# Integration of activity-based and agent-based models

## Recent developments for Tel Aviv, Israel

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**Integration of Activity-Based and Agent-Based Models: Recent developments for Tel Aviv, Israel**

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# ABSTRACT

This paper describes how the initial MATSim model of Tel Aviv has been updated and extended since its first version presented by Bekhor et al. *(*see *1*). Main innovations are the inclusion of road pricing in the scenario and the incorporation of destination choice as an endogenous choice in the model. By conducting several experiments, it is shown that this implementation is able to fully replace the ad-hoc destination choice part of the first model. Furthermore, the model has been improved by several substantial updates in terms of data, such as population, network, zonal information, traffic counts, road pricing, trip length distribution.

The outcomes of the calibrated model are compared to real world data as well as to the outcomes of the original model using EMME/2 for the traffic assignment. It is shown that the MATSim model reproduces the traffic flows very accurate and even better than EMME/2.

## INTRODUCTION

Activity-based models have become popular in the last decade. Some examples for such models can be found for regions inside the United States (e.g. Portland, Oregon *(2)*, Dallas-Forth Worth, Texas *(3)*, Sacramento, California *(4)* and New York *(5)*) as well as for other countries (e.g. Jakarta, Indonesia *(6)* and the Netherlands *(7)*).

In recent years, researches started to integrate activity-based models into agent-based traffic assignment frameworks *(e.g. 8, 9)*. Results from such studies indicate that the results produced by agent-based simulations are not only comparable to those resulting from static assignments but also have a higher level of detail from a temporal point of view.

Another example for combining an activity-based model with an agent-based simulation is the MATSim model of Tel Aviv which was presented at TRB in 2011 *(see 1, for details)*. This paper reports recent updates and improvements of that model. Besides updated (population, network, zonal information), also additional (traffic counts) and new data (road pricing, trip length distribution) was available and included in the model. Work conducted can be separated into four steps:

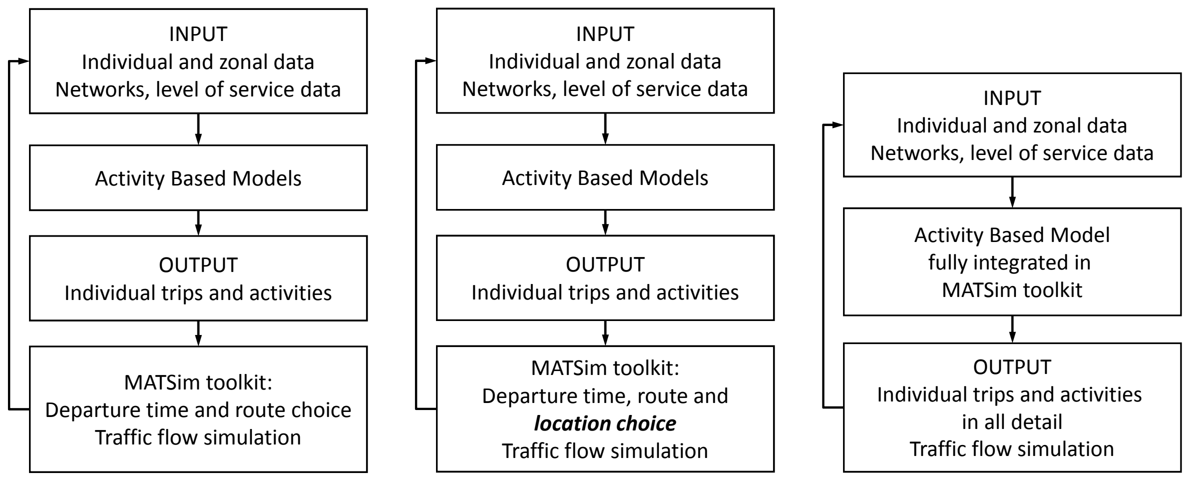
1. Updating the existing MATSim model using the latest data.
2. Adding two new features to the model: road pricing and destination choice.
3. Re-run and calibrate the model.
4. Analyzing the outcomes.

In the next section, the structure of the model is discussed. Afterwards, the simulation framework MATSim is introduced. Then, the process to create the initial demand for the MATSim model is described. The next section depicts the calibration process and presents the outcomes of the calibrated MATSim model. Finally, an outlook is given.

## MODEL STRUCTURE

Figure 1 shows the structure of the MATSim model of Tel Aviv. Traditionally, activity-based models use a structure comparable to sub-figure (a), but instead of a dynamic agent-based model, a static assignment module is used which needs OD matrices as input. As as result, the high resolution (individual agents instead of aggregated flows) gets lost. This drawback was overcome by using MATSim for the traffic assignment. In the first implementation of the model, only departure time and route choice optimization were part of the implemtation in MATSim. However, feedback from MATSim to the activity-based still needs to be aggregated data.

As part of the work presented here, also location choice was added to the model's implementation (sub-figure (b)). The long-term goal is to reach the structure shown in sub-figure (c). There, the activity-based model is fully integrated into MATSim, i.e. it is not necessary anymore to aggregate the outcomes from the traffic flow simulation. Instead, the entire optimization loop is using individual agents.




(a) Past (b) Present (c) Future

**FIGURE 1 Structure of the MATSim model of Tel Aviv**

## MATSIM

MATSim is a framework for iterative, agent-based transport system micro-simulations written in Java. It is continuously developed since more than 10 years by teams at ETH Zurich and TU Berlin as well as senozon AG, a spin-off company founded by former members of both institutes. MATSim consists of several modules that can be used independently or as part of the framework. Moreover, it is possible to extend the modules or replace them with new implementations. Balmer *(10)* and Balmer et al. *(11)* give a detailed description of the framework, its capabilities and its structure.

Due to its agent-based approach, every person in the system is modeled as an individual agent in the simulated scenario. Each agent has personalized parameters such as age, gender, available transport modes and scheduled activities. MATSim has been applied to several scenarios all over the world. A large-scale scenario of Switzerland including over 6 million agents simulated on a high resolution network with 1 million links is presented by Meister et al. *(12)*. Other models have been implemented e.g. for Gauteng, South Africa *(13)*, the Greater Toronto and Hamilton Area, Canada *(9, 8)*, Padang, Indonesia *(14, 15)* and Singapore *(16)*.

Figure 2 shows the structure of a typical iterative MATSim simulation run. After creation of initial demand, agents' plans are modified and optimized in an iterative process until a relaxed system state (typically a user equilibrium) is found, which allows to use the results for analyses, under the assumption of a Nash equilibrium *(17)*.

The loop shown in the figure contains *execution (simulation)*, *scoring* and *replanning* elements. Within the simulation module, agents' plans are executed. A description of MATSim's

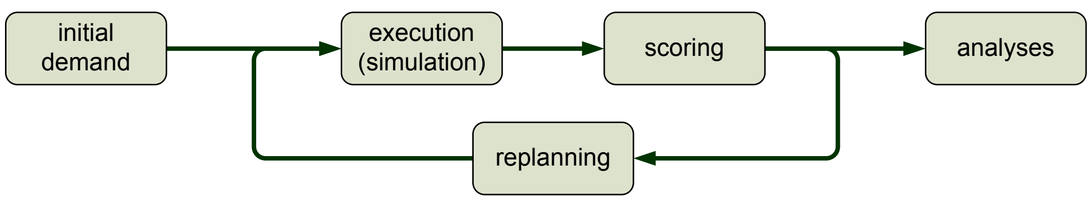



**FIGURE 2 Structure of the iterative MATSim loop**

mobility simulations is given in the next section. After executing the simulation, the scoring module uses a utility function *(18)* to calculate the executed plans' quality. Based on this, the replanning module creates new plans, e.g. by varying start times, durations and locations of activities, as well as routes and modes used to travel from one activity to another.

## CREATION OF THE INITIAL DEMAND

In this section, the input data as well as the performed steps to update and extend the MATSim model of Tel Aviv are described. Data was provided by Ayalon Highways Ltd.

### Population

The population was created based on the outcomes of the population generator from the Tel Aviv activity-based model *(19)*, which were exported to a csv-file. The attributes contained in the file are listed and described in Appendix A (Tables 1 and 5). Each line represents a single person, including socio-demographic attributes and a daily schedule containing up to six activities.

To simplify the conversion to a MATSim population, the timing of the activities, i.e. their start- and end times, was defined in a pre-processing step by the project partner. In the Tel Aviv activity-based model, those times are only defined by time periods (*Combined Time Of Day*; see Appendix A, Table 6; e.g. MO (early morning): 03:00 - 06:00). For the file used as input, those periods were replaced by seconds after midnight. The values were selected randomly within the given period *(see 1, for details)*. To keep the computational effort manageable—for the preparation of the csv-file as well as for the MATSim simulations—only 10% of the population were included in the file and therefore included in the MATSim population file.

Additional data was provided for external trips. In this context, this are trips where origin and/or destination are not located within the study area. As a result, they are not included in the prepared population file. For each of the three types (car, truck, commercial), values for three different time periods (AM, OP, PM) were available. For each combination of type and period, a csv-file was available containing three columns: from-zone, to-zone and number of trips. Within the zones, the location where the trips start respectively end has been selected randomly.

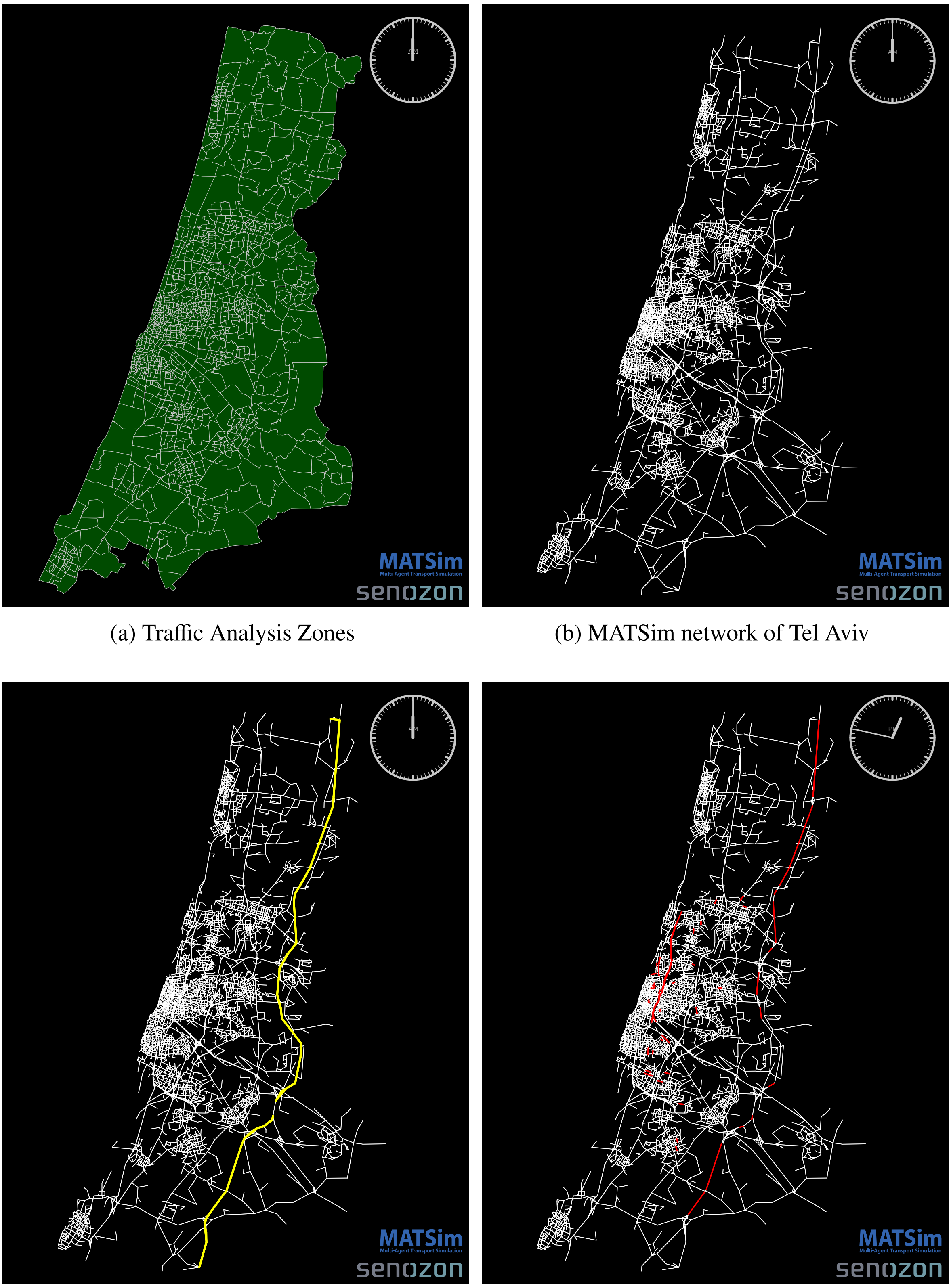
Finally, internal and external population files were merged in a single file. A person's affiliation (internal respectively external) was stored in an additional file. The simulation used this information to determine how a person's daily schedule should be optimized (internal: timing, destination and route choice; external: route choice only).

### Traffic Analysis Zones

The modelled area is divided into 1'219 traffic analysis zones (TAZ; see Figure 3(a)). The geometry was provided as shape file *(20)*. Attributes available for each zone are listed in tables 2 to 4 in Appendix A. The attributes contain information related to the population living in the zone as well as the types of activities that can be performed.

### Network

Input data for the network was taken from the EMME/2 model *(see 21)* which is used by the Assignment Unit of the existing Tel Aviv Model. Details about the conversion process can be found in Gao et al. *(9*). Turning restrictions were considered by adapting the network structure, resulting in a network containing 9'474 nodes and 18'570 links (see Figure 3(b)). Capacities of



(a) Traffic Analysis Zones

(b) MATSim network of Tel Aviv

(c) MATSim network of Tel Aviv with tolled roads

(d) MATSim network of Tel Aviv with counted roads

**FIGURE 3 Initial demand creation**

some major roads were corrected manually because they were obviously too low (e.g. noticably lower than traffic counts indicated).

## Facilities

Facilities are another input component of a MATSim scenario. Basically, a facility is a construct that defines a place where activities can be performed. Therefore, a facility can roughly be interpreted as a building (a park where people can go for a walk would also be modelled as a facility allowing leisure activites).

For each facility a set of activities was defined that can be performed there (e.g. work, shop, leisure). This set depends on the zone where the facility is located, i.e. is derived from the attributes in the zonal file. Facilities were created for all links where buildings could be expected (e.g. not next to highways).

When agents optimize their daily schedule, one option is to relocate activities to other places. When doing so, they can only choose facilities (respectively zones) where the desired activity is possible.

Moreover, capacities can be assigned to facilities, e.g. selected based on zonal attributes. If a facility is overcrowded, agents performing activity there will gain less utility and therefore might select another facility to optimize their daily plan. However, this feature is not used so far in the current implementation of the MATSim Tel Aviv model. To do so, detailed information related to the available capacities per zone would be necessary.

## Road Pricing

For highway number 6, a list of links which are tolled was provided. Figure 3(c) shows the location of those links in the MATSim network. Highway number 1 is also tolled but with a flebile toll. As in the original model, this toll is taken into account by adapting the capacity of the road network.

## Traffic Counts

Traffic count data was provided from three different sources (Ayalon highway, Runway number 6 and some selected links) in 15 minute time bins. Since MATSim expects 1 hour time bins, the data sets were prepared accordingly. Figure 3(d) shows the location of all links in the MATSim network where count data was available. Comparing figures 3(c) and 3(d) shows that for most of the tolled links on highway number 6 count data is available.

Additionally, the outcomes from the EMME/2 model used in the Assignment Unit of the existing Tel Aviv Model were provided. There, only peak data is available for three periods of the day (AM, OP and PM). To be able to compare those values to the count data and the outcomes of the MATSim model, the peak values in the count data in the corresponding time spans were identified.

## Trip Length Distribution

A last dataset which was provided contained the length distribution of car trips for the various activity types produced by the EMME/2 model (see Figure 4). Real world data, e.g. from a travel survey, has not been available so far. To compare the data to the outcomes of the MATSim model, the data was assigned to distance classes with a width of 1 km. Figure 5 shows the

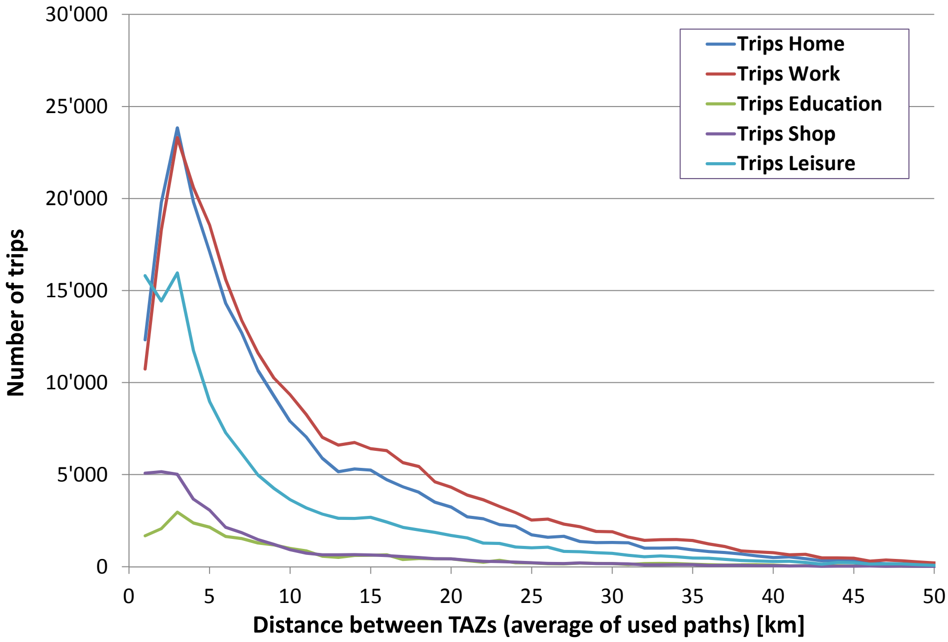
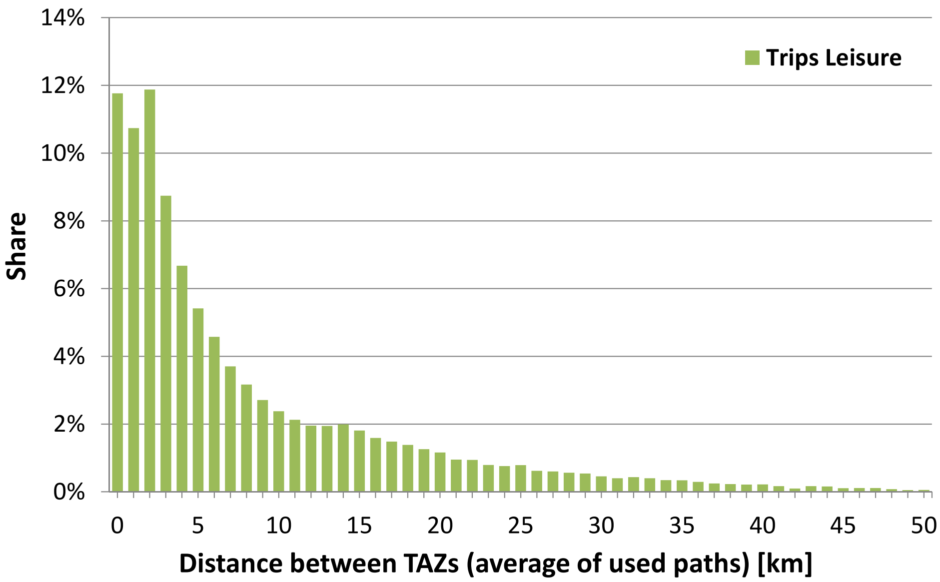
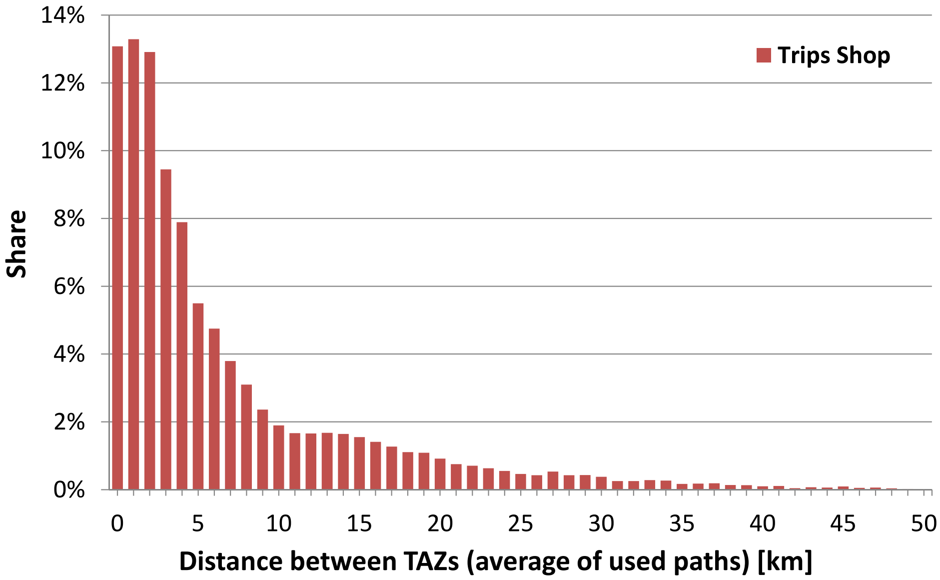



**FIGURE 4 Trip length distribution per activity type**

distributions for shopping and leisure activities. Using MATSim's destination choice extension *(see 22, 23, for details)*, the distribution of those two activity types could be reproduced.




(a) Shopping




(b) Leisure

**FIGURE 5 Trip length distribution for optimized activity types**

# INTEGRATION OF THE MATSIM DESTINATION CHOICE MODULE

## MATSim Destination Choice Module

As described by Horni *(23)*, MATSim now includes destination choice in the iterative equilibration process. The module is based on an MNL model. As always with MATSim, the utility function can be parameterized with estimated values or with values derived from calibration using observed network measures such as distance distributions.

In this paper, estimated values were taken from the activity-based model of Tel Aviv as an initial state, where the random error terms are calibrated to match the activity-based model distance distributions.

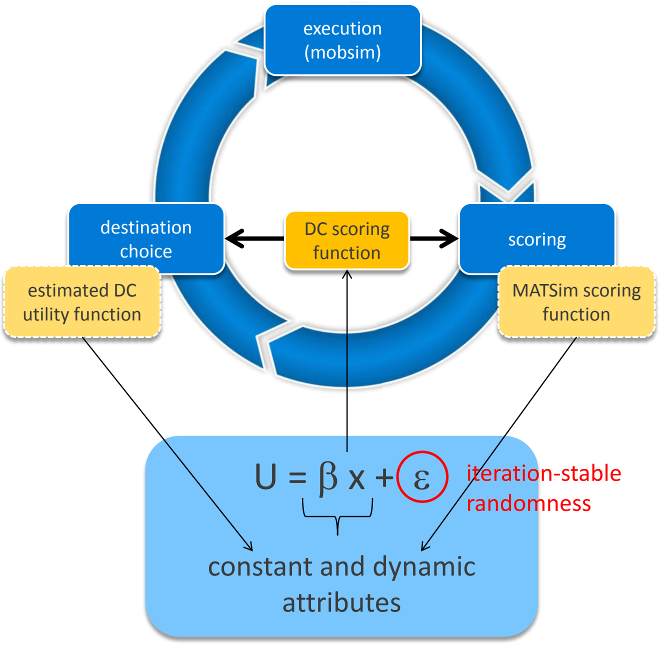



**FIGURE 6 MATSim Destination Choice**

## Consistency of Destination Choice

Different than in the previous MATSim Tel Aviv model, destination choice is now integrated consistently; both in the replanning part as well as in the scoring part the same utility function is applied (see Figure 6). In other words, the former potentially poor convergence due to random selection of destinations based on probabilities is now solved by computing quenched randomness *(24)*, meaning that the random elements of the choices, here the random error terms, remain identical for any person-destination pair over all iterations and do not randomly fluctuate anymore between iterations.

## Integration

Although a non-zonal, combined estimated model relating time, route, and destination choice would be optimal, for backwards compatibility and in absence of such an estimation, the zone-based estimations are applied. The dynamic factors were already included in the standard MATSim destination choice utility function. The constant factors of the Tel Aviv utility function are added now. As the shopping and leisure values for $logsumModeChoice \cdot betaDriverTime \cdot 3600s/h$ (shopping 4.44 utils/h; leisure: 7.12 utils/h) are quite similar to the standard MATSim disutility for traveling (6 utils/h) *(e.g., 25)* no extensive scaling was necessary in parameterizing the new MATSim destination choice utility function.

# SIMULATION RESULTS

## Calibration

Using a model based on the input data described previously, several simulation runs were conducted to calibrate the model. Depending on an agent's type (internal agents created based on outcomes from the activity based model or external agents based on external trips data), different strategies to optimize its daily schedule were applied. While external agents could only adapt their routes, internal agents additionally were allowed to change their activity timings (start time and duration) and the location of their shopping and leisure activities.

As part of the calibration process, the values of the following parameters were optimized with the objective to match the traffic count data as well as the travel distance distributions:

**Flow capacity factor**
This factor influences the traffic flow model of the mobility simulation. Its value defines how many vehicles can leave a link within a time step.

**Flow and storage capacity factors**
How many vehicles can be physically present on a link at a time is defined by the storage capacity factor. It also directly influences the traffic flow model.

**Destination choice parameter**
For each optimized activity type a parameter is defined which influences the shape of the distribution.

**Road toll**
A final parameter that was optimized are the costs of the tolled regions of the road network.

## Trip Length Distribution

Figure 7 shows the outcomes of the destination choice calibration runs. Each sub-figure shows the results of $\varepsilon$ values from 1 to 10. In addition, also the reference values from the EMME/2 model are included in the plots. For leisure activities, a value of 7.0 produces best results; for shopping an optimal value of 4.0 was found.

The outcomes of the calibrated model are shown in Figure 8. Its sub-figures show the trip length distribution of both activites as well as the EMME/2 model. Comparing the outcomes shows a very good match.

After having found the optimal parameter setting for MATSim's destination choice module, another simulation run was conducted. In contrast to the previously performed simulations, the initial population was altered. Shopping and leisure activities were relocated to the closest location to their previous activity, which resulted in a trip length distribution with a single bar to the very left, i.e. all trips are performed within a 1 km radius.

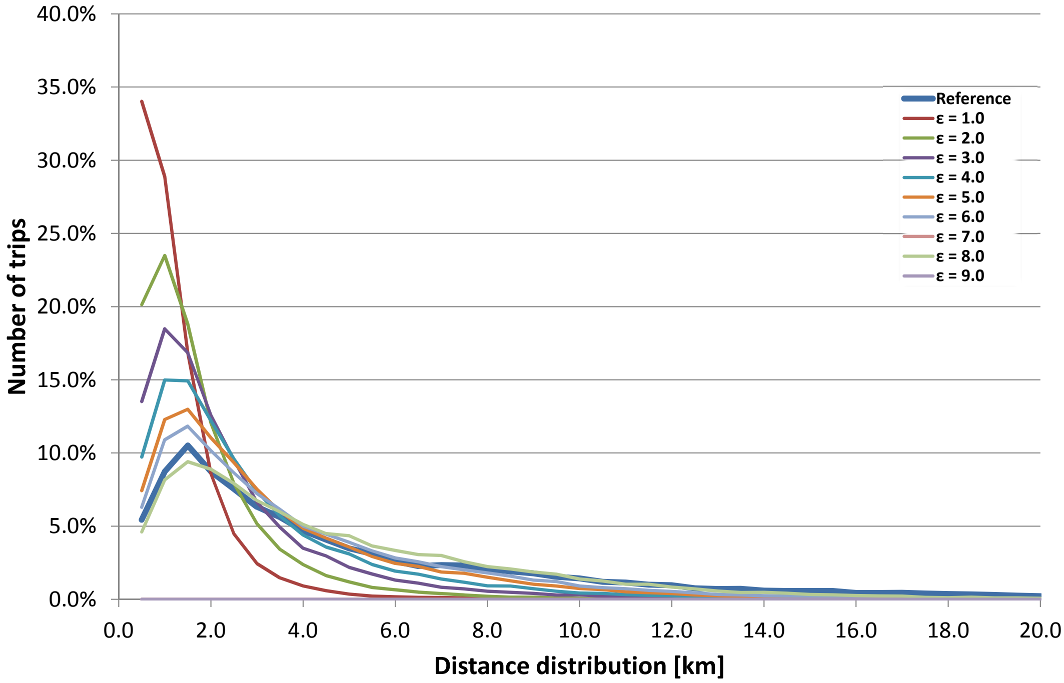
Comparing the outcomes to those from the calibrated model shows again a very good match. This proves that MATSim's destination choice module is able to reproduce the distance distribution even if the initial population does not contain any information about it (see Figure 9).

## Road Pricing

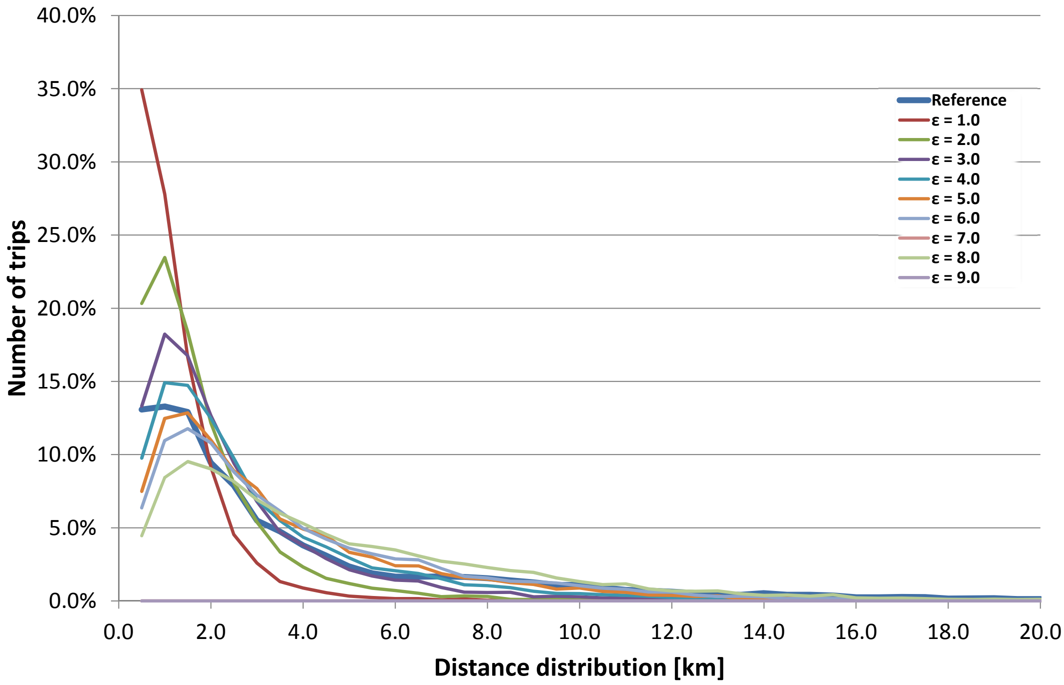
After calibrating road tolls, an additional simulation run was conducted where road pricing was disabled. Comparing the outcomes of runs with and without road pricing shows that enabling it improves the results. However, comparing the number of simulated cars per time period to real world counts indicates that there too many trips in the OP period and a too few in the AM and PM hours.

## Traffic Counts

Figure 10 compares the outcomes of the calibrated MATSim model to real world data (the black diagonal lines) and the EMME/2 results. In the left column, the peak values for the three time periods are compared. While EMME/2 produces to much traffic, the MATSim results are a bit

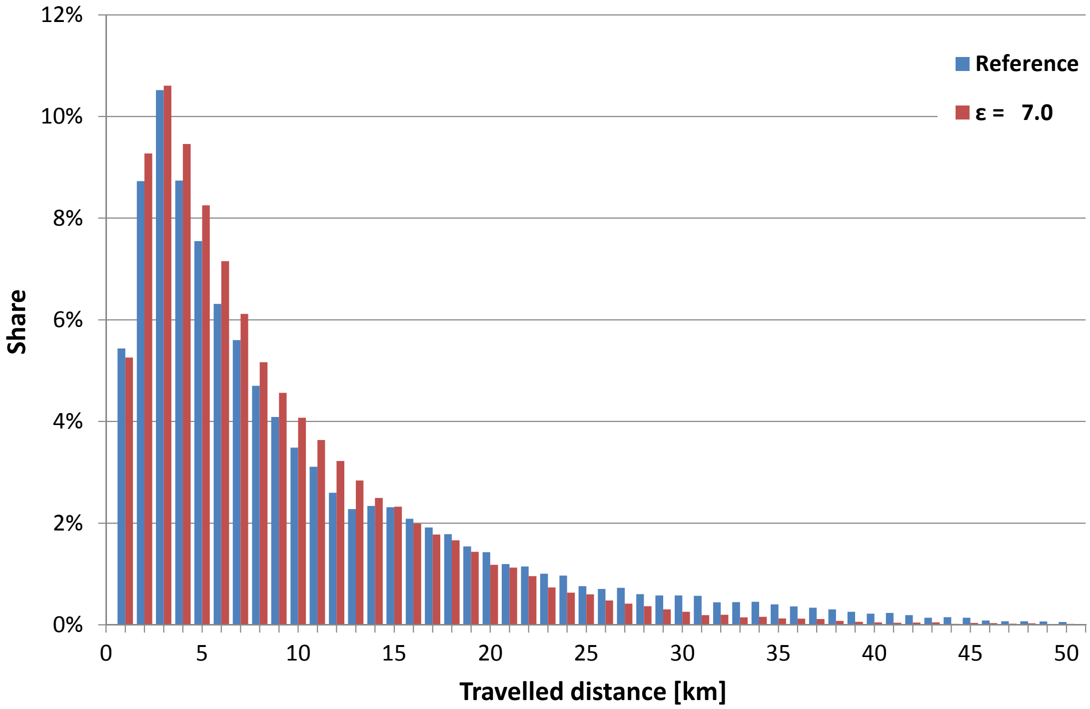



(a) Leisure

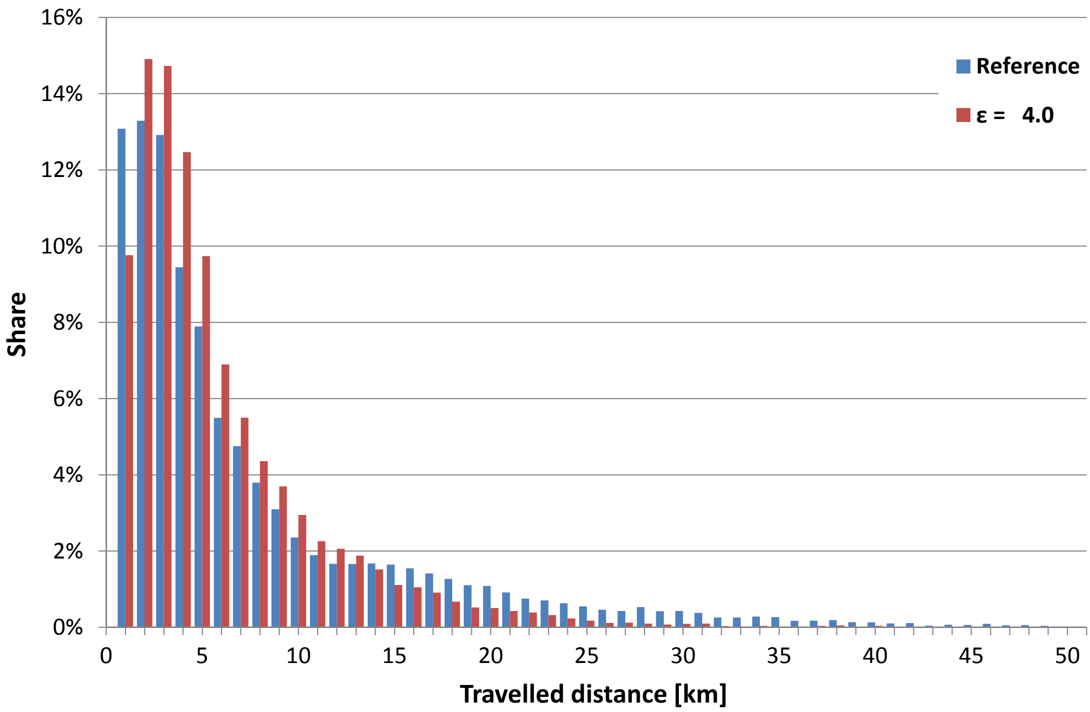



(b) Shopping

**FIGURE 7 Destination choice calibration**

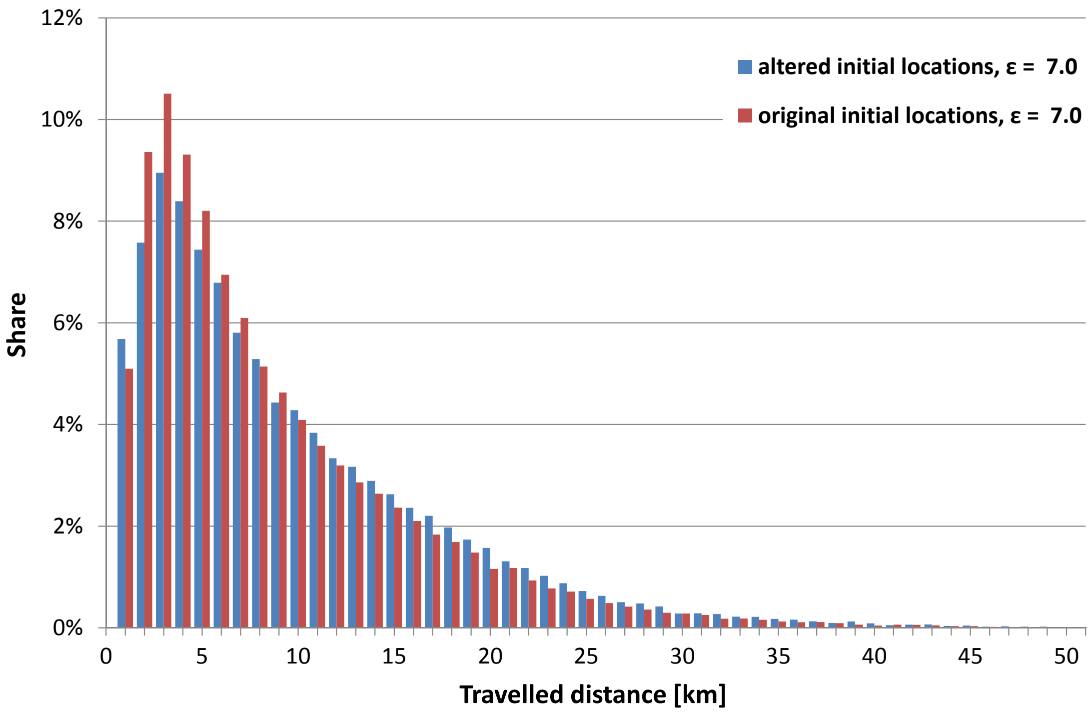



(a) Leisure

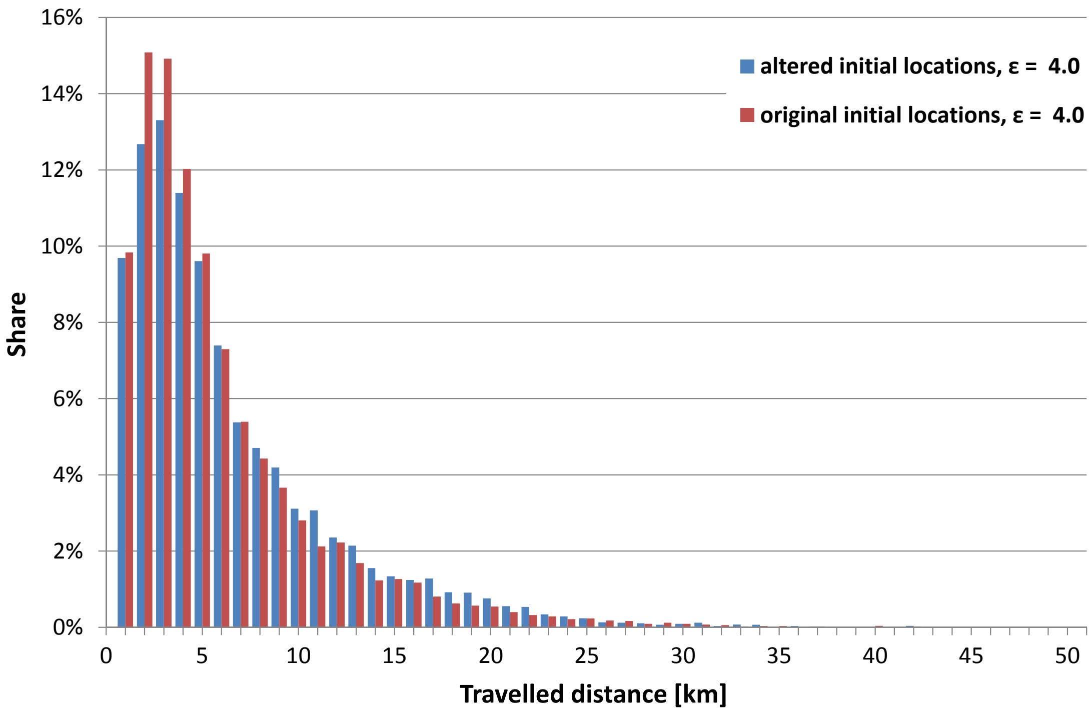



(b) Shopping

**FIGURE 8 Calibrated destination choice: MATSim vs. EMME/2**




(a) Leisure



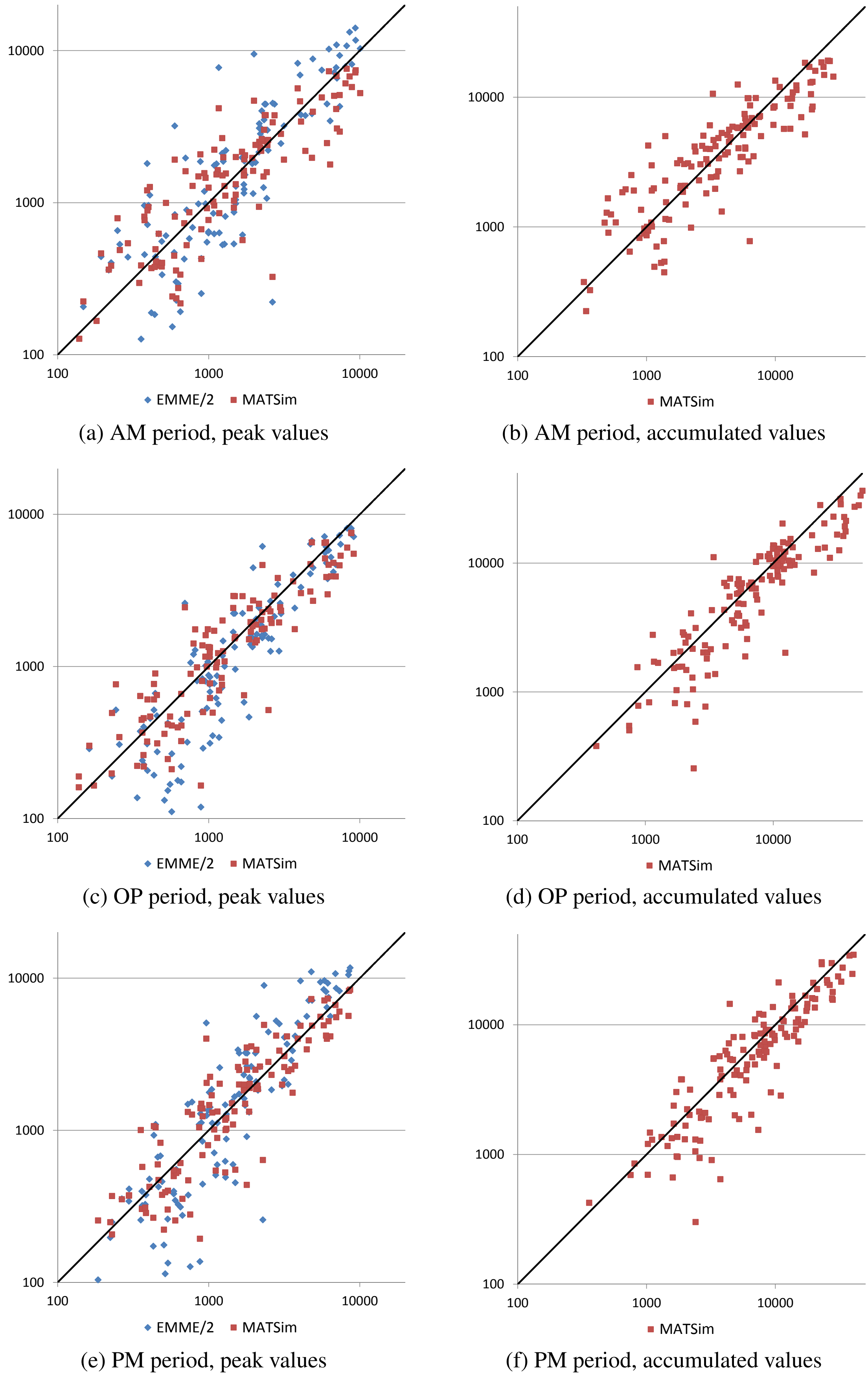

(b) Shopping

**FIGURE 9 Calibrated destination choice: Original vs. altered initial destinations**

lower than the real world values. For the AM and PM peaks MATSim produces more accurate results (RMSE[1] for EMME/2 vs MATSim: AM - 1552 vs. 1240; PM: 1502 vs. 873); for the OP period, the EMME/2 results are slightly better (903 vs. 975).

The right column compares the accumulated values of the three time periods of the MATSim outcomes to real world values. Again, the results show a very good match. This analysis cannot be performed for the EMME/2 results since they are only available for the peak hours in the periods.

[1]root-mean-square error - smaller values correspond to a better fit




(a) AM period, peak values

(b) AM period, accumulated values

(c) OP period, peak values

(d) OP period, accumulated values

(e) PM period, peak values

(f) PM period, accumulated values

**FIGURE 10 Traffic counts calibration results**

# OUTLOOK

To sum up, the update and extension of the MATSim model for Tel Aviv was presented in the previous sections. First, the model's input data (population, road network, traffic counts, road pricing) was updated. Second, the destination choice related parts of the original Tel Aviv model's utility functions were implemented in MATSim. In combination with MATSim's destination choice module, it is not necessary anymore to provide agent's leisure and shopping destinations in the initial population data. In a next step, this could be extended to other activity types such as education or work. The implementation of those utility functions is another step toward a full integration of the Tel Aviv activity-based model into MATSim.

Compared to the previous version of the model, the run time has increased from 2 hours to a few hours due to the additional effort for the location choice. The increase highly depends on the qualitity of the initially selected locations. If they are selected according to the activity-based model, run time duplicates to 4 hours. In contrast, the runtime of the experiments with the altered initial locations was above 10 hours since a lot more iterations where neccessary to reach a user equilibrium.

A look at the outcomes of traffic count comparisons indicates that the MATSim model reproduces the traffic flows very accurate and even better than EMME/2. The limiting factor now is data availability; with further data—such as travel survey diaries containing people's trip chains—available, the quality of the MATSim model could be improved even further. In a currently planned follow up project, further functions of the activity-based model shall be integrated of the MATSim model of Tel Aviv. Results of that project will be reported in a subsequent paper.

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# APPENDIX

## Documentation of population and zonal attributes

The subsequent tables are taken from the documentation of the Tel Aviv activity schedule model *(19, Tables 2.1 to 2.6)*.

**TABLE 1 Fields in the Personal File**

| Field name | Description |
|---|---|
| NEWID | Temporary field for storing indexes during processing |
| PERSONID | Original personal ID |
| FACTOR | Expansion factor for given record |
| AGE | Age of person |
| GENDER | Gender (1 - male, 2 -female) |
| STUDY | 1 - is student, 2 - no |
| YRSTUDY | Years of study: 1: no, 2: to 8, 3: 9-12, 4: 13-15, 5: 16+ |
| ECONBRCH | Economic branch of work, according to CBS definition |
| HHID | Household ID |
| NUMVEH | Number of vehicles in HH; filled by TDM Unit |
| GENAGE | Age group + gender*10<br>(age groups: 1: 0-14, 2: 15-19, 3: 20-24, 4:25-34, 5:35-64, 6: 65+) |
| HHSIZE | Household size |
| HHWORKERS | Number of employed in household |
| MENLICENY | number of licenses held by males |
| WOMLICENY | number of licenses held by females |
| HHLICENSES | total number of licenses in HH |
| HHEDU14 | Number of HH members with education > 14 years |
| CODE | working field |
| TAZH | TAZ of residence |
| WORKSTA | Employment status: 1: full time, 2: part time, 3: soldier |
| LICENSE | 1 - car license holder, 0 - no |
| NUMCHILD | number of children of age <8 in HH |

**TABLE 2 Fields in the Zonal File**

| Field name | Description |
|---|---|
| AREA | zone area in sq. km. |
| TYPE | zone type (see Table 4) |
| CULTURAL | Zonal indicator (see Table 3) |
| EDUCATION | Zonal indicator (see Table 3) |
| OFFICE | Zonal indicator (see Table 3) |
| SHOPPING | Zonal indicator (see Table 3) |
| HEALTH | Zonal indicator (see Table 3) |
| RELIGIOSIT | Zonal indicator (see Table 3) |
| URBAN | Zonal indicator (see Table 3) |
| TRANSPORTA | Zonal indicator (see Table 3) |
| EMPL_COMM | Employment in commerce |
| EMPL_INDU | Employment in industry |
| EMPL_SERV | Employment in Services |
| EMPL_TOT | Total employment |
| STUDENTS | Number of students studying in zone |
| POPULATION | population |
| HOUSEHOLDS | Number of households |
| PARKCOST | Parking cost |
| PARKWALK | Parking walk time |
| POPDENS | Population density (1000 person/sq. km.) |
| GA21 | Number of persons in Gender-Age group 21 |
| GA22 | Number of persons in Gender-Age group 22 |
| GA23 | Number of persons in Gender-Age group 23 |
| GA24 | Number of persons in Gender-Age group 24 |
| GA25 | Number of persons in Gender-Age group 25 |
| GA26 | Number of persons in Gender-Age group 26 |
| GA11 | Number of persons in Gender-Age group 11 |
| GA12 | Number of persons in Gender-Age group 12 |
| GA13 | Number of persons in Gender-Age group 13 |
| GA14 | Number of persons in Gender-Age group 14 |
| GA15 | Number of persons in Gender-Age group 15 |
| GA16 | Number of persons in Gender-Age group 16 |
| WORKERS | Total number of employed in zone |
| WORKPERC | Employment/population ratio |
| AVGHH | average household size |
| SOCECO | Socio-economic level of zone (according to definition of NTA) |
| MLIC2 | Number of licenses in Age group 2, males |
| MLIC3 | Number of licenses in Age group 3, males |
| MLIC4 | Number of licenses in Age group 4, males |
| MLIC5 | Number of licenses in Age group 5, males |
| MLIC6 | Number of licenses in Age group 6, males |
| FLIC2 | Number of licenses in Age group 2, females |
| FLIC3 | Number of licenses in Age group 3, females |
| FLIC4 | Number of licenses in Age group 4, females |
| FLIC5 | Number of licenses in Age group 5, females |
| FLIC6 | Number of licenses in Age group 6, females |
| EMP2POP | Employment/population ratio |
| PARKCAP | overall parking capacity |
| PARKAM | intermediate values for parking model |
| PARKPM | intermediate values for parking model |
| PARKOP | intermediate values for parking model |

**TABLE 3 Zone Types**

| Indicator | Description | Values |
|---|---|---|
| Cultural Areas | Include entertainment centers (Theatres/-movies/concert halls); "Social event" locations (clubs/cultural centers) which are open on normal working days. Differentiation was made between cultural areas that are significant at the metropolitan level and those with more local character. | 0 - none, 1 - Metropolitan Cultural area, 2 - local Cultural area |
| Education | Zones were educational institutions are located, identified by the type of school. | 0 - none, 1 - higher education (College, university), 2 - high school, 3 - elementary schools |
| Office | Office Concentrations (like the Ramad Gan Bursa area) | 0 - none, 1 - Major office concentrations, 2 - Other zones with offices use (City center, commercial/industrial) |
| Shopping | Shopping areas including shopping malls, commercial streets and markets. | 0 - none, 1 - Shopping mall, 2 - shopping streets, 3 - Market |
| Health Institutions | Location of major hospitals. | 0 - none, 1 - hospitals |
| Urban cores | Zones with urban character. | 0 - none 1 - Cities over 20,000 inhabits |
| Religious Character | Identify areas with special populations by religious cultural groups. | 0 - none, 1 - Religious Jewish areas, 2 - Religious Islamic areas |
| Transportation | Identify areas were transportation facilities are located. | 0 - none, 1 - transportation facilities |

**TABLE 4 Zone Types**

| Zonal Type | Description |
|---|---|
| 1 | Metropolitan CBD: follows the borders delineated by Tamam 5 subject to the zone being built up with CBD uses |
| 2 | Urban Residential - Low-density: zones under 5,000 inhabitants per sq. km. |
| 3 | Urban Residential - High-density: zones over 5,000 inhabitants per sq. km. |
| 4 | Major public institutions: educational / legal / hospitals. |
| 5 | Commercial: include city centers, shopping centers and markets. |
| 6 | Major Employment centers: employment centers over 4,000 employees. |
| 7 | Medium Employment centers: employment centers under 4,000 employees. |
| 8 | Mixed Use Areas: areas with a mix of residential, commerce and employment. |
| 9 | Major Transport facilities: airports, ports and bus stations. |
| 10 | Sports and Tourism: areas with concentrations of hotels, beaches and sport facilities. |
| 11 | Rural Areas: rural settlements (like moshavim and kibutzim), agricultural land and isolated developments. |
| 12 | Open Areas: empty or non-built areas with no special use. |
| 13 | Military Areas: zones used by the army. |
| 14 | Cemetery |
| 15 | Small Settlements: isolated development of urban residential uses outside the urban core. |

**TABLE 5 Additional Fields in the Personal File**

| Field name | Description |
|---|---|
| MAINACTPRI | Main activity, primary tour (0 - no, 1 - work, 2 - study, 3 - shopping, 4 - other) |
| PRIMCTOD | Primary tour Combined Time of Day (CTOD) |
| TAZDPR | TAZ of main destination, primary tour |
| MAINMODPR | Main mode, primary tour |
| INTSTOPPR | Intermediate stops for primary tour: 0 - no, 1 - before main dest., 2 - after main dest., 3 - both |
| INTACTBP | Activity at stop before main destination (code is the same as for main activity) |
| INTACTAP | Activity at stop after main destination (code is the same as for main activity) |
| TAZBPR | TAZ of intermediate stop before main destination |
| TAZAPR | TAZ of intermediate stop after main destination |
| SWMODPR | mode switch at main dest.:1 - no switch, 2 - to rail, 3 - to bus, 4 - to taxi, 5 - to driver, 6 - to passenger |
| MAINACTSEC | Main activity, secondary tour |
| MAINMODSE | main mode, secondary tour: 1 - Bus, 2 - Driver, 3 - Car Passenger |
| TAZDSEC | TAZ of main destination, secondary tour |
| SECCTOD | Secondary tour Combined Time of Day (CTOD) |
| INTSTOPSEC | Intermediate stops for secondary tour: 0 - no, 1 - before main destination, 2 - after main destination, 3 - both |
| TAZBSEC | TAZ of intermediate stop before main destination, secondary tour |
| TAZASEC | TAZ of intermediate stop after main destination, secondary tour |

**TABLE 6 Definition of Combined Time of Day (CTOD)**

| CTOD | POD of Tour Start | POD of Tour End | Name Start POD | Name End POD |
|---|---|---|---|---|
| 1 | 1 | 1 | MO | MO |
| 2 | 1 | 2 | MO | AM |
| 3 | 1 | 3 | MO | MD |
| 4 | 1 | 4 | MO | PM |
| 5 | 1 | 5 | MO | EV |
| 6 | 2 | 2 | AM | AM |
| 7 | 2 | 3 | AM | MD |
| 8 | 2 | 4 | AM | PM |
| 9 | 2 | 5 | AM | EV |
| 10 | 3 | 3 | MD | MD |
| 11 | 3 | 4 | MD | PM |
| 12 | 3 | 5 | MD | EV |
| 13 | 4 | 4 | PM | PM |
| 14 | 4 | 5 | PM | EV |
| 15 | 5 | 5 | EV | EV |

Note: POD stands for Period of Day; EV is evening, PM is PM peak, MD is midday, AM is AM peak, and MO is morning.