Institute of Transport Economics
Norwegian Centre for Transport Research

TraModSim

an open-source tool to add dynamic traffic assignment to a traditional travel demand model

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Summary

In this report, we introduce TraModSim, a tool designed to generate Level-of-Service matrices from the origin-destination demand data calculated by a traditional travel demand model (here TraMod_By). This tool integrates the dynamic traffic assignment model of MATSim, and is compiled into a single Java executable. TraModSim is adept at performing the necessary data transformations to couple a macroscopic demand model with an dynamic and agent-based assignment model. The report presents some initial empirical tests conducted within the Greater Oslo. The report includes also a short discussion of limitations of the approach and of possible developments towards fully agent-based model systems.

Kort sammendrag

I denne rapporten presenteres TraModSim, et verktøy utviklet for å generere Level-of-Service matriser fra opprinnelse-destinasjon etterspørsels-data beregnet i levert i en tradisjonell etterspørsels-modell (her TraMod_By. Verktøyet integrerer MATSims dynamiske trafikkavviklingsmodell og er samlet i en enkelt Java-kjørbar fil. TraModSim utføre de nødvendige datatransformasjonene for å koble en makroskopisk etterspørselsmodell med en dynamisk og agentbasert avviklingsmodell. Rapporten presenterer noen innledende empiriske tester utført i Stor-Oslo området. Rapporten inneholder også en diskusjon om begrensningene ved tilnærmingen og potensielle utviklinger mot fullstendig agentbaserte modellsystemer.

Preface

Facilitating the option of dynamic traffic assignment in strategic transport models (as in the Norwegian RTM model systems) is a prominent challenge which is approached in the report by building an interface between TraModBy (the demand model in RTM) and the traffic assignment model in MATSim.

Compared to Cube Voyager, which is a static and macroscopic assignment model, our new tool, TraModSim, is making use of the dynamic simulation of traffic flow and the microscopic route choice modelling offered through the MATSim framework. The traffic flow model respects the maximum flow capacity on each network link and allows for spillback congestion of bottlenecks upstream in the network.

This report was written in cooperation between TØI and Linkjøping Universitet (LIU). The project was led by Stefan Flügel (TØI). Gunnar Flötteröd and Rasmus Ringdahl (both LiU) devolved the MATSim interface and wrote chapter 3 of the report. Christian Weber contributed to the empirical test in chapter 4.

We want to thank Tom Hamre (NUMERIKA) and Erik Lunke (TØI) for providing data for chapter 4.

The project was financed by the Norwegian Public Roads Administration (NPRA). We want to thank our main contacts Børge Bang and Oskar A. Kleven for good cooperation throughout the project.

We also thank Trude Kvalsvik for help with finalizing the report.

Oslo, December 2023
Institute of Transport Economics

Bjørne Grimsrud	Frants Gundersen
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- We present a new approach to calculate Level-of-Service matrices given origin-destination demand matrices of car traffic from TraMod_By.
- The resulting tool, TraModSim, is based on the dynamic traffic assignment model of MATSim and is compiled together with MATSim into one Java executable.
- TraModSim handles the necessary data transformations needed to couple a macroscopic demand model with an agent-based assignment model
- The report includes some preliminary empirical tests for the Greater Oslo Area.
- The report includes also a short discussion of limitations of the approach and of possible developments towards fully agent-based model systems.

NORSK

Sammendrag

TraModSim:

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- Vi presenterer en ny tilnærming for å beregne Level-of-Service matriser gitt etterspørselsmatriser fra TraMod_By.
- Det resulterende verktøyet, TraModSim, er basert på den dynamiske trafikkavviklingsmodellen til MATSim og er kompilert sammen med MATSim til én Java-kjørbar fil.
- TraModSim håndterer de nødvendige datatransformasjoner som kreves for å koble en makroskopisk etterspørselsmodell med en agentbasert tildelingsmodell.
- Rapporten inkluderer noen foreløpige empiriske tester for Stor-Oslo området.
- Rapporten diskuterer svakheter av tilnærmingen og mulige utviklinger mot agentbaserte modellsystemer.

1 Introduction

1.1 Background

This report is commissioned by the Norwegian Public Road Administration (NPRA) through the framework agreement for the development of short distance transport models. The NPRA wants to explore possibilities to generate Level-of-Service (LoS) data with alternative modelling frameworks. The LoS-data needs to be compatible with TraMod_By, the demand model of the regional transport models (RTM) (Rekdal et al. 2021). In the current RTM system, traffic assignment is done with Cube Voyager [1], while the specific model for the Oslo region, RTM23+, relies on the EMME assignment tool.

Both Cube Voyager and EMME are macroscopic and static assignment models that calculate link-delays by Volume-delay-functions without modelling the spatial propagation of congestion. Such models have certain disadvantages compared to more dynamic approaches and are deemed unsatisfactory for modelling congested traffic in cities (Flügel et al 2014).

In this report, we document a new approach to calculate LoS based on origin-destination (OD) matrices from TraMod_By. The tool is referred to as TraModSim as it is based on the traffic assignment method in the MATSim framework (Horni, Nagel and Axhausen (eds) 2016).

1.2 Objectives and limitations

The purpose of this work is to demonstrate that LoS-variables can be calculated within the MATSim framework given OD-matrices from TraMod_By. This is not a trivial task, as the data structure in TraMod_By is fundamentally different from the data structure typically used in MATSim.

Our proof-of-concept is currently limited to car drivers, but the TraModSim tool is straightforwardly extendable to public transport given that a public transport supply representation (e.g. based on GTFS-data) is added to the MATSim scenario.

The TraModSim functionality is not limited to specific regions. Current tests were made for the Oslo region, corresponding to the model area of RTM23+.

The resources in this project did not allow for sufficient calibration of the tool and the underlying network. Our empirical comparison of the resulting LoS-data needs therefore to be taken with a grain of salt.

Note that TraModSim is not making full use of the agent-based modelling framework of MATSim. The last section of the report discusses possible developments towards fully agent-based model systems.

1.3 Structure of the Report

Chapter 2 gives an overview over the main mechanisms and methods of TraModSim.

[1] https://www.bentley.com/en/products/product-line/mobility-simulation-and-analytics/cube-voyager

Chapter 3 provide a description of the technical solution and a short user manual with on installation, system requirements and functionality. Details are left the appendix that documents in-code comments.

Chapter 4 provides empirical test based on the MATSim network for Oslo and OD-matrices from RTM23+.

Chapter 5 concludes and discusses possible further developments.

1.4 Definitions

Below we provide a short descriptions of the most common terms and abbreviations used in this report.

Terms and abbreviations	Short explanation
TraModSim	The MATSim-based network assignment model developed in this project
TraMod_By	The demand model of the RTM-model systems (C++)
MATSim	A Java-based framework for multi-agent transport simulation
RTM	The regional transport models systems for trip up to 70km
RTM23+	The RTM model specific to the Oslo region
BSU	Basic statistical unit ("grunnkrets"); the geographical granularity of OD- and LoS matrices
OD-matrix	The number of trips (here: car trips) between all pair of BSU within given time period
LoS-matrix (cost matrix)	In our case distance, travel time and road tolls for car drivers, between all pair of BSU within given time period
EMME	The traffic assignment model currently implemented in the RTM23+ model
Link	Edges of the transport network
Nodes	Connections of links in the transport network
Mobsim	A term used in MATSim to describe the traffic flow model
QSim	The default traffic flow model in MATSim
Flow capacity	The maximum number of cars that can leave a link in a given time period
KWM	Kinematic Wave Model; the underlying traffic flow method of QSim
FD	Fundamental Diagram; defines the flow-density relationship in KWM
Greedo	The applied (non-standard) replanning mechanism in TraModSim

2 Mechanisms and methods

2.1 Overview

gives on overview over the main mechanism in the TraModSim tool. The arrows do not precisely document the actual data flow, and are meant as logical steps to support intuition about the tool.

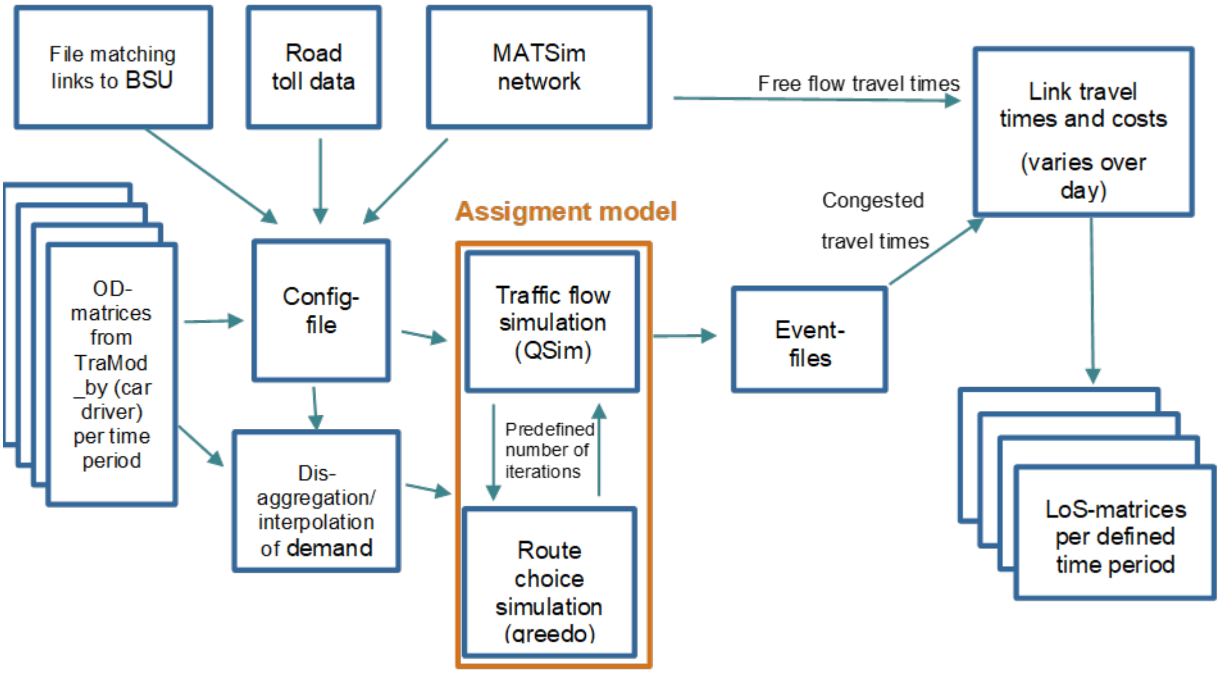

Figure 2.1: Non-technical illustration of main mechanism in TraModSim

TraModSim requires three data inputs

- A transport network in the MATSim format
- OD-matrices on a BSU level
- A file matching BSU to network links

Optionally, road toll data (in the standard MATSim xml format) can be read in.

A configuration file links to these data inputs and defines technical parameters (as the number of iterations) and behaviour parameters (as the marginal utility of travel time and travel cost).

To feed transport demand into the assignment model, the OD-matrices are disaggregated in space and interpolated in time, yielding a minimalistic traveller population (a set of agents).

The assignment model initially calculates the route with highest utility in uncongested traffic for each agent. These trips are then simulated by a means of a traffic flow model (QSim). Agents can adjust route choice given the simulated network conditions by means of a route switching logic described in Flötteröd (2022).

The systems iterates between the physical (network flow) and the route choice simulation as often as defined in the configuration file.

After the last iterations, event files are written out, recording agents' movements in the simulation "second-by-second". These event-files can be visualized in tools such as VIA (see section 4.3).

TraModSim calculates (average) link travel times and costs given information in the event-files. For links without traffic in a given time period, free flow travel time as defined in the MATSim network is used.

Lastly, LoS-matrices per time period are calculated. The time intervals automatically match the time intervals of the OD-matrices, e.g. when hourly OD matrices are given as input (e.g. 24 hours for a whole day), hourly LoS matrices (N=24) are produced.

See section 3.1 for a more technical description of the underlying mechanisms (and the appendix for the implemented codes).

2.2 On the assignment model

To give more background on the applied method for traffic assignment in TraModSim, we give on overview of some important aspects of the traffic flow model and the route choice model

2.2.1 Traffic flow model

The applied traffic flow model is a particle-discrete approximation of the kinematic wave model (KWM; Lighthill and Witham, 1955) and it is categories as dynamic and mesoscopic. It omits details such as lane changing and signalling in order to be applicable for larger scenarios.

The traffic flow model is parameterised given information from the transportation network and the configuration file.

The transport network requires a standard MATSim format. Tools exist to convert from OpenStreeMap or other sources to MATSim. A minimal MATSim network consists of nodes and there coordinates as well as links with the following information: up- and downstream nodes, link length (l), flow capacity ($\hat{q}$), number of lanes (n) , free flow speed (v) and allowed transport modes.

In our case, the flow capacity ($\hat{q}$) is the maximum number of vehicles that can be drive through that link in an hour. It can be calculated as (Flötteröd 2016):

(1) $$\hat{q} = \frac{v * w * \hat{p}}{v + w}$$

In equation 1) w is the backward speed and relates to vehicle length and the safety time gap. Its numerical value is set to -13.2 km/hour in the current application.

$\hat{p}$ is the maximum density. It is set to 140 vehicles per hour and lane.

From these parameters we can calculate a triangular function, the so-called fundamental diagram (FD), that gives the flow (q) through a network link given a link density (p).

As illustrated in the Figure below, flow is increasing linearly with free flow traffic speed in uncongested traffic up to the flow capacity and is then – under congestion - decreasing linearly with the backward wave speed (w).

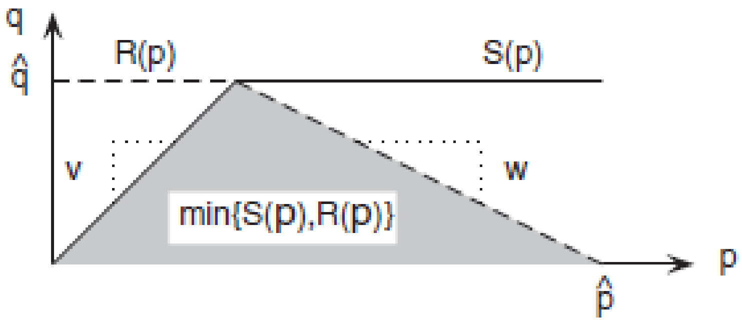

Figure 2.2: Flow as a function of density in TraModSims traffic flow model (source: Flötteröd 2016).

For a dynamic simulation in TraModSim, where flow and density is changing second-be-second, the FD is applied continuously. Flows that enter and leaving links are defined by a link- and a node model (see details in *Flötteröd 2016).* We note that nodes in TraModSim have no spatial dimension and that no travel time or delay is calculated for passing nodes.

2.2.2 Route choice model

The decision makers within TraModSim are agents that are generated from the OD-matrices based on a sampling rate. With a sampling rate of 100 %, the number of agents in TraModSim is supposed to be the same as the number of trips implied by the OD-matrices.

Opposed to standard MATSim that has an agent-based demand representation in form of all-day-activities plans, the agents in TraModSim are not concerned with maximising utility for the whole day. Instead they are concerns with maximising the utility of single trips.

In the current set up of version 1, TraModSim simulates only route choice within the mental simulation. The behavioural models regarding changing travel mode and changing departure choice are deactivated.

The utility function of agent/ car trip *n* for route *k* is given as:

$$U_{n,k} = \beta_{travelling} * T_{n,k} + \beta_{money} * \Delta M_{n,k} + \left(\beta_{distance} + \beta_{money} * \gamma_{distance}\right) * D_{n,k}$$

Where $T_{n,k}$ and $D_{n,k}$ are respectively the travel time and distance of route k for a given trip *n*. $\Delta M_{n,k}$ is the loss in money caused – in our case – by road tolls. $\gamma_{distance}$ is the monetary cost per meter. These variables are calculated based on transport network and simulated network performance (i.e. congested travel times).

The beta parameters are behavioural parameters that can be set in the config-file (see section 4.2).

Note that the set of possible routes is typically very large and the travel time for a given route depends on the decisions (routes) taken by other agents.

The assignment aims to approximate a situation where no simulated traveller wants to switch to a better (higher-utility) route. For this, MATSim's default route swapping logic is replaced by an assignment module that specifically aims at approximating this type of point equilibria (Flötteröd, 2022).

3 Implementation and functionality

3.1 Technical solution and computational steps

The TraModSim system relies on a Java program through which the external travel demand model Tramod_By can interact with the MATSim network assignment package. Given that MATSim is also coded in Java, the technical solution is to compile the TraModSim interface code together with MATSim into one java executable. To run the system and to evaluate interactions between the Tramod_By demand model and the MATSim assignment package, an external logic (not included) is required that alternatingly calls the demand model and the network assignment package. The technical solution described here focuses on enabling technically convenient calls to the MATSim assignment package, using standard (Tramod_by and MATSim) data structures. MATSim system is in detail described in Horni et al. (2016).

MATSim is designed to simulate the all-day travel experience of individual travelers. Tramod_By, on the other hand, represents travellers in terms of real-valued origin/destination matrices. To feed a Tramod_By travel demand into MATSim, a disaggregation step is implemented, where individual trip-makers are created such that their totals (by zone and time-of-day) are consistent with the Tramod_By matrices. MATSim is then used to iteratively approximate a time-of-day dependent route choice equilibrium, in which the traveler-specific travel cost perception is configured consistently with the parameters also used in the Tramod_By travel demand model. Once a solution is obtained, network-wide performance measures are computed and again made available to Tramod_By for a possible update of the travel demand. These performance measures are computed by aggregating trip-maker specific travel times, distances, and costs into time-of-day dependent inter-zonal cost matrices.

The Java program implementing this logic is in-code commented throughout; an overview presentation of its computation steps follows.

1. Configurations and input files (network, demand, … as detailed further below) are read into the program.
2. A zonal system representation is built that bridges the zone-based study representation of Tramod_By and the link-based (no zonal aggregation) representation of MATSim.
3. Time-dependent travel demand matrices (OD matrices) produced by Tramod_by are imported and translated into a traveller population. This includes (i) sampling of origin/destination links within the respective zones, and (ii) sampling of departure times within the time interval to which the considered OD matrix applies.
4. Given the disaggregate scenario representation, MATSim can be run without further modifications. To precisely approximate a user equilibrium solution, the usual "co-evolutionary" assignment logic of MATSim is replaced by a problem-specific assignment logic (Flötteröd, 2022).
5. Upon completion of the assignment process, travel time, cost, and distance matrices are computed by (i) sampling representative trip start/end points from all zones, computing paths of minimal generalized cost between all points, and aggregating the time, cost, distance statistics along all paths into suitable matrix structures.

3.2 Short user manual on installation and basic functionality

TraModSim is published on the public repository: https://github.com/vtisweden/matsim-projects/tree/master/tramodby.

The program is available as an executable jar file; to run it, a Java Runtime Environment needs to be installed. The program was tested using Java version 11. The program is multi-threaded and hence runs the faster the more cores the used machine has. Memory requirements depend very much on the considered scenario; the test presented further below in this report were computed with 25GB of RAM allocated to the java program.

The java program takes two command-line arguments, indicating the work directory and the configuration file name. All further configuration is put into this configuration file. A call to the java program may look as follows:

```
java -jar -Xmx1G tramodsim.jar work-directory ./directory config-name config.xml
```

The configuration file format is part of the MATSim system. An additional configuration module was added to insert TramodSim specific settings. An example configuration is described below, focusing on the Tramod_sim specifics. The general-purpose MATSim configurations are described by Horni et al. (2016).

The simulation requires a MATSim representation of the road network. The corresponding file is indicated as follows:

```
<module name=”network”>
   <param name=”inputNetworkFile” value=”network file location”/>
</module>
```

The following are Tramod_sim specific settings; they are explained immediately below.

```
<module name=”tramod_by”>
   <param name=”zoneDefinitionFile” value=” zone file location”/>
   <param name=”sampledLinksPerZone” value=”2”/>
   <param name=”samplingRate” value=”0.1”/>
   <param name=” startTime_s” value=”0”/>
   <param name=”binSize_s” value=”3600”/>
   <param name=”binCount” value=”24”/>
   <param name=”odFilePrefix” value=”prefix of OD files”/>
   <param name=”odFileStartIndex” value=”index of first OD file”/>
   <param name=”costFilePrefix” value=”prefix of (output) cost files”/>
</module>
```

The zoneDefinitionsFile maps road segments onto zones. The sampledLinkPerZone parameter defines how many different links are used in each zone to compute inter-zonal cost matrices. The samplingRate parameter allows to simultaneously scale the number of simulated travelers and the network capacities. For instance, a sampling rate of 0.1 (10 percent) means that only 10 percent of the amount of travelers indicated in the od matrices are turned into trip-makers and that network capacities are scaled down by the same amount, allowing to simulate realistic congestion patterns at a reduced computational cost. Very small sampling fractions (e.g., one percent) may, however, lead to imprecision that justify their use only for sketch planning.

The time discretization is represented by the following three parameters: startTime_s defines the start of the analysis period (in seconds), binSize_s defines the size of an analysis time interval (in seconds), and binCount defines the number of considered time bins. In the above example, the day is split into 24 time bins of one hour length each.

The travel demand is defined in the form of one or more OD matrices. The names of these matrices are composed of a prefix (defined above through the odFilePrefix parameter) and an integer matrix index. The first OD matrix index is indicated in the field odFileStartIndex; the program then reads in as many matrices are there are time bins defined and assumes that each matrix corresponds to a time interval defined by binSize_s, starting at startTime_s.

Similarly, cost matrices are written by concatenating a file prefix (called costFilePrefix in the configuration file) with an integer matrix index. The number of cost matrices and their time structure corresponds to that of the demand matrices. All non-MATSim file formats comply with the standard Tramod_by setup.

The newly developed code is integrated with the MATSim simulation framework and hence is put under the same license as that framework, which is GPL. The code is currently located in an internal GIT repository; the publication of the code on a public repository is possible; when and how this happens is currently not decided. Given that that the code is freely available under GPL, this publication is possible anytime in the future.

4 Empirical tests

4.1 Data

The following data inputs were used for the empirical tests

- A MATSim network generated from the Cube-network in xml-format
- A csv-file coupling BSU of the RTM23+ area and links in the MATSim network
- 24 OD-matrices from RTM23+, segmented by full hours. The data was provided by Tom Hamre in Numerika. The OD present internal trips excluding school trips and freight transport.

Our scenario consists of 2832 BSU and 208479 network links. Arguably the network is too large for convenient testing. A smaller network would have reduced running times considerable.

4.2 Configuration

As described above, the TraModSim is parameterised by a config-file. It follows the same structure and syntax as the typical config-file in MATSim.

The Value of Time (VOT) relevant for route choice is defined based on the following two variables

<param name="marginalUtilityOfTraveling_util_hr" value="-1.32" />

<param name="marginalUtilityOfMoney" value="0.15" />

The marginal utility of travel is given in Utils per hour and the marginal utility of money is given as Utils per Euro (our road toll file is in Euro). This gives an implicit value of time of 8.8 Euro per hour. This value is chosen in correspondence with the 88 NOK/hour which is value of time in the route choice model in EMME. This value is likely too low and should be increased in further test. For comparison with EMME (section 4.4.), we kept the value for now.

In the current test, costs related to distance travelled are set to zero

<param name="marginalUtilityOfDistance_util_m" value="0.0" />

<param name="monetaryDistanceRate" value="0.0" />

No other behavioural modules (in addition to route choice) are implemented in these tests and all agents and trips are handled generically (e.g. without segmentation by observables such as trip purpose).

In the presented test, we loaded 24 OD-matrices representing a full day. We used a sampling rate of 10% yielding 191565 simulated trips.

4.3 Illustrations

Before inspecting the resulting LoS-matrices, we illustrate aspects of the traffic simulation within TraModSim.

The following figures are made with VIA, a commercial software, that can visualize and further process input and output data from MATSim.

Figure 4.1 shows the network for the Oslo-area.

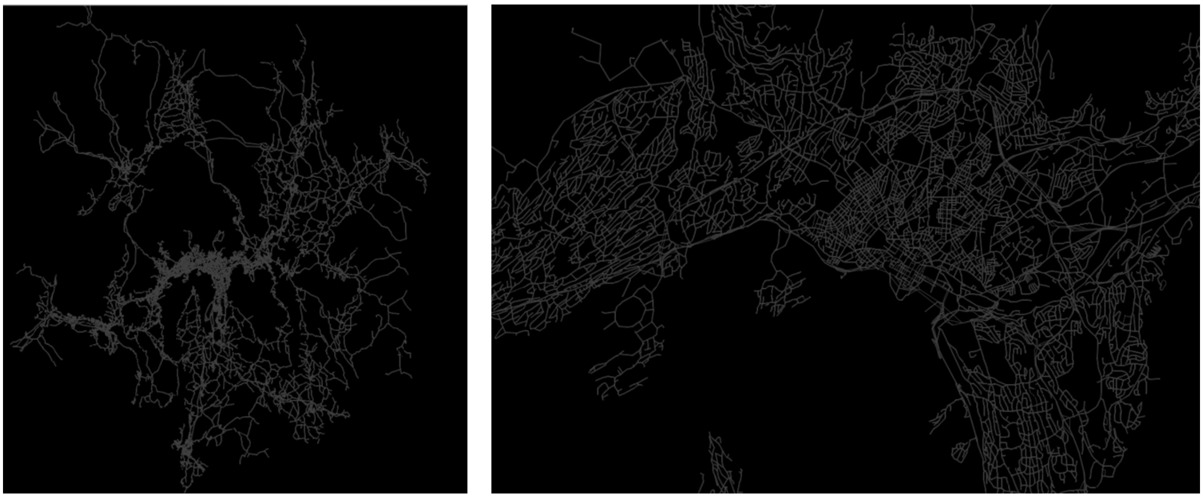

Figure 4.1: MATSim network for Oslo; left panel shows entire network, right panel shows network in Oslo city center

Figure 4.2 shows agents with start- and end-location of trips are allocated to the network (this implies a disaggregation from the OD-matrices). Figure 4.3 below illustrates how departure times are interpolated based on the sequential hourly OD matrices (the actual interpolation is with a time resolution of seconds).

Figure 4.2: Illustrations of agents being allocated to network links; red pots show start location, yellow pots show end-location.

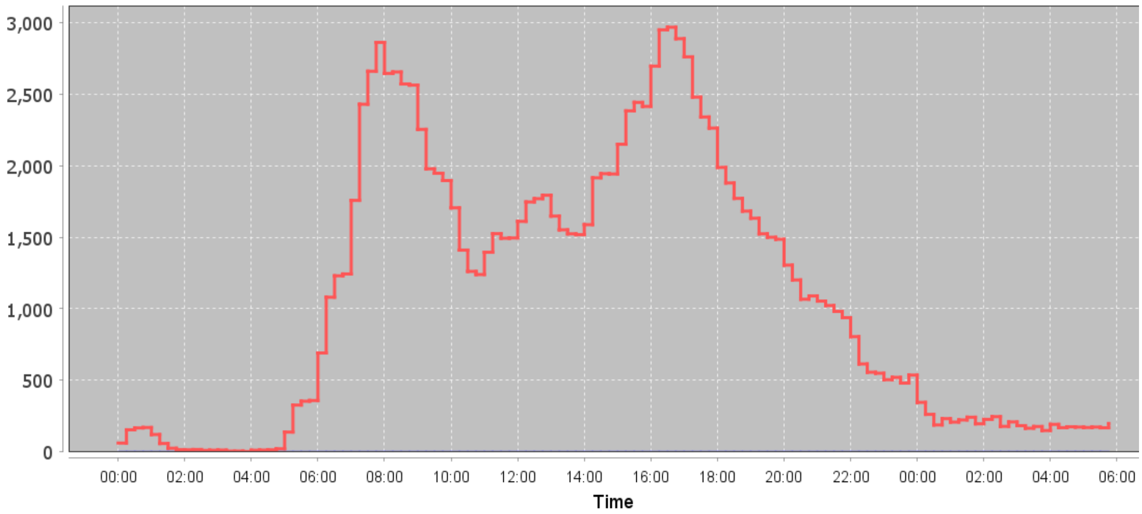

Figure 4.3: Distribution of trips over a full simulated day.

Figure 4.4 exemplifies a trip and a chosen route of an single agents.

Figure 4.4: Illustration of a single trip and chosen route (green, orange and red points show cars from a 10% sample).

Figure 4.5 shows the simulated traffic before, during and after the morning rush. Congestion can be identified by red colored cars. Red cars experience at the second of the snapshot a reduced speed of at least 50 % (this parameters are adjustable in VIA).

Note that in a 10 % sample, cars get implicitly assigned 10 times the normal length in order to account for the appropriate traffic flow calculation. On very small links (e.g. in roundabouts) a single simulated car may therefore cause congestion.

In the current run, the simulation shows a major grid-lock building up already in the morning rush that expanding over the remaining simulated day. This issue is likely to be resolve by further calibration, more iterations within TraModSim and/or iterations against TraMod_By. Without iteration against TraMod_By, the demand in the simulation is not consistent with network performance (LoS-matrices).

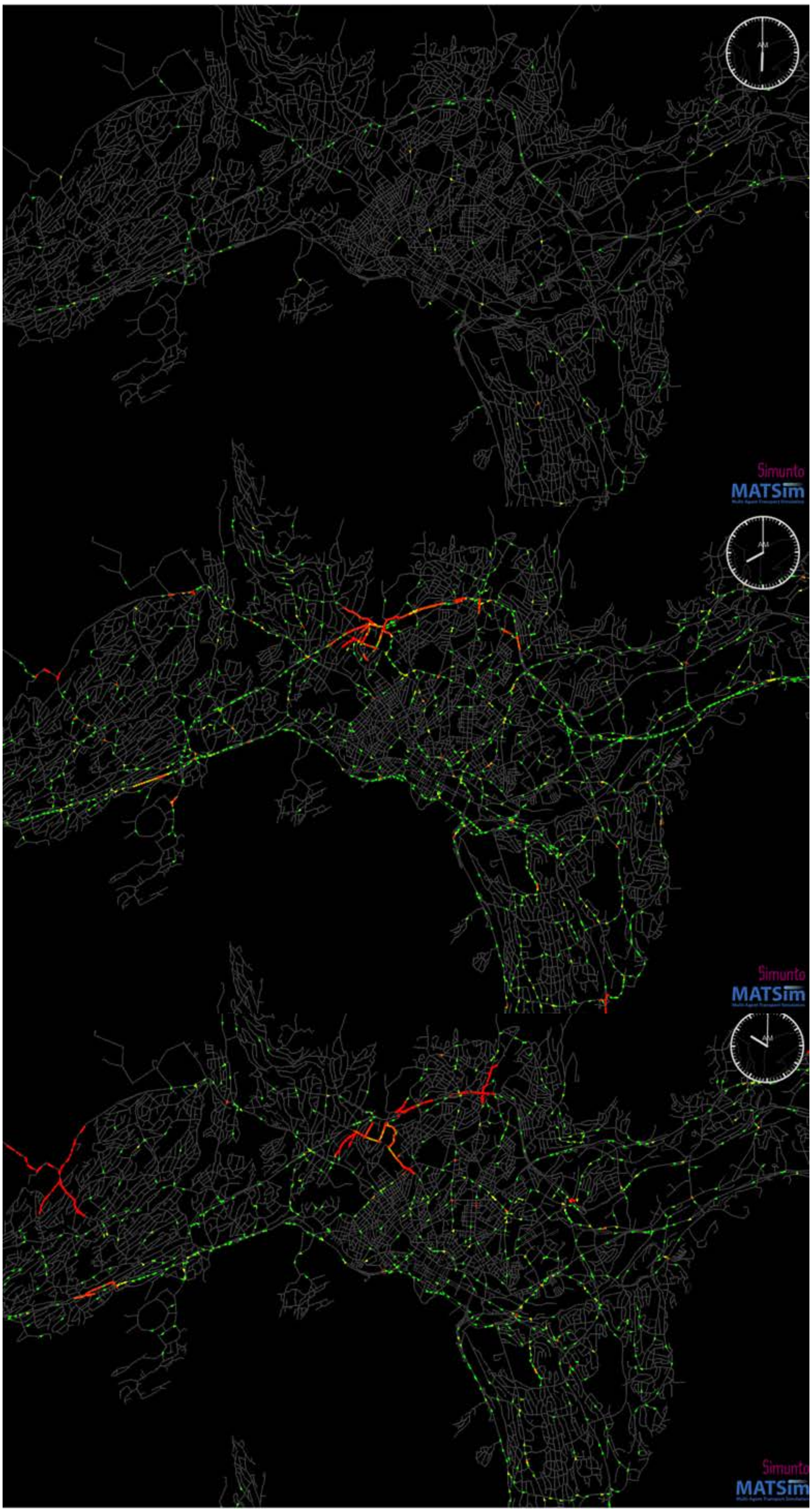

Figure 4.5: Simulated traffic in Oslo center at 6:00, 8:00, 10:00; simulation of 10% of trips, red cars indicate reduced speed by at least 50%.

4.4 Resulting LoS-data

LoS matrices ("cost_matrices") are written out by TraModSim. The suffix behind the file names indicate the time period and is consistent with the suffix used in the corresponding OD-matrices.

Currently the matrices have the following variables: From_BSU, TO_BSU, Tid, Avstand, BomBf.

Travel time ("Tid") is in seconds, distance ("Avstand") in meters and road tolls ("BomBf") in Euros. For later comparison, these values are transformed to minutes, kilometres and NOK respectively.

Table 4.1 shows summary statistics for all BSU to the BSU related to Oslo city center (3010104) for three time periods.

Table 4.1: Average LoS-variables to Oslo city center as simulated in TraModSim (N=2044).

Variable	4-5 o'clock	7-8 o'clock	10-11 o'clock
Distance	34.30 km	34.08 km	35.95 km
Travel time	29.43 min	31.76 min	31.80 min
Road toll	23.75 NOK	28.15 NOK	23.78 NOK

From Table 4.1, we see that average values are already influenced by the gridlock building up during and after the morning rush (compare Figure 5).

4.5 Comparison against traffic counts

As a quick validation test, we compare simulated traffic flows in TraModSim against traffic counts. The traffic counts were provided by SVV as part of the PRELONG project (Prosjekt: PRELONG - Transportøkonomisk institutt (toi.no)).

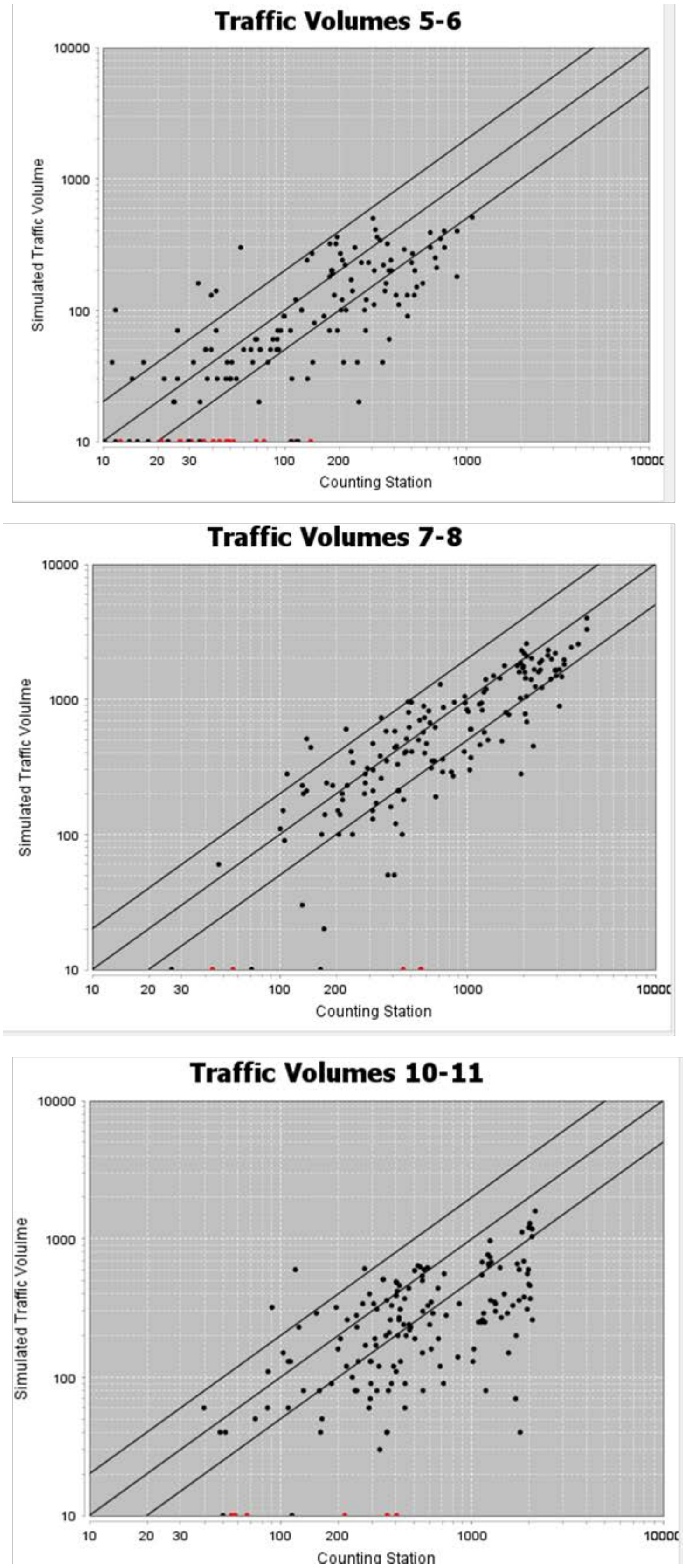

Figure 4.6: Comparison of simulated traffic flow against real traffic counts at different times of day

From Figure 4.6 we observe that counting station have higher values for most stations, especially before and after the morning rush. This might be a consequence of the simulated grid-lock. Better calibration and iterations against TraModBy should be performed in order to get a better picture of how well TraModSim can approximate real traffic counts.

4.6 Comparison against external data

As a last empirical test, we have compared the resulting LoS-variables from MATSim against three external data sources.

- **LoS data from the Emme** assignment model that is currently used in RTM23+. Emme is a macroscopic and static assignment tool. Note that the travel time calculation is from BSU-center to BSU-center and that there is no assigned for zonal internal trips (trips starting and ending in the same BSU). The data is provided by Tom Hamre in Numerika.
- **LoS-data calculated based on the Elveg transport network**. Routes are based on shortest path between geometric center points (based on buildings) of two BSU. Travel times are calculated based on speed limit. E.g. travel times due not account for congestion or crossing delay
- **LoS-data retrieved from Google maps.** This is based on a API extracted from 2019 for different time-of-days. This data is not available for all BSU pairs. The most relevant end-point included is Oslo city center which is used the comparison below.

Figure 4.7 gives the distance distribution for all four methods/datasets. The red square shows distribution within TraModSim and the correlation again Emme, Elveg and google maps respectively.

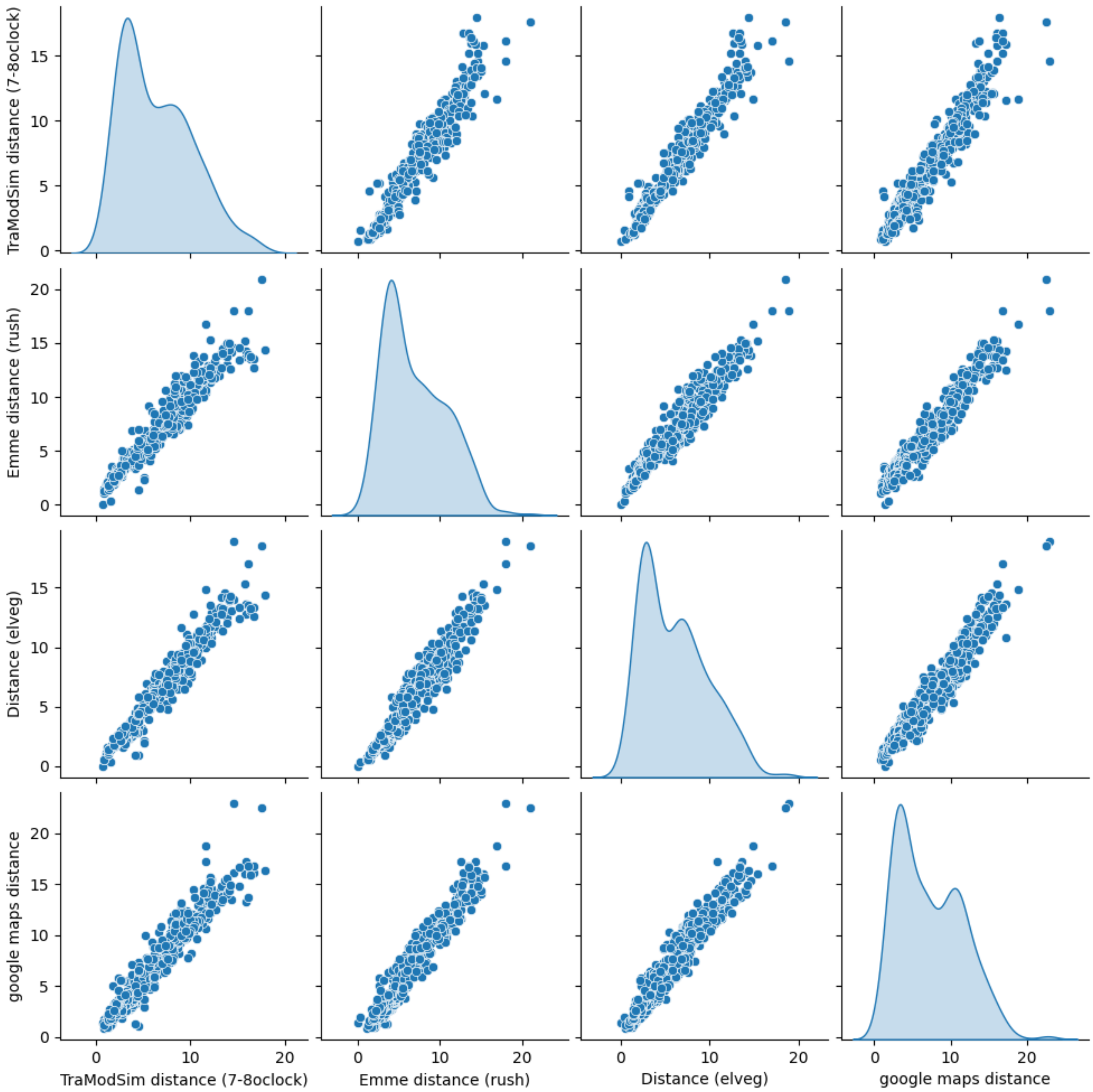

Figure 4.7: Distance distribution (km) for trip from all BSU to Oslo city center with different methods/datasets, red square indicates results from TraModSim; each point represents one relation between a BSU and Oslo city center (BSU=3010104).

Difference in distance can stem from differences in the network and/or differences in the assumed/ simulated route choice. In general, the correlation between TraModSim and the other sources seems reasonable.

The following figures show one-to-one comparisons of travel times for the morning rush (7-8 o'clock in TraModSim).

Compared to Evelg data (Figure 4.8) which is only based on speed limit (without congestion, we see that travel times in TraModSim are on average higher, indicating some congestion effects.

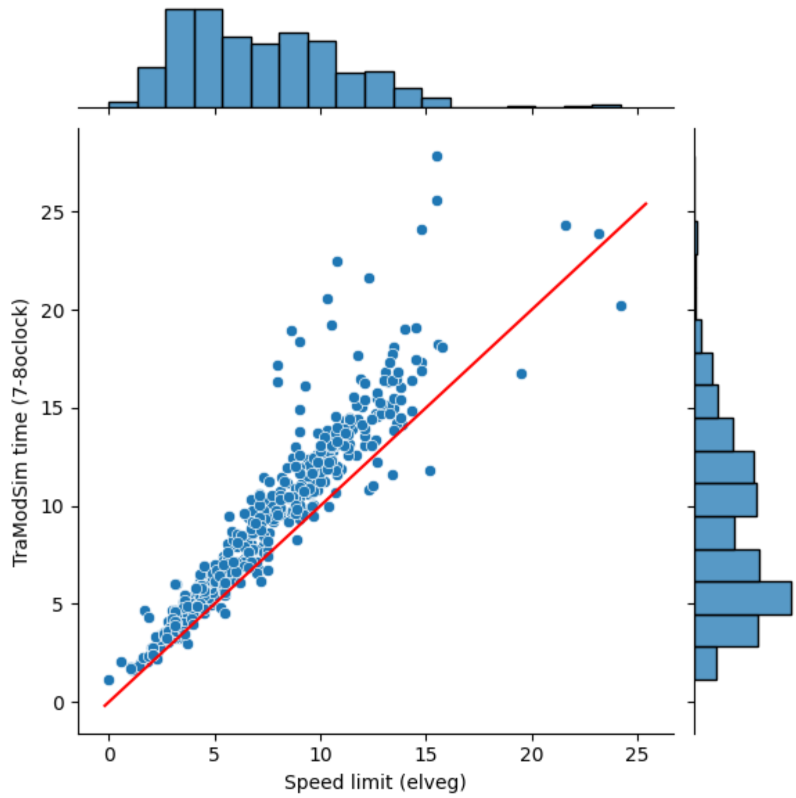

Figure 4.8: Travel times (in minutes) in TraModSim between 7-8 o'clock against travel times purely based on speed limit (in the Elveg network); each point represents one relation between a BSU and Oslo city center (BSU=3010104).

However, compared to google maps and Emme travel times seem faster in TraModSim (Figure 4.9). A likely explanation is the missing delays in crossing in the current version of TraModSim.

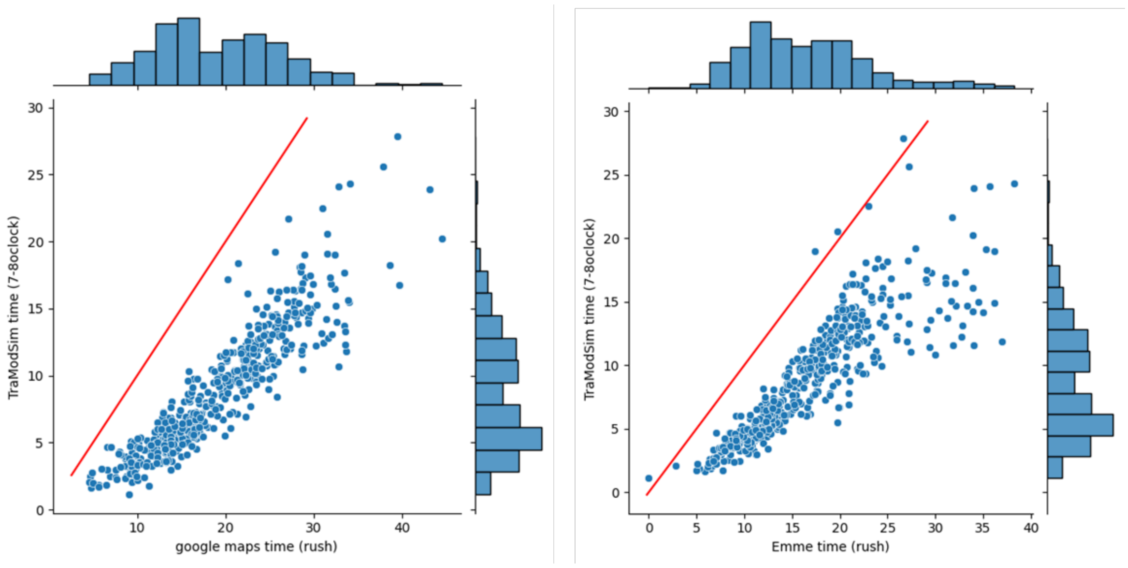

Figure 4.9: Travel times (in minutes) in TraModSim between 7-8 o'clock against travel times based on google maps (left panel) and Emme (right panel); each point represents one relation between a BSU and Oslo city center (BSU=3010104).

5 Conclusion and Discussion

5.1 Conclusion

This report documented a new tool, TraModSim, for traffic assignment of car demand data based on OD-matrices from TraMod_By.

Compared to Cube Voyager, which is a static and macroscopic assignment model, TraModSim is making use of the dynamic simulation of traffic flow and the microscopic route choice modelling offered through the MATSim framework. The traffic flow model respects the maximum flow capacity on each network link and allows for spillback congestion of bottlenecks upstream in the network.

Compared to Aimsun, which has previously been coupled with TraMod_By, TraModSim has an advantage of being license-free and open-source. We also believe that the set-up of TraModSim offers greater flexibility for adjustment and future development as it makes use of the modular structure of MATSim. The modular structure makes the tool expandable and one can draw from a large range of MATSim extensions developed by researchers around the world. Most extensions are available as open-access.

Our initial empirical tests for the Oslo region showed that TraModSim is applicable for large scenarios. Computation times and memory (RAM) demands are, however, high for such scenarios: Depending on the number of iterations and sample rate, simulations took several hours to complete.

A weakness in the current model is that delays (and upstream congestion) due to traffic lights and priority of right of way rules are not incorporated. This leads to an underestimation of travel times compared to sources that are better calibrated against actual travel times (such as Emme and Google Maps).

Our empirical tests showed that the Oslo-models needs better calibration before it can be used in practice (see next section).

5.2 Short-term improvements

To improve the practicability of TraModSim the model requires more work on the testing and calibration part.

Resources in this project did not allow detailed calibration of the flow capacity parameter in the transportation network. The simulated gridlocks that arose doing some of the tests are likely resolved by adjustments to the network.

Further tests should also include iterating back to TraMod_By. This is expected to make demand more consistent to the simulated network conditions in TraModSim.

To demonstrate applicability for cost-benefit analysis, one should also demonstrate that the LoS-matrices in TraModSim can be used to calculate user benefits within the official CBA-tools ("trafikantnyttemodul"). For this to make sense however, the model first needs to be better calibrated.

We also recommend doing test against the MATSim model developed in the PRELONG project (https://www.toi.no/project-prelong/). The model uses the same network as in our TraModSim tests but uses a different demand representation. In the simulation performed in PRELONG so far, no gridlock was observed in the simulations. This is likely explained by the fact that agents in MATSim in these simulation, can also adjust departure time and travel mode, making demand for car trips consistent with travel costs after sufficiently many iterations in MATSim.

Regarding the calculation of travel times, one should explore how delays due to traffic lights and priority of right of way rules could be best captured in upcoming versions of TraModSim. The modular approach allows for extension to the traffic flow model, but concrete approaches need to be investigated.

5.3 Discussion and possible further development

The coupling between a macroscopic and static demand model (TraMod_By) and a micro/ mesoscopic and dynamic traffic assignment (as in MATSim) involves some heavy data transformations. These are automatically handled in TraModSim (and some functionality is added such that users can adjust the underlying calculations). It is however important to note that the disaggregation of OD-matrices into a traveller populations implies certain assumptions and that the aggregation of link costs into LoS-matrices implies a certain loss of information.

A preferable set up is a one where the demand model and the assignment model share the same data structure. Different couplings are discussed in Flötteröd and Flügel (2015). The following figure summaries challenges pointed out in that paper.

Table 1: Coupling models with different time representations and resolutions.

		Network assignment package		
		Static macro	**Dynamic macro**	**Dynamic meso/micro**
Travel demand model	Static macro	Adequate.	Adequate for studying peak-period congestion dynamics, but dynamic network performance data cannot be utilized by demand model.	Adequate for studying peak-period congestion dynamics, but dynamic network performance data cannot be utilized by demand model.
	Dynamic macro	Suffers from simplistic representation of congestion.	Adequate.	Adequate.
	Dynamic micro	Suffers from simplistic representation of congestion. May suffer from coarse representation of traveler heterogeneity in the network.	May suffer from coarse representation of traveler heterogeneity in the network.	Adequate if demand is represented through trip lists.

Figure 5.1: Coupling between demand and assignment models (source: Flötteröd and Flügel 2015); colored squares added for this report

The yellow square corresponds to coupling of TraMod_By and Cube Voyager. This coupling is smooth as the tools share the same data format in their inputs and outputs. The resulting RTM model systems is widely used in Norway. The model systems has several weaknesses in particular for transport analysis in (congested) cities (see e.g. Flügel et al 2021).

The red square in Figure 5.1 corresponds to coupling of TraMod_By and TraModSim. As described in this report, a disaggregation/interpolation of the demand representation in TraMod_By has to be done and the dynamic information from the traffic simulations (QSim) are largely lost when aggregating time-dependent links costs into LoS-matrices, even when LoS-matrices are written out on an hourly basis. Note also that TraMod_By has limited capacity to make use of the hourly LoS-matrices in its demand modelling.

The black square in Figure 5.1 corresponds to integrated approach in a standard MATSim model with trips list (all-day activity plans) as a demand representation. This data structure is much richer than

OD-matrices, not only as it has a higher spatial and temporal resolution, but also as it logically connects trips and activities. In the demand modelling in MATSim one can therefore account for departure time changes given reasonable assumptions about acceptable activity starting time (opening hours). All-day activity plans are the preferred input in to (all-day) traffic simulations as trips are already distributed in time and space.

An disadvantage of a standard MATSim model is that long term demand effects (such as trip frequency and destination choice) are not incorporated (they are exogenous and defined by the input data). While relevant extension for MATSim do exist, there are still more on the experimental side and long term demand modelling in preferably modelled in strategic model systems (such as RTM/TraMod_By). This is one of the motivations for a coupling as described in this report.

There is however an alternative for strategic demand modelling in the form of activity based demand models (ABDM). These models are intended to predict activity types, frequency and location (among others). The development of such models is time- and data demanding. However, new data types, e.g. from apps with GPS-tracking, could make a leap in this respect. New machine learning techniques, as explored in the PRELONG project (Prosjekt: PRELONG - Transportøkonomisk institutt (toi.no), could also help in building such models.

A coupling between an ABDM and MATSim was recently demonstrated in Ziemke et al 2021. From a perspective of (long-term) transport model development in Norway, we recommend to look into such opportunities. The presentation by Flügel (2023) outlines some possibilities and we attach some of the slides of the presentation in the Appendix.

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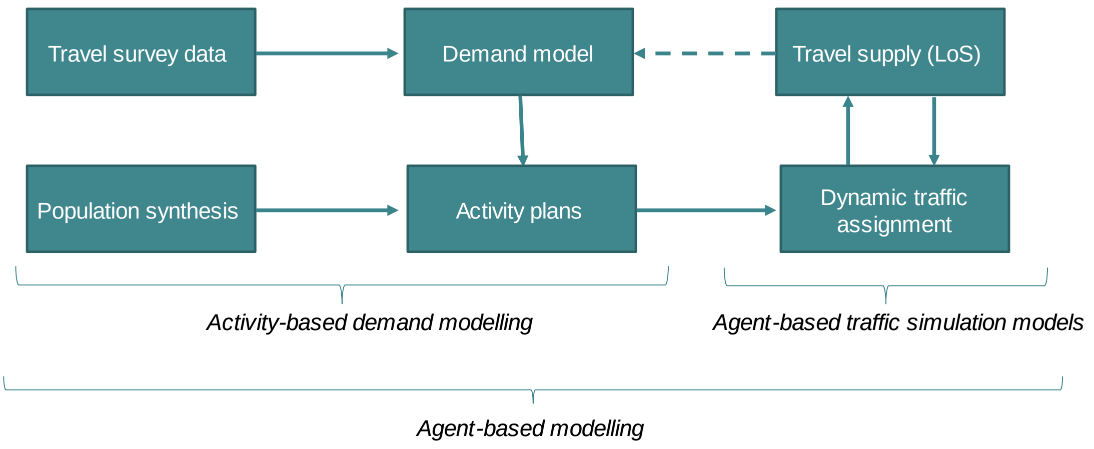
Ziemke. D, L. Knapen, K. Nagel (2021) Expanding the analysis scope of a MATSim transport simulation by integrating the FEATHERS activity-based demand model, *Procedia Computer Science*, Volume 184, Pages 753-760.

Attachment

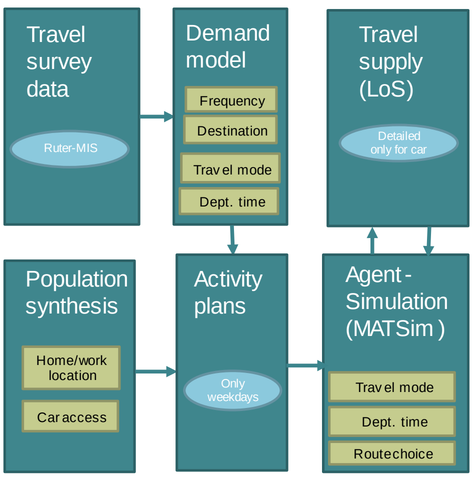
Selected slides of presentation "Generation of activity plans for the Oslo Area" presented by Stefan Flügel at workshop on activity-based models, 12. April 2023, in Oslo.

Path forwards with activity based models



Side 50

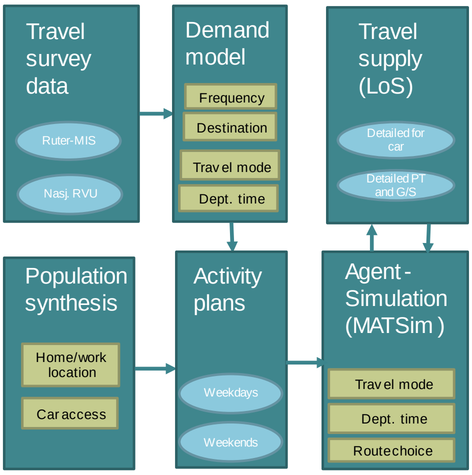
Path forward: current PRELONG approach



Choice dimension	Method	LoS-sensitiv for policy analyses
Home/work location	Sampling	No
Car access	Sampling	No
Frequency	Machine Learning	No
Destination	Machine Learning and randomisation	No
Travel mode	Inital : Machine Learning Final: Co-evolutionary simulation	Yes
Departure time	Inital : Machine Learning Final: Co-evolutionary simulation	Yes
Route choice	Co-evolutionary simulation	Yes, only car in current form

Aspect	current PRELONG approach
Scope (area)	RTM23+
Managment perspective	Tactical focusing on traffic flow
Application for future years	Population forecasts files as input in pop.synth .
Basic unites	Agents and cars
Interactions between basic units	Road congestion
Behavioral parameters in demand modelling	Neural network weights and biases (not interpretable)
Behavioral parameters in traffic supply modelling	Utility function in MATSim
Main limitations	1. Interpretability for economic analysis 2. several choice dimensions not sensitive to changes in LoS

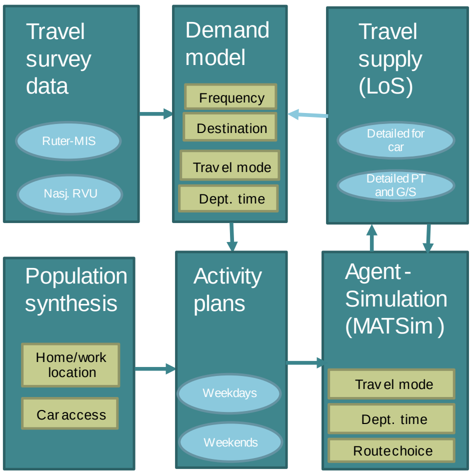
Extensions of scope of PRELONG approach 1 : More cities and route choice for all modes



Choice dimension	Method	LoS-sensitiv for policy analyses
Home/work location	Sampling	No
Car access	Sampling	No
Frequency	Machine Learning	No
Destination	Machine Learning and randomisation	No
Travel mode	Inital : Machine Learning Final: Co-evolutionary simulation	Yes
Departure time	Inital : Machine Learning Final: Co-evolutionary simulation	Yes
Route choice	Co-evolutionary simulation	Yes, all modes

Aspect	current PRELONG approach
Scope (area)	Cities over all Norway
Managment perspective	Tactical focusing on all modes
Application for future years	Population forecasts files as input in pop.synth .
Basic unites	Agents, cars, public transport vehicles
Interactions between basic units	Road congestion, and crowding PT
Behavioral parameters in demand modelling	Neural network weights and biases (not interpretable)
Behavioral parameters in traffic supplymodelling	Utility function in MATSim
Main limitations	1. Interpretability for economic analysis 2. several choice dimensions not sensitive to changes in LoS

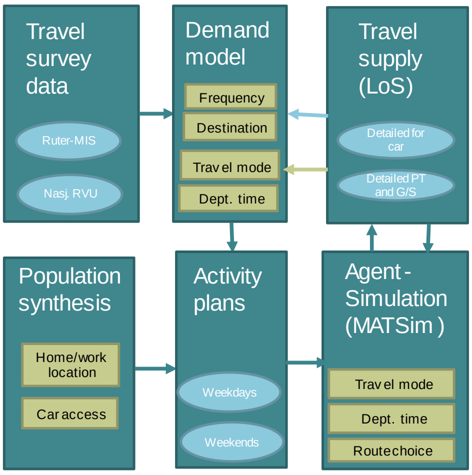
Extensions of scope of PRELONG approach 2 : LoS-dependency of demand model



Choice dimension	Method	LoS-sensitiv for policy analyses
Home/work location	Sampling	No
Car access	Sampling	No
Frequency	Machine Learning	Yes
Destination	Machine Learning and randomisation	Yes
Travel mode	Initial: Machine Learning Final: Co-evolutionary simulation	Yes
Departure time	Initial: Machine Learning Final: Co-evolutionary simulation	Yes
Route choice	Co-evolutionary simulation	Yes, all modes

Aspect	current PRELONG approach
Scope (area)	Cities over all Norway
Managment perspective	Tactical focusing on all modes; Better capability for long term predictions
Application for future years	Population forecasts files as input in pop.synth .
Basic unites	Agents, cars, public transport vehicles
Interactions between basic units	Road congestion, and crowding PT
Behavioral parameters in demand modelling	Neural network weights and biases (not interpretable)
Behavioral parameters in traffic supplymodelling	Utility function in MATSim
Main limitations	1. Interpretability for economic analysis 2. resolved

Extensions of scope of PRELONG approach 3 : Interpretable mode choice model



Choice dimension	Method	LoS-sensitiv for policy analyses
Home/work location	Sampling	No
Car access	Sampling	No
Frequency	Machine Learning	Yes
Destination	Machine Learning and randomisation	Yes
Travel mode	Logit model	Yes
Departure time	Inital : Machine Learning Final: Co-evolutionary simulation	Yes
Route choice	Co-evolutionary simulation	Yes, all modes

Aspect	current PRELONG approach
Scope (area)	Cities over all Norway
Managment perspective	Tactical focusing on all modes; Better capability for long term predictions
Application for future years	Population forecasts files as input in pop.synth .
Basic unites	Agents, cars, public transport vehicles
Interactions between basic units	Road congestion, and crowding PT
Behavioral parameters in demand modelling	Neural network weights and biases (not interpretable), Interpretable parameters for travel mode choice
Behavioral parameters in traffic supplymodelling	Utility function in MATSim (make them consistent with demand model, at least for travel mode choice)
Main limitations	1. resolved 2. resolved

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