ETHEKWINI TRANSPORT AUTHORITY

MANUAL FOR
MICRO-MESO SIMULATION MODELLING

Traffic Engineering

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MANUAL FOR MESO-MICROSIMULATION MODELLING

CONTENTS

1 BACKGROUND

1.1 Introduction

The aim of this document is to ensure uniform and consistent requirements and standards for the development of micro-meso simulation models submitted to the eThekwini Transport Authority (ETA).

The document is intended for:

- ETA staff and;
- Traffic / transport professional engineers involved in preparing micro-meso simulation models for transport assessments.

The document was prepared by the ETA's Traffic Engineering Branch.

It must be recorded that this document must not be construed as being exhaustive and conclusive. In addition, the ETA reserves the right to reasonably require information to be supplied relating to the simulation modelling that is not covered in this manual.

If any aspect is silent in this manual, the ETA will make a determination on the issue and convey same to the professional undertaking the assessment.

Currently, ETA accepts the following modelling software:

- AIMSUN : Micro simulation modelling
- SATURN : Meso simulation / tactical modelling

The document contains seven sections:

1. Background
2. Simulation study area
3. Model scope
4. Model development
5. Traffic demand
6. Future network and model scenarios
7. Reporting

2 SIMULATION STUDY AREA

2.1 General

The extent of the study area is a key aspect required to obtain the necessary areas of influence from a land and transport perspective.

The simulation model must assess the impacts of a scheme or proposal (e.g. transport intervention) on all road users over the impacted area.

2.2 Study area

The model study area must include the area within which traffic flows and traffic operations (e.g. travel / journey times, delays) will be significantly affected by the implementation of the scheme or proposed intervention.

It is required that the study area be agreed at an inception meeting with the ETA and approved by the ETA prior to subsequent phases of model development. The list of intersections to be included in the model must also be agreed.

As a guideline, the following intersections must be included where:

- Traffic flows are expected to change significantly given the proposed scheme / proposal;
- There are changes to operation of traffic control; and
- Include physical changes to the transport network;

3 MODEL SCOPE

The model scope must be determined and agreed with the ETA and includes the following:

- Peak periods to be assessed
- Traffic data collection
- Vehicle classes and pedestrians
- Model scenarios

Based on the project requirements various peak hour assessments may be required (e.g. Weekday peak, Midday Peak).

Traffic data collection must include the required number of:

- Traffic counts
- Journey time surveys
- Public transport operational data
- Onsite observations regarding traffic operations
- Transport network information

Vehicle classes range from public transport (including sub classes such as bus, taxi, ROW services, etc), private vehicles, heavy goods / freight vehicles. Pedestrians typical occur at pedestrian crossing points on the transport network and must be included were necessary.

Model scenarios includes the required base year scenarios including any horizon year coupled with various options. The number of model scenarios must be agreed with ETA.

4 MODEL DEVELOPMENT

4.1 Data collection

4.1.1 Survey periods

Collection of data should be undertaken during periods where the traffic conditions are typical of the periods to be modelled. The typical period may not necessarily be a normal day but may require consideration of effects from:

- Day of week – select representative days (weekday/weekend, late night shopping, etc)
- Time of day – peak periods, off-peak, warm-up, warm-down
- School holidays
- Public holidays or special events
- Traffic incidents or changes in traffic control
- Adverse or abnormal weather conditions
- Special events

This list of issues will need to be critically assessed and monitored during any data surveys. If the target conditions are not met during the survey period, additional data collection may be required.

During data collection, modellers should ideally visit the site to observe and understand traffic conditions during survey periods as follows:

- General traffic conditions (light/heavy/incident etc):
- Study area layout
- Land use within/adjacent to study area
- Traffic network operation (signal times, queues etc.)
- Traffic issues and causes (queue spillback, blocking, merge etc.).
- Public transport (stops, dwells, interaction with general traffic)
- Active transport (pedestrian interaction/cycle interaction)
- Network boundary effects (blocking back, queue formation, signal timings) that influence behaviour on the network.
- Other relevant information

4.2 Network and parameters

The network coding requires that correct information is collected in order to replicate the existing transport network to a modelled network. The basic information includes:

- Number of lanes.
- Lane widths.
- Gradients.
- Intersection geometry and traffic control
- Public transport

Coding of the transport requires additional parameters such as speed, saturation flow (or speed-flow / volume delay functions), gap acceptance, pedestrians walking speeds, public transport services parameters such as headways, etc.

In addition, the number of zones / centroids representing traffic loading for developing the traffic demand matrix must be clearly defined as follows:

Where the centroid / zone represents land use, the extent of area of the land use must be presented in terms of a mapping diagram including the land use information and traffic demand estimates associated with this land use

4.2.1 Saturation flows / volume-delay functions

Saturation flows or volume delay functions varies per class of road and consequently it is required that each class of road be identified such as access roads, collector roads, arterial roads, etc. The various classes of roads to be used in the model along with the appropriate saturation flows or volume delay functions must be defined.

4.2.2 Vehicle speed limits

Vehicle speed limits should be assessed for the full extent of the study area and coded for the transport network. The method by which the vehicle speed limits are applied varies between packages since some apply speed distributions to entire links whilst others use explicit locations to inform drivers of speed changes.

4.2.3 Gap acceptance

Gap acceptance is an important parameter affecting the capacity. Consequently the appropriate values must be used for the model.

There are many factors that influence the value of gap acceptance and these should be assessed and taken into account on an individual location basis (where a particular model allows). Key factors that might affect gap acceptance include:

- Visibility
- Geometry
- Vehicle type
- Level of congestion

4.2.4 Blocking

The impacting of vehicle blocking (intersections being blocked by vehicle queuing through the intersection) is an important aspect of model development. This generally decreases the capacity of some movements at priority intersections and roundabouts and is therefore an important calibration tool in defining the capacity and efficiency of the local road network. This must be observed onsite and replicated in the model where possible.

Most software packages offer a direct or indirect method of achieving different levels of blocking. This is achieved, either through specific blocking parameters, or via the use of a number of other network coding tools (that can be applied through workarounds).

4.2.5 Turning lanes

Turning lanes allow traffic to undertake a particular turning movement to queue without blocking traffic on other turning movements. They can play an important role in local road capacity since congestion can quickly develop when a turning lane become full and begins to block other movements on the same approach. It is therefore essential to ensure that turning lanes are defined correctly both in length, entry location and upstream driver awareness. The correct calibration of turning lanes in the base model also has implications for any future year scenarios to be assessed. This is important since many intersections in the network may operate at or below capacity in the base year but subsequently operate over capacity in future year scenarios. Correct calibration of turning lane parameters in the base year will therefore ensure that the behaviour of vehicles within future year models is realistic and that the model will be able to provide an accurate assessment of intersection performance.

In addition, if a carriageway is wide enough to accommodate passing vehicles (but only marked as a single lane) it is reasonable for the model to be coded using two lanes to allow for the passing vehicles. Care must be taken that the passing lane is available and not blocked by parking, bus stops or local driver behaviour.

4.2.6 Signalised intersections

Signalised intersections have a significant impact upon the capacity of modelled traffic networks as they are the focus of high volume conflicting traffic movements that are only allocated a portion of available green time to undertake their manoeuvre. The adjustment of signal timings, and associated parameters that affect stop line saturation flows, directly control the throughput of each approach in the model and often hence capacity.

Since most simulation model applications are of congested urban areas, with many signalised intersections, the accurate calibration of these parameters is often critical in the development of a robust base model.

The development of an accurate simulation of on-street signal operation has further benefits beyond the calibration stage of the study. One of the key benefits of simulation models is the ability to simulate signalised intersections operating as part of an integrated wider adaptive control network or as vehicle actuated. It is therefore important that base models are developed to a sufficiently high level of accuracy to realise these benefits during the scenario testing stage.

4.2.7 Impact of pedestrians

Pedestrian activity can impact upon traffic movement and road capacity in some networks and therefore should generally be modelled in some form. Modelling packages provide a variety of ways to account for pedestrian activity and the modeller should choose the most accurate and relevant method – where required this will include pedestrian modelling at signalised intersections and midblock crossings. In additional the appropriate pedestrian walking speeds must be used in the model.

4.2.8 Public transport

The level of detail to which public transport should be represented within a simulation model is dependent upon the objectives of the study and the impact that public transport may have upon the overall operation of the network. The development and calibration of public transport elements within a model therefore varies on a case by case basis, however, for the majority of arterial roads, under congested conditions, there would be a requirement to model public transport operations directly. The modeller should assess the likely implications that public transport movements may have upon traffic flow in the study area and discuss the modelling technique to be adopted with the ETA.

4.2.9 Behavioural parameters

There are a wide range of behavioural parameters that may affect simulation accuracy and replication of real world scenarios. Each software package will use some or all of these parameters to simulate driver behaviour in the model. Each package uses the parameters differently and it is therefore not possible to specify appropriate values for each.

Some packages allow the user to adjust high-level parameters which influence or determine lower-level parameters (e.g. aggressiveness, awareness). Modellers should ensure that they are familiar with the effects of the high-level parameters before making adjustments to these as the use of these parameters may have unintended impacts throughout the network.

Typical behavioural parameters used by majority of the software packages include:

- Headway
- Lane changing gap acceptance
- Reaction time
- Awareness of other vehicles
- Vehicle performance characteristics (ie acceleration, braking etc).
- Distance between vehicles at standstill

5 TRAFFIC DEMAND

5.1 Matrix demand development

The development of demand for a simulation model can be undertaken using a number of different methodologies. ETA accepts that each study may require a different approach and is therefore open to a variety of techniques to develop accurate trip demands for models. The methodology chosen, must be documented in the base model reporting and trip totals for each matrix should be reported by vehicle type and for each time period. Guidance in the use of several commonly used techniques for developing trip demand is outlined below. This is not an exhaustive list and other methods may be used or these methods may be combined as considered appropriate. The ultimate aim of demand development is to use the best available data to provide an accurate simulation of trip patterns and volumes throughout the study area.

5.1.1 Strategic model sub-area cordon

A typical approach to developing matrices for micro-meso simulation models is to extract travel demands for the study area from an existing strategic model of the wider area. A well-calibrated strategic model can be cordoned to provide an origin-destination (O-D) matrix for each vehicle type and for each time period consistent with the micro-meso simulation model.

Before proceeding with this approach it is important to understand the level to which the strategic model has been calibrated. This is particularly the case for the area to be cordoned since data for this area will be imported directly into the micro-meso simulation. Strategic models are generally calibrated using screen lines (rather than individual turning volumes) and as such it is common to find that the demand from a calibrated strategic model is not sufficiently accurate to immediately calibrate within a micro-meso simulation model. It may therefore be necessary to make further adjustments to the demand to ensure that the micro-meso simulation model is fit for purpose. Care should be taken to ensure that any further adjustments that are made to the demand are documented and reported. If the strategic model is to be used at a later stage to provide demand for option testing or future year scenarios then these adjustments will need to be applied to the extracted matrices in some form to ensure consistency with the base model.

5.1.2 Balancing intersection counts

Another common method for developing demand for micro-meso simulation models is to collate network-wide turning movement data from recent traffic count surveys. This data can be input into a spreadsheet to show the turning movements at each key location throughout the network. The use of this technique can provide accurate turning volumes for each individual intersection but does not provide robust data relating to trip origins and destinations (O-D). It is therefore often necessary to undertake an O-D survey for key locations within the study area to gain an understanding of the distribution of trips through the network. Any discrepancies between total arrivals and departures at adjacent count sites must be assessed and some minor adjustments may be required in order to provide balanced volumes at each location. Generally the larger figure should be assumed in this process where possible. Further, if major discrepancies are noted then it will be necessary to investigate the cause of these rather than simply make large adjustments to the observed values.

5.1.3 Demand adjustment

The demand development stage outlined above provides an initial estimate of trip demand through the study network. ETA accepts that this demand may require further manual calibration in order to ensure that the model accurately reflects turning movement counts and other link and screen line data. The purpose of micro-meso simulation is often to provide a detailed assessment of intersection performance and it is therefore preferable for the base model to provide the most accurate possible representation of turning volumes at key locations.

There are a number of methods available to the modeller in order to undertake this additional demand adjustment and each should be used with a degree of caution and in a manner that can be audited independently should this be required at a later stage.

5.1.4 Matrix furnessing

Matrix furnessing is a procedure that factors rows and columns within a demand matrix to attempt to match a number of user-specified observed values. The main advantage of furnessing over other techniques is that the proportional distribution of trip origins and destinations for each zone remains consistent with the original demand matrix. The process simply uniformly uplifts or reduces the rows and columns until the best match is found with the observed data for each origin or destination zone.

5.1.5 Matrix estimation

Matrix estimation is a more complex technique that requires both the original demand matrix (termed a “prior” matrix) and a reasonably calibrated network of the study area (with particular attention to well calibrated route choice). The process assigns the original trip demand to the model network and then factors individual O-D cells until the modelled turn volumes are sufficiently close to the observed values.

This technique requires vigilance as it can significantly distort the trip pattern and distribution of the original demand. Detailed checking of changes to the demands is required and the process should be constrained as far as is possible to ensure that only a limited number of cells are adjusted where absolutely required. The factor by which cells can be adjusted should also be constrained to an appropriate value. A common issue with this process is the over-estimation of short trips in order to infill the matrix to fit the observed values.

5.1.6 Manual adjustment

The trip demand can also be manually adjusted by the modeller if no other option is available. Major changes should be documented and should again be constrained so as not to significantly alter the pattern and distribution of the original demand.

6 MODEL CALIBRATION AND VALIDATION

6.1 Calibration

Calibration is a method of a wide range of adjustments that can be made to model coding, parameters and demand in order to assist in the development of an accurate simulation of on-street conditions. Calibration can generally be split into three core areas:

- Network and parameter verification – refinement of network inputs – refer to Section 4
- Demand calibration – refinement of trip volumes, patterns and driving behaviour – refer to Section 5.
- Route choice calibration – refinement of parameters that influence a driver's routing decisions – refer below.

Models that involve route choice must undergo an additional process of route choice calibration. This process relates to the refinement and analysis of the manner in which drivers choose their paths through the network and ensures that the modelled paths are logical and realistic. Route choice calibration is focused upon a number of model parameters that affect a driver's perception of the attractiveness of any given path through the network. These can be broken down into global parameters and local parameters which is discussed below.

Assignment type

Each modelling package provides a variety of different assignment methods. ETA accepts that each study may require a different approach and it is incumbent upon the modeller to select the appropriate assignment technique in each case. The adopted technique should be outlined in the Model Development Report together with an indication of the reason for its selection and any relevant parameters that are used.

Generalised costs

Every route choice model (regardless of software package) relies upon a generalised cost equation to calculate a driver's most attractive route or routes through the model. The concept of the equation is that a driver perceives each route to have a total cost and can therefore rank each route from most attractive to least attractive. The equation initially takes factors of time and distance into account for each route and has an additional cost added to account for tolls or other manually included impediments. The basic equation is shown below:

Generalised cost = (A x time) + (B x distance) + (C x additional cost)

The factors A, B and C are used to adjust the influence of time and distance and can significantly affect a driver's choice of route. It is therefore important that appropriate values be used in order to ensure that drivers take logical routes through the network. It is also important to note that different vehicle types will often have different values of time and distance (i.e. a truck driver may have a different value of time to a car driver). ETA does not provide default values for the generalised cost equation and it is therefore incumbent upon the modeller to assess the values that are appropriate for the study.

Strategic models that incorporate the study area may provide relevant cost factors and may be used for this purpose.

Link hierarchy

Some software packages provide default link types that allow the stratification of links into major and minor routes. This is generally achieved by automatically applying a link cost or a link cost factor to each link of that type. For software packages that do not provide this functionality this can often be undertaken by manually applying a categorised cost or cost factor to each link.

This is a useful technique for refining the assignment of traffic through the network as it can be used to deter or attract drivers from using certain routes (e.g. rat-runs or signposted routes) by adjusting their perception of the route cost. The stratification of link type costs is considered an appropriate form of assignment calibration and is preferred to the isolated adjustment of individual link costs.

Localised cost adjustments

In some isolated cases it may be necessary to adjust the costs of individual links. Care should be taken to ensure that all other techniques that might resolve the issue have been attempted before cost factors are applied to isolated links.

Route assignment

During the calibration exercise it is essential to undertake logic checking to ensure that the route choices available to drivers are sensible and realistic. Most packages allow the modeller to select individual O-D pairs and assess the available routes and the proportion of drivers using them.

It is unlikely that routing survey data will be available and it can therefore be a relatively subjective exercise to assess the route choices that drivers make through the model. However, the primary purpose of the exercise is to ensure that drivers have been deterred from using any illogical routes through the network. The use of illogical routes would likely impact upon model performance and therefore remains an important step in the calibration process.

6.2 Model Validation

Model validation is the term used to describe the independent verification process used to demonstrate that a model has been calibrated to a sufficient extent to accurately reproduce on-street conditions. The process is far simpler than model calibration since it does not require any adjustment to parameters or inputs. The modeller simply runs the simulation and compares a set of model outputs with an equivalent set of observed site data (<u>this must be data that has not been used during the calibration process –</u> this must be discussed with ETA).

The guidelines below provide statistical criteria that will help to indicate if a model is performing adequately (validated). The following data types are addressed:

- Traffic volumes
- Journey time routes
- Queue lengths (optional)

6.2.1 Traffic flows

Traffic volumes are often used as a key statistical indicator that the model is sufficiently calibrated as they provide an easily measurable dataset both in the model and on site. Traffic volumes can be in the form of link flows or turning movement flows. These can also be aggregated to provide screen lines or cordons.

Traffic volumes can also be used in the validation process (rather than the calibration process) but this can only occur where independent volume data that has not been used during calibration exists. This is unusual since most modellers will use all of the available traffic volume data during the calibration process in an attempt to provide the most accurate distribution of demands possible.

Target validation criteria for traffic flow as follows:

Criteria	Acceptability
Differences between modelled flows and counts on screen lines should be less than 5% of the counts	All or nearly all screen lines (>95% of cases)
GEH statistic < 5 for individual flows Individual flows within 15% of counts for flows from 700-2700 veh/h Individual link flows within 100 veh/h of counts for flows less than 700veh/h Individual flows within 400 veh/h of counts for flows more than 2700 veh/h	>85% of cases
R^2 value to be included with plots and to be > 0.95	

6.2.2 Journey time routes

A common technique used to assess the accuracy of a model is to compare surveyed and modelled journey times along key routes in the study area. This is an important comparison since journey times can affect driver route choice through the model and therefore have a significant impact on traffic volumes and the development of delays and congestion.

It is important to ensure that sufficient number of journey time surveys have been undertaken during the data collection stage of the study. This will provide an accurate understanding in two key areas required for any subsequent statistical comparison:

- Average journey time for each route.
- Variability in journey time for each route

Validation Criteria:

- Journey time average - Average modelled journey time to be within 15 per cent or one minute (whichever is greater) of average observed journey time for full length of route. Each route should be cumulatively graphed by section
- Section time average - Average modelled journey time to be within 15 per cent of average observed journey time for individual sections

7 FUTURE NETWORK AND MODEL SCENARIOS

Following calibration and validation of the base model, the model can be used for scenario testing. This can vary widely although essentially involves:

- The alteration of the base model to reflect a defined set of proposed or anticipated changes.
- The comparison of the scenario test model against the base model to determine impacts of the scenario.

Future network development – Requirements for future year modelling, specifying the number of future years to be modelled. The requirements for the development of future year demands should also be considered.

Option testing – Description of options to be tested (or at a minimum the number of options to be tested). If the modelling is to be used to assist in the development of options this should also be discussed.

Future year models are developed where a project requires testing under forecast future traffic conditions.

Future models should be developed for a “do-nothing” or “do-minimum” scenario. The “do-nothing” scenario refers to the base model with future traffic volumes (and potential signal time changes only).

While the “do-minimum” also includes other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed. The development of a “do-nothing” or “do-minimum” scenario provides a basis for comparison to the future option scenarios.

Models are developed for each option to be tested. Parameters set in the base case and future case models should generally not be altered in the development of the options.

The performance of options should be compared to the relevant base case or future “do-nothing” or “do-minimum” models.

8 REPORTING

8.1 Model development

The base model reporting is intended to provide ETA with an understanding of how the model has been developed and to demonstrate that it is fit for purpose to be used in the study. There are a number of key areas that must be included in the reporting and these are as follows:

- Purpose of the study
- Model extents
- Software package used
- Modelled time periods
- User class/vehicle type definition
- Data collected
- Outline of techniques used to develop network
- Justification for changes to default parameters
- Methodology used to develop demand
- Calibration issues and statistical comparison
- Validation statistics

ETA does not provide a mandatory report structure as each model will be different and may have been developed using a methodology that varies from any other model. It is therefore incumbent upon the modeller to develop a report that provides the most logical and accurate outline of the development, verification, calibration and validation process in each case.

The structure set out below therefore simply provides a guide to assist inexperienced practitioners who wish to develop a basic Base Model Development Report:

- Introduction – study objectives, network extents, core area extent, software package, time periods.
- Data Collection – description of data collected including type, date, location etc.
- Network Development – outline of coding used for links, intersections, signals etc.
- Demand Development – description of methodology used to develop demand.
- Model calibration – statistical comparison of observed and modelled outputs.
- Model validation – graphical or statistical comparison of observed and modelled outputs.
- Summary – brief summary outlining data that demonstrates model is fit for purpose.

8.2 Model Scenarios and Options Report

The Model Scenarios and Options Assessment Report (MSOR) can vary in its scope depending on the project brief requirements but would normally include:

- Description of options tested
- Summary of key results obtained
- Interpretation of model results
- Conclusions about the adequacy of the options tested

The reporting of model application results may vary widely depending on the objectives of the study being undertaken. Often the modelling reporting is part of a larger study report. The report may be a standalone report or a chapter in a larger report. The content of scenario assessment reporting should include a description of the proposed scenario(s) scheme and any expected impacts.

The modifications made to the validated base model to develop the scenario model(s) should all be based on these key details. All changes made in order to develop the scenario model(s) should be documented, along with the reasoning behind them. Specific items that could therefore be included in the scenario assessment report are:

- Scenario summary.
- Scheme objectives/problem.
- Scenario assessment methodology.
- Evaluation of scenario results.
- Conclusions and recommendations.
- Model source data.
- Modelling assumptions.
- Electronic copies of model input file with descriptions of the data files.