde{V}_{ni}$ denotes aspects often assumed as random in choice models, but fixed in typical MATSim runs. An example is walking distance to the next PT stop, which may have to be assumed as random in an estimation context based on travel analysis zones, but which is fixed in the context of a MATSim run.

  → To be consistent, a choice model and a MATSim implementation used together should use exactly the same disaggregated attributes.
- In most MATSim runs, the $\tilde{\varepsilon}_{ni}$ are either assumed as zero (`BestScore`), or are parameterized by the MATSim choice model (`ChangeExpBeta` or `SelectExpBeta`), which can be interpreted as that the $\tilde{\epsilon}_{ni}$ are re-drawn from the distribution every time a choice is made. This leads, for example, to purely random "logit" switchers between a base and a policy case (e.g., Grether et al., 2010).

  Moreover, the default plans removal (Sections 4.5.1.4 and 97.3.2) has a tendency to remove all alternatives except the best, effectively setting the $\tilde{\varepsilon}_{ni}$ to zero for *all* typical MATSim configurations when run for sufficiently many iterations.

  This is acceptable in situations where most of the noise can be assumed to be in the $\tilde{V}_{ni}$ and/or the $\boldsymbol{\beta}^T \boldsymbol{\eta}_{\mathbf{ni}}$ (and thus generated with hopefully plausible structure by the MATSim dynamics); this may be the case for the choice dimensions of route, mode, and time. It is clearly wrong for locations where $\tilde{\varepsilon}_{ni}$ subsumes preferences that are specific to each person-alternative-pair and that often cannot be included into the $\tilde{V}_{ni}$. For example, a person may have a strong preference for "swimming" in a situation where the data only knows about "leisure" facilities. In this situation, a possible approach is to generate random but "frozen" $\tilde{\varepsilon}_{ni}$, as described in Chapter 27.

  → One should thus evaluate how far, and how, a similar approach could be introduced for choice dimensions beyond destination choice.

97.4.7 Economic evaluation

As the above Section 97.4.6 already indicates, further work is desirable to better understand the connection between MATSim scores and utility from consumer theory. At face value, Equation (97.7) could be taken as each agent's utility. As also discussed in Section 51.2.5, problems arise when the $\tilde{\epsilon}_{ni}$ are not explicitly known for each person-alternative-pair *ni*.

In many past MATSim studies, their effect has therefore been parametrized by a logit choice model (with the use of `Change/SelectExpBeta`). In these cases, the logsum of all plans' scores of an agent is each agent's correct utility measure. See Section 51.2.5.1 for details.

In other MATSim studies, the $\tilde{\epsilon}_{ni}$ were effectively assumed to be zero (with the use of `BestScore`). In these cases, the highest of all plans' scores of an agent is each agent's correct utility measure. Because of the `BestScore` plan selection model, the plan with the highest score will at the same time also be the selected plan. See Section 51.2.5.2 for details.

For some of us, it seems attractive to move into the direction of working with frozen randomness, as discussed in Section 97.4.6. That approach would combine the advantages of the two approaches from above: It would inherit the parsimonious interpretation of the `BestScore` approach, where only the plan with highest score (= the selected plan) of each agent needs to be considered, and at the same time include the idea of random utility theory, and, hence, the effect of the ϵ_{ni} on individual choices.

Another avenue of research is to further push the understanding of the econometric and statistical properties of the MATSim choice modeling, cf. Section 51.2.5.5.

97.5 Double-Queue Mobsim

The standard MATSim mobsim QSim implements a single-queue model as described in Chapter 50. The associated FD (flow vs. density) is horizontal for medium densities, and falls to zero very steeply at very high densities. This is consistent with the fact that a vehicle leaving a link opens up its space already in the next time step; jam patterns thus have a backwards traveling speed of $L/1\,s$ (L is the length of respective link) rather than the conventional approx. 15 kilometers per hour (see also Charypar et al., 2009).

The JDEQSim (Section 4.3.2) and the deprecated DEQSim (Section 43.1) implement a double-queue model with backward traveling gaps. Recently, the QSim has also implemented a double-queue variant (Agarwal et al., 2015a), switched on by using a "holes" option in the config; it is, however, not yet thoroughly tested.

97.6 Choice Dimensions, in particular, Expenditure Division

As shown in Section 46.2.2.3 and pictured in Figure 46.1, the Zürich group targets a fuller scheduling model. In addition to standard choice dimensions (printed in red in the cited figure), numerous choices are subject to ongoing research. In particular, "expenditure division" is unexplored not only in MATSim, but in transport planning in general; studies have focused on single-travelers or household-based groups. The field's understanding of both expenditure patterns and allocation styles inside a household are poor, which is no surprise since relevant questions are missing in surveys. First tests for necessary survey works are currently in process and will lead to a better understanding of activity participation and time values that travelers bring to their decisions.

97.7 Considering Social Contacts

Apparently, social contacts, within households as well as within extended social networks, have a substantial influence on travel decisions, particular for social activities in leisure time (Kowald et al., 2009). An early social networks study, in context, but not based on MATSim, is by Marchal and Nagel (2005). Further work based on or, again, in context of MATSim was undertaken by Hackney (2009); Illenberger (2012); Illenberger et al. (2011); Kowald et al. (2009). The most recent work on joint trips is reported in Chapter 28. Despite this range of valuable work, future research is required on this topic, especially for leisure destination choice (Horni, 2013).

Acronyms

ABM Activity-Based Model. 510, 513
ABMS Agent-Based Modeling and Simulation. 203, 204
AI Artificial Intelligence. 24, 534
API Application Programming Interface. xxxi, xxxii, 9, 231, 232, 255, 267, 290, 294, 296, 297, 488, 544
ARC Australian Research Council. xxiii
ARTEMIS Assessment and Reliability of Transport Emission Models and Inventory Systems, a harmonized emission model in the EU, possibly a predecessor of HBEFA, version 3.1. 248
ASET Available Safe Evacuation Time. 440
ASTRA BundesAmt für STRAssen, French: Office fédéral des routes OFROU, Italian: Ufficio federale delle strade USTRA. xx

BABS Bundesamt für Bevölkerungsschutz, Switzerland. xxii
BASt Bundesanstalt für Straßenwesen. 434
BCA Benfit-Cost Analysis. 353, 360, 362
BDI Belief Desire Intention. xxiii, 201–210
BEV Battery Electric Vehicle. 95
BfS Bundesamt für Statistik – Federal Statistical Office. xxii
BMBF Bundesministerium für Bildung und Forschung/Federal Ministry of Education and Research. xxi, xxii
BVG Berliner Verkehrsbetriebe (started as Berliner Verkehrsaktien-Gesellschaft). xxii, 113, 369

CA Cellular Automaton. 403
Cadyts Calibration of Dynamic Traffic Simulations. See Chapter 32 and Flötteröd(accessed 2015). 213–215, 372, 433–435, 540
CART Committee on Advanced Road Technology. xxiv
CAS Complex Adaptive Systems. 3, 533–535
CCEM Competence Center Energy and Mobility. xxii
CDR Call Detail Record. 397, 486, 488
CEMDAP Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns (Bhat et al., 2008). 372

CO_2 Carbon Dioxide. 407
ComPuTr Complexity in Public Transport. xxiv
CONICYT Comisión Nacional de Investigación Científica y Tecnológica – National Commission for Scientific and Technological Research. xxiii
COOPERS Co-Operative Networks for Intelligent Road Safety. xxi
CREATE Campus for Excellence and Technological Enterprise. 379
CSV Comma-Separated Values. 257
CTI Commission for Technology and Innovation. 295
CUDA Compute Unified Device Architecture, a parallel computing platform and API by NVIDIA. 267, 303

DAAD Deutscher Akademischer Austauschdienst – German Academic Exchange Service. xxii
DB AG Deutsche Bahn AG. 431
DB ML AG DB Mobility Logistics AG. 431
DEQSim Discrete Event Queue Simulation. 6, 38, 267, 285, 542
DFG Deutsche Forschungsgemeinschaft. xx–xxii, 295
DMQ District Métropolitain de Quito, Quito Metropolitan District, Ecuador. 473–475
DRT Demand Responsive Transport. 152, 527, 528
DRVs Disaster Response Vehicles. 461, 462, 465–467
DTA Dynamic Traffic Assignment. 213, 315, 320, 326, 513, 518
DTD Document Type Description. 43, 61
DVRP Dynamic Vehicle Routing Problem. 146–148, 151, 152, 471, 528

EBPTR Events-Based Public Transport Router. 124, 127, 128, 130, 131
EMEF Enquesta de Mobilitat en dia Feiner, Barcelona's annual transport survey. 398
EMME Equilibre Multimodal Multimodal Equilibrium. See `http://www.inrosoftware.com/en/products/emme/`. 50, 62, 115, 495, 523, 524, 544
EMME/2 Version 2 of EMME. 115, 495, 497, 515
EMT Emission Modeling Tool developed by Hülsmann et al. (2011) and Kickhöfer et al. (2013), see Chapter 36. 247–251, 383
EMU Expected Maximum Utility. 358, 550
EPSG European Petroleum Survey Group. 13
ERA European Research Action – Country consortia. xxii, xxiv
ERD Entity Relationship Diagram. 256, 257
ERP Electronic Road Pricing. 381
ESRI Environmental Systems Research Institute. 224, 274, 276, 440, 515
ETH Eidgenössische Technische Hochschule. xx–xxii, 159, 219, 290, 309, 310, 313, 379, 397, 497
EU European Union. xx–xxiv, 360, 384, 543
EUNOIA Evolutive User-centric Networks for Intraurban Accessibility `http://www.eunoia-project.eu`. xxiii, xxiv, 397
EV Electric Vehicle. 92–95, 529–532

FCL Future Cities Laboratory. xxii, 265, 290, 379
FD Fundamental Diagram. 347, 348, 351, 542
FEATHERS Forecasting Evolutionary Activity-Travel of Households and their Environmental Repercussions (Arentze and Timmermans, 2006). 176, 372
FIFO First In, First Out. 79, 152, 459, 460
FIT feed-in tariff. 529
FONDECYT Fondo Nacional de Desarrollo Científico y Tecnológico. xxiii

GA Genetic Algorithm. 394

GB Gigabyte. 11, 128, 131, 132, 310, 510, 511
GDP Gross Domestic Product. 429
GFIP Gauteng Freeway Improvement Project. 429
GIS Geographic Information System. 13, 240, 254, 277, 280, 281, 386, 408, 497, 503
GmbH Gesellschaft mit beschränkter Haftung. 503, 506
GPL GNU General Public License. 161
GPLv2 GNU General Public License version 2.0. 290
GPLv3 GNU General Public License version 3.0. 213
GPS Global Positioning System. 13, 19, 115–118, 120, 155, 223, 501
GRIPS GIS-based Risk analysis, Information, and Planning System for the evacuation of areas. xxi
GTFS General Transit Feed Specification. xix, 116, 117, 120, 121, 486, 491, 493, 524
GTHA Greater Toronto and Hamilton Area. 523
GUI Graphical User Interface. 10, 21, 254, 257, 272, 274, 278, 281, 440

HAFAS HaCon Fahrplan-Auskunfts-System. 110
HBEFA Handbook on Emission Factors for Road Transport, version 3.1. See `http://www.hbefa.net`. 247–252, 543
HHTSD Household Travel Survey Data. 497
HITS Household Interview Travel Survey. 379, 380
HOV Highly Occupancy Vehicle. 407
HPCC High-Performance Computing Clusters. 37
HSAR Household Sample of Anonymised Records. 448

IATA International Air Transport Association. 422
ICT Information and Communications Technology. 145, 485
IDE Integrated Development Environment. 66, 295, 309
IfV Institut für Verkehrswesen/Institute for Transport Studies. 312, 313
ILS Institut für Land- und Seeverkehr – Institute for Land and Sea Transport Systems. 290, 467
INTS Irish National Travel Survey. 414
IPF Iterative Proportional Fitting. 373, 379
ITS Intelligent Transport Systems. 534
ITSOS Intermodal Transport Simulation & Operation System. 503–506
IVT Institut für Verkehrsplanung und Transportsysteme – Institute for Transport Planning and Systems. xxii, 159, 290, 377

JAR Java ARchive. 10, 35, 66, 100
Java SE Java Standard Edition. 9
JAXB Java Architecture for XML Binding. 292
JDBC Java Database Connectivity. 255
JDEQSim Java Discrete Event Queue Simulation. 6, 38, 90, 263, 267, 268, 285, 347, 349–351, 542
JOGL Java OpenGL. 231
JOSM Java Open Street Map Editor. 65, 66

KiD Kraftfahrzeugverkehr in Deutschland. 161
KPI Key Performance Indicator. 478
KTH Kungliga Tekniska Högskolan – Royal Institute of Technology. xxiv
KTI Kommission für Technologie und Innovation. xxii
KVMZH Kantonales Verkehrsmodell Zürich. 155, 375
KWM Kinematic Wave Model. 348, 350, 351

LANL Los Alamos National Laboratory. 308
LAU Local Administrative Unit. 400, 431
LTA Singapore Land Transport Authority. 380
LTDS London Travel Demand Survey. 448, 449
LUTI Land-Use and Transport Interaction. 403

MATSim Multi-Agent Transport Simulation. See `http://www.matsim.org`. xix–xxii, xxxi, xxxii, 3–7, 9–21, 23, 24, 26, 27, 29–32, 35–42, 47–51, 55–58, 61, 62, 65–67, 70, 77, 78, 83–93, 95, 97–100, 105–107, 109–113, 115, 121, 123, 124, 126–128, 130–132, 135, 136, 140, 142, 143, 146–151, 155–157, 159, 165–168, 170–172, 175, 177–179, 183, 188, 190–192, 196, 197, 200–210, 214, 215, 219–221, 223–227, 231, 237–245, 247, 249–255, 257, 259, 263, 264, 267, 268, 272–274, 278, 280, 281, 283–286, 289, 290, 292–301, 303, 304, 307–315, 320–322, 324, 326–332, 335, 337–344, 347–351, 353–356, 358–360, 362, 363, 367–369, 371–373, 375–377, 379, 381, 383, 385–387, 391–395, 399–402, 405, 408, 409, 411, 413, 414, 416, 417, 419–421, 423, 427–429, 431, 433, 434, 436–438, 441, 445, 449, 451, 453, 457, 459, 461, 462, 467, 469, 473, 474, 477–479, 482, 483, 487, 489, 491–495, 497, 499, 501–506, 509–511, 513, 515, 518–520, 523–525, 528–530, 532–542, 549, 553, 554
MAUP Modifiable Areal Unit Problem (Openshaw, 1984). 242
MB Megabyte. 11, 130, 131
MFD Macroscopic Fundamental Diagram. 387
MH Metropolis-Hastings. 342, 343
MiD Mobilität in Deutschland (MiD 2002, Follmer et al., 2004). 383, 432, 434
MIMOSA Modélisation Isentrope du transport Méso-échelle de l'Ozone Stratosphérique par Advection. 248
MINTE MItigating Negative Transport Externalities in industrialized and newly industrializing countries. xxi
MLIPF Multi-Level Iterative Proportional Fitting. 451
MNL Multinomial Logit Model. 41, 169, 286, 338, 354, 357, 363, 423, 501
mobsim Mobility simulation. Also, depending on the context and specific mobility simulation capabilities, called network loading, traffic flow simulation or synthetic reality. 4–6, 11, 12, 16, 17, 19, 21, 27, 31, 36, 37, 127, 130, 134–136, 170, 191, 192, 197, 202, 226, 227, 230–232, 263, 267, 268, 286, 292, 297, 298, 301, 303, 304, 309, 310, 312, 347, 350, 542, 551
MOVES Motor Vehicle Emission Simulator. See `http://www.epa.gov/otaq/models/moves/`. 248
MPI Message Passing Interface. 267, 310
MRE Mean Relative Error. 394
MRT Mass Rapid Transit, Singapore. 130, 381
MSA Method of Successive Averages. See, e.g., Liu et al. (2007). 31, 32, 41, 322, 324, 325, 338
MTC Metropolitan Transportation Commission. 486–488
MVI An OTFVis Movie File, not to be confused with the "Musical Video Interactive" file usually abbreviated mvi. 225–231

NFP Nationales Forschungsprogramm. xxii
NFPA National Fire Protection Association. 389
NHTS National Household Travel Survey. 429
NO_2 Nitrogen Dioxide. 384
NOK Norwegian Krone. 526
NPTS US Nationwide Personal Transportation Survey. 386
NRF Singaporean National Research Foundation. xx, xxii
NYBPM Nederlandse Organisatie voor Wetenschappelijk Onderzoek – Netherlands Organization for Scientific Research. xxiv

NYBPM New York Best Practice Model. 453

O-D Origin-Destination. 126, 224, 302, 316–319, 325, 371, 372, 386, 391, 405, 408, 409, 422–427, 429, 431–436, 469, 471, 482, 487, 497, 501, 515, 518, 519, 530, 552
OAG Official Airline Guide: `http://www.oag.com/`. 420–422
ODBC Open Database Connectivity. 254
OpenGL Open Graphics Library. 231, 232
OS Operating System. 226, 231
OSM OpenStreetMap (OpenStreetMap, 2015). xix, xxiv, 20, 58, 62, 65, 66, 220, 242, 245, 273, 274, 276, 281, 387, 391, 400, 401, 405, 408, 411, 413, 414, 429, 432, 438–441, 469, 473, 477, 482, 486, 491, 493, 501, 507, 528, 551
OTFVis On The Fly Visualizer. 19, 225–233, 483

PCU Passenger Car Unit. 459
PEMS Transportation Performance Management System. 487
PETRA PErsonal TRansport Advisor. xxiv
PhD Philosophiae Doctor – Doctor of Philosophy. 290, 308, 312
PHEM Passenger Car and Heavy-duty Emission Model. 248
PHEV Plugin Hybrid Electric Vehicle. 94
POI Point of Interest. 414
POWSCAR Place of Work, School or College Census of Anonymised Records. 414
PSim Pseudo-Simulation. 263–266, 268
PSRC Puget Sound Regional Council. 495
PT Public Transport. 133, 134, 357, 491, 493, 539–541
PTO Public Transit Operator. 478
PV Photovoltaic Panel. 529–531

QGIS Quantum GIS. 13, 50, 391, 445

RAM Random Access Memory. 11, 226, 268, 309, 510, 511
RMIT Royal Melbourne Institute of Technology. xxiii
RSET Required Safe Egress Time. 440

SANRAL South African National Roads Agency Limited. 429
SATURN Simulation and Assignment of Traffic to Urban Road Networks (SATURN, 2014). 405
SBPTR Schedule-Based Public Transport Router. 123, 128, 130, 131
Scala SCAlable LAnguage. See `http://www.scala-lang.org/`. 50
SCCER Swiss Competence Center for Energy Research. xxii
SEC Singapore-ETH Center for Global Environmental Sustainability. 379
SI Système International (d'Unités): International System (of Units). 56
SMA Seoul Metropolitan Area. 497
SNF Schweizerischer Nationalfonds. xx, xxii, 294
SOC State of Charge. 95
SOP Signal Optimizer. 473, 474
SPI Service Provider Interface. 298
SPSS Statistical Package for the Social Sciences. 497
SQL Structured Query Language. 254, 257
SrV System repräsentativer Verkehrsbefragungen (Ahrens et al., 2009). 372
SUE Stochastic User Equilibrium. 316, 317, 319–322, 324, 326
SUMO Simulation of Urban Mobility. See `http://www.dlr.de/ts/sumo/en/`. 50
SURPRICE Sustainable mobility through Road User Charging. xxii

TASHA Travel Activity Scheduler for Household Agents. 368, 523
TAZ Traffic Analysis Zone. 389, 431, 433, 486–488, 515, 516
TESF Transportation Energy Simulation Framework. 93–95
TfL Transport for London. 447
THELMA Technology-centered ELectric Mobility Assessment. xxii
TML Transport & Mobility Leuven. 377
ToPDAd Tool supported Policy Development for regional Adaptation. xxii, 376
TransCAD Transportation Computer Assisted Design. 397
TRANSIMS TRansportation ANalysis and SIMulation System. See `https://code.google.com/archive/p/transims/`. 3, 309, 310, 448, 534
TRENoP Transport REsearch with Novel Perspectives. xxiv
TRV Trafikverket – Swedish Transport Administration. xxiv
TSA Transport System Analysis. 399
TTS Transportation Tomorrow Survey. 523
TU Technische Universität. xx, xxi, 50, 290, 369, 507

UCL University College London. xxiv
UE User Equilibrium a.k.a. Wardrop's first principle. 316, 317, 319–322
UIB Universitat Autónoma de Barcelona. xxiii
UK United Kingdom. xxiv
URL Uniform Resource Locator. 10
UTC Temps Universel Coordonné – Coordinated Universal Time. 422
UTM Universal Transverse Mercator. 12, 13
UVEK Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation. 374

V2C Vehicle to Community. 529, 532
V2G Vehicle-to-Grid. 94, 95
VGI Voluntary Geographic Information. 242
VISSIM Verkehr In Städten – SImulationsModell. See `http://www.ptv.de`. 248
VISUM Verkehr In Städten – UMlegung. See `http://www.ptv.de`. 50, 63, 106, 110, 115, 292, 369, 383
VPL VerkehrsPLanung. See `http://www.ivt.ethz.ch/vpl/`. 290
VRP Vehicle Routing Problem. 95, 146, 147
VSP VerkehrsSystemPlanung und Verkehrstelematik – The Transport Systems Planning and Transport Telematics group at TU Berlin. See `https://www.vsp.tu-berlin.de`. 290, 467
VTTS Value of Travel Time Savings. 26, 28, 354, 356, 360

WKT Well-Known Text. 13

XML Extensible Markup Language, see `http://www.w3.org/XML/`. 14, 57, 61, 70, 250, 254, 255, 257, 274, 275, 292, 298, 299, 309, 440, 445, 504

Glossary

Activity The central element of modern activity-based modeling (see below). 4, 221, 552
Activity location People perform activities at activity locations, which can be as small as one single building or large zones. In MATSim, activity locations are often further specified by using the facility object, which (in addition to others) define open times. xix, 14, 550
Activity-based Modern transport planning assumes that "*travel demand is derived from activity demand*" (Jones, 1979; Bowman, 2009a,b; Bhat and Koppelman, 2003; Ettema and Timmermans, 1997; Bowman and Ben-Akiva, 1996, 2001). People travel because they want to perform a certain activity, which is best captured by activity-based models with activities the central element of modeling. 4
Agent According to Wooldridge (2009, p. 21) an agent is "*a computer system situated in an environment, capable of autonomous action in this environment to meet its delegated objectives*". 307
Algorithm A set of operations to solve a specific problem. 7, 30
ArcGIS ESRI's geographic information system. 254, 503, 504, 506

C++ An object-oriented programming language with full control of memory management. 6, 285, 309, 310
C# An object-oriented .NET programming language. 310
Configuration file The main configuration screw for MATSim, often just referred to as `config file` or as `config.xml`. Also see config. xxxi, xxxii, 11–14, 16, 18, 19, 21, 35–40, 44, 48, 49, 55, 56, 58, 79, 86, 226, 227, 241, 268, 284, 290, 294, 298, 504, 549, 550, 554
Configuration object The object in the MATSim code containing configuration options. It can be modified by the config file, but also by other mains, in particular by scripts-in-Java. 549
Contribution An extension contributed by the MATSim community and hosted in the MATSim repository. See `http://matsim.org/extensions`. xxxi, 48, 49, 92, 95, 121, 135, 140, 146, 157, 159, 226, 259, 272, 274, 281, 293, 294, 296, 437, 443, 471, 528

Eclipse The standard integrated development environment (IDE) used by the MATSim developers. 295, 309
Equilibrium A system state where are competing forces are balanced. 7

Event Small pieces of information reported by the mobsim, describing a simulation object action at a specific time. xxxii, 17, 127, 298, 301–304

Extension Core MATSim uses only a config file, population file and network file, corresponding to the book's part I. An extension is any code that extends this core MATSim, corresponding to this book's part II. They hook to MATSim via the extension points described in Chapter 45. xxxi, xxxii, 39, 48, 49, 290, 294, 298, 299, 311, 549

Facility An optional element in MATSim to further specify an activity location. 57, 221, 549

Framework A software concept, providing generic functionality and application-specific software. It is selectively changed by user code. MATSim is currently a framework, but is developing towards also being useful as a library/toolbox. xix, xx, 4, 188, 302, 303

Geocoding Adding geographic coordinates to locations identified by addresses. 501

Git A free and open source distributed version control system. 292, 295

GitHub A web-based Git repository hosting service, see `https://github.com/`. 9, 292–294

Google Earth Google's virtual globe. 13

Identifier A name that labels an object in a unique way. 12, 77, 78, 299

Iteration Numerical equilibrium search methods, such as MATSim, are iterative. A MATSim run is thus composed of a configurable number of iterations. xix, 11, 16, 550

Java A modern, object-oriented, cross-platform programming language run in virtual machines. xxxii, 4, 11, 35, 37, 38, 42, 48–50, 56, 59, 61, 62, 78, 120, 210, 219, 220, 225, 226, 231, 254, 255, 267, 285, 290, 292, 293, 298, 299, 303, 309–311, 409, 510, 539, 549–551

Javadoc Source code documentation compiled from javadoc annotations in the source files. 88, 173, 295

Jenkins A software tool for continuous integration. 295

Large-scale Denoting large, extended simulation scenarios, often modeling complete cities, or even countries. 3, 140, 313, 461, 502

Leg A plan element, part of a trip performed with a specific mode. In transport planning, this is often called a stage. 15, 302, 551, 552

Library A set of routines providing services to independent programs. Usually not executable on its own. 10

Link A network component representing streets. 14

Linux A unix-like operating system released by Linus Torvalds at the end of 1991. 10, 309

Logsum The Expected Maximum Utility (EMU) for a user that has several options. Computed as the logarithm of the sum of exponential functions. 241, 244

Mac OS The operating system by Apple Inc. developed for their Macintosh computer systems. 10, 309

MATSim run A configurable number set of iterations, typically ending with an equilibrium solution of transport supply and demand. 4, 10, 16, 36, 298, 550

Maven A build automation tool tailored to Java. 10, 66, 259, 292, 294, 295, 297

Microsimulation The modeling of the temporal development of a real-world system, or process, by explicitly considering the interactions of micro units such as individuals or vehicles. For concise definitions and further information, see e.g., Miller (1996, Section 2) or Banks J (2001, p. 3), Bossel (2004) or Orcutt (1957), who is often referred to as the inventor of microsimulation. xxxi, 176, 309, 413, 414, 424, 541, 550, 551

Model A universal concept reducing a real system to the aspects relevant for understanding or solving a specific problem. 327, 551

Module According to Merriam-Webster (http://www.merriam-webster.com), a module is "one of a set of parts that can be connected or combined to build or complete something" or more specifically "a part of a computer or computer program that does a particular job". That is, "module" is not a very specific term, and, in consequence, modules exist in MATSim at many levels. xxxii, 57, 221, 304, 311

Multimodal Combining different means of transport. 38, 49, 79, 106, 112, 135, 136, 140, 416, 453, 477, 486, 523, 524

NAVTEQ A geographical information system data provider, particularly for navigation maps. 67, 117, 374, 380

Node An element of a MATSim network representing intersections. Note that intersections are not modeled explicitly in MATSim, i.e., cars do not interact at intersections. 14

Objective function A central element in optimization problems, among others. An objective function, sometimes also called loss or cost function, is mapping of candidate solutions onto a real number. 165, 551, 552

OmniTRANS A transport Modeling Software Platform. 115

Osmosis Command line Java application for processing OSM data. See http://wiki.openstreetmap.org/wiki/Osmosis. 62

Plan The agent's day schedule and, after run completion, an associated score. xix, 4, 15, 301

QSim The standard MATSim mobsim. 6, 19, 36–38, 42, 44, 77–79, 106, 135, 191–193, 195, 196, 263–268, 298, 347, 350, 351, 542

Replanning The stage when agents modify their plans. xix, 4, 12, 15, 297, 301, 304, 479, 501, 504

Scenario In MATSim context, a scenario is defined as: the combination of specific agent populations, their initial plans and activity locations (home, work, education), the network and facilities where, and on which, they compete in time-space for their slots and modules, i.e., behavioral dimensions, which they can adjust during their search for equilibrium. xix, xxxi, xxxii, 6, 9, 11, 303

Score After execution in the infrastructure, the agents' day plans are evaluated through an individual objective function, the MATSim scoring function. Also see utility. xxxii, 4, 24, 304, 551, 552

Scoring see score. 304

Senozon AG A spin-off company founded by two core developers of MATSim. xxii, 110, 219, 290, 291, 295, 392, 443, 467, 497, 503, 552

Simulation Evaluating a model capturing the temporal development of a real-world system or process. 327

Stage A stage is part of a trip, performed with a single mode. In MATSim called leg. 550

Study The basic organizational unit of research in empirical science. Comparable to the experiment in natural sciences. 4

SustainCity A project addressing the modeling and computational issues of integrating modern mobility simulations with the latest microsimulation land use models, see http://www.sustaincity.org. 405

Teleportation Moving vehicles from origin to destination, at a predefined speed, without considering interactions in the network. 16, 42, 44, 79, 106, 135, 136, 419, 505

Teleported see teleportation. 105, 374, 375, 380, 386, 525

Traffic assignment Traditionally, this is the last step of the four-step model, calculating trip distribution over the different routes between O-D-pairs. Dynamic traffic assignment may additionally consider departure time choices. xxxii

Trip The connection between two activities, composed of multiple legs. 17, 550

UrbanSim Software-based simulation system for supporting planning and analysis of urban development. See `http://www.urbansim.org`. 283, 284, 405, 495, 540

Utility A central economic concept representing satisfaction through goods consumption. The MATSim score can be interpreted in utility units. xxxii, 24, 551

Utility function A MATSim agent's objective function. See also score. xix

Via The Senozon AG visualizer. 19, 47, 292, 392, 443, 445, 446, 450, 483, 526

Windows An operating system developed by Microsoft, first released in 1985. 10, 309, 310

Symbols and Typographic Conventions

Symbols

Variables

c	monetary costs
d	distance
t	time
U	utility variable ($V + \varepsilon$)
V	systematic component of utility variable
S	score (= the un-interpreted MATSim value)
β	utility function coefficient
$\hat{\beta}$	estimated utility function coefficient
ε	random component of utility variable
φ	replanning share
μ	scale parameter of the multinomial logit model

Indices and Subscripts

i	index of plans
k	index of iterations
n	index of agents
q	index of plan activities
ℓ	index of activity locations/facilities

Typographic Conventions

The `listing-format` is used for text that you typically see when you run MATSim, i.e., program snippets, commands, on-screen computer output, input and output file names and content, and configurations to be specified in the config file. Larger snippets are shown as complete listings.

```
... main( ... ) {
    // construct the config object:
    Config config = ConfigUtils.xxx(...) ;
    config.xxx().setYyy(...) ;
    ...
}
```

Important passages are *emphasized*.

Vertical bar | is a separator for mutually exclusive items. For example: “`KeepLastSelected | BestScore | SelectExpBeta`”

Math mode, e.g., $x = 42$ is used for mathematical terms.

Acronyms are given with the abbreviation and the description following in parenthesis (e.g., MATSim (Multi-Agent Transport Simulation)) on first occurrence, later only the abbreviation (e.g., MATSim) is given.

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The MATSim (Multi-Agent Transport Simulation) software project was started around 2006 with the goal of generating traffic and congestion patterns by following individual synthetic travelers through their daily or weekly activity programme. It has since then evolved from a collection of stand-alone C++ programs to an integrated Java-based framework which is publicly hosted, open-source available, automatically regression tested. It is currently used by about 40 groups throughout the world. This book takes stock of the current status.

The first part of the book gives an introduction to the most important concepts, with the intention of enabling a potential user to set up and run basic simulations.

The second part of the book describes how the basic functionality can be extended, for example by adding schedule-based public transit, electric or autonomous cars, paratransit, or within-day replanning. For each extension, the text provides pointers to the additional documentation and to the code base. It is also discussed how people with appropriate Java programming skills can write their own extensions, and plug them into the MATSim core.

The project has started from the basic idea that traffic is a consequence of human behavior, and thus humans and their behavior should be the starting point of all modelling, and with the intuition that when simulations with 100 million particles are possible in computational physics, then behavior-oriented simulations with 10 million travelers should be possible in travel behavior research. The initial implementations thus combined concepts from computational physics and complex adaptive systems with concepts from travel behavior research. The third part of the book looks at theoretical concepts that are able to describe important aspects of the simulation system; for example, under certain conditions the code becomes a Monte Carlo engine sampling from a discrete choice model. Another important aspect is the interpretation of the MATSim score as utility in the microeconomic sense, opening up a connection to benefit cost analysis.

Finally, the book collects use cases as they have been undertaken with MATSim. All current users of MATSim were invited to submit their work, and many followed with sometimes crisp and short and sometimes longer contributions, always with pointers to additional references.

We hope that the book will become an invitation to explore, to build and to extend agent-based modeling of travel behavior from the stable and well tested core of MATSim documented here.

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MATSim
Multi-Agent Transport Simulation

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