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AIMSUN SATURATION FLOW CALIBRATION FOR HYBRID SIMULATION – CHALLENGES AND RECOMMENDATIONS

Microscopic and mesoscopic traffic modelling has increased in popularity across Australia over the last decade. Recently, these two levels have been facilitated in Aimsun within a common model network; enabling a simulation referred to as hybrid.

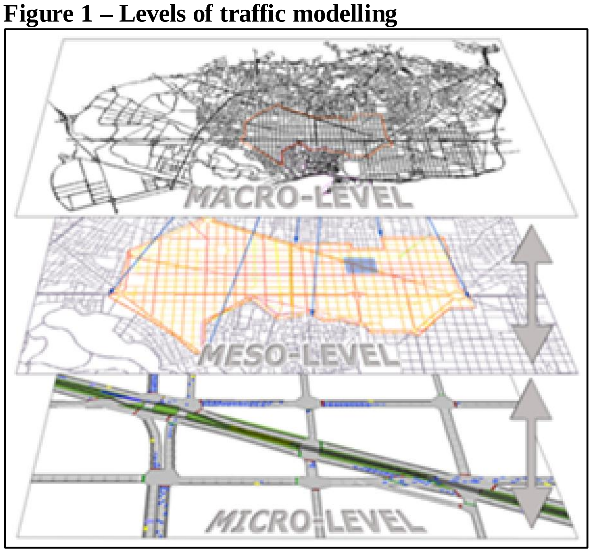
A key component of operational model calibration is saturation flow at intersections. It has been determined through research that the key factors impacting saturation flow are related to lane widths, gradients and turn radii; however the primary factors impacting the car-following model in Aimsun are related to other parameters such as vehicle reaction times.

The analysis in this paper has determined that default parameters in Aimsun version 8.2.0 may lead to an overestimation of saturation flow rates in micro and meso simulation. The analysis has identified indicative parameter values that could be used as a starting point in the calibration of saturation flows; which produce comparable operation at the meso and micro levels to assist in hybrid network development.

1. Introduction

Microscopic (micro) and mesoscopic (meso) level traffic modelling has played an important role in transport infrastructure planning and development across Australia over the past two decades. Traffic modelling is undertaken at three general levels of detail; namely macroscopic (macro), meso and micro; with macro providing a relatively coarse level of detail and micro providing the highest level of detail (refer **Figure 1**).

Figure 1 – Levels of traffic modelling



Source: Barcelo, J. Casas J, Garcia D & Perarnau J (2005)

At the macro level it is common for only the primary road network to be represented; with no detailed representation of intersection congestion. At the micro level, networks are represented at the highest level of detail; with each individual vehicle modelled explicitly. The meso level sits within the macro and micro level – it represents detailed intersection operation and congestion, but at a more abstract network level. This in theory provides benefits for the analysis of larger study areas, for which micro level modelling may be too time consuming and data intensive.

In recent years, hybrid level simulation (in traffic model networks incorporating a combination of areas simulated in micro and meso) has grown in popularity as some projects require operational analysis of larger study areas that may not need all locations to be modelled in the highest level of detail.

A prominent traffic modelling software package that is capable of hybrid level simulation is Aimsun, developed by Transport Simulation Systems (TSS). Despite the rise in popularity of Aimsun as a tool to perform analysis at the meso and hybrid levels; little published guidance exists to guide industry practitioners on recommended practice in terms of model inputs, parameters, assumptions and calibration.

An important requirement of any model network that facilitates hybrid simulation is to achieve a reasonable level of comparability between meso and micro operation along mid-block sections and at intersections. This is particularly important for congested networks with route choice – if there are significant differences in operation between network areas simulated in meso and micro, route choice calculations may favour one model area over another on the basis of the simulation method; and ultimately calibration inaccuracies.

Inputs such as signal data, traffic demands, traffic arrival patterns and network geometry are fairly straight forward in Aimsun in terms of achieving comparability between the different simulation levels; however intersection stop line saturation flow rates pose a greater challenge due to differences in the algorithms used in micro and meso assignment.

This paper investigates the parameters used to calibrate intersection stop line saturation flow at the micro and meso simulation levels in Aimsun, with the aim of achieving a level of operational comparability for hybrid network simulation. The key objectives for the investigation are to:

- Review the factors impacting saturation flow as determined through industry research and how these parameters are used to predict saturation flow in deterministic traffic modelling.
- Identify the parameters in Aimsun that have the most impact on saturation flow rates in micro and meso simulation.
- Determine parameters that result in typical saturation flow rates in micro and meso simulation, which could be used as a starting point in a model calibration process.
- Recommend parameters that result in comparable intersection operation in micro and meso, thereby providing a level of comparability for hybrid simulation.

2. Background and theory

2.1 What is saturation flow?

Saturation flow was defined by the Transport and Road Research Laboratory (TRRL) in 1963 Traffic Signals - Note 34 (Webster FV & Cobbe BM) to be 'the maximum uniform discharge rate across a stop line' and can be measured on-site as follows:

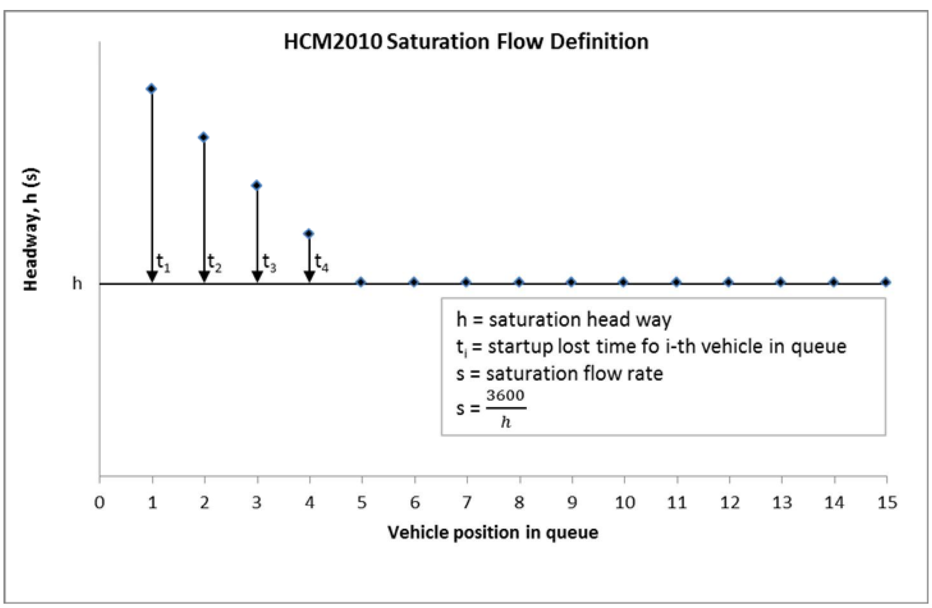
- *When the stop line signal turns green and vehicles start to move, allow three cars to cross the stop line to allow traffic to reach saturation flow rate.*
- *When the rear of the third vehicle crosses the stop line, start the stopwatch. Count and record the number of PCUs that cross the stop line within the saturated period.*
- *When the saturated period comes to an end or the traffic stage being measured terminates (including any vehicles crossing in the amber and red periods) stop the stopwatch when the rear of the last vehicle crosses the stop line.*
- *Record the number of PCUs against the time in seconds (to 1/10 second).*
- *Average at least 15 readings and calculate saturation flow in pcu/hr.*

Saturation flows are defined in the Transportation Research Board (TRB) - Highway Capacity Manual 2010 (HCM2010) in a similar manner:

'The number of vehicles per hour per lane that could pass through a signalised intersection if a green signals was displayed for the full hour, the flow never stopped and there were no large headways'

Headways for vehicles in a queue are illustrated, together with start-up loss time for the first four vehicles, in **Figure 2**.

Figure 2 – HCM saturation flow rate definition



2.2 Parameters affecting saturation flow

Linking the response of drivers to real world operations has resulted in the development of predictive equations for saturation flows that link measurable variables for intersections to observed operations (Webster & Cobbe 1966, Akcelik 1981 and Kimber et.al. 1986 and HCM2010). Typically these equations consider geometric parameters such as lane entry / exit widths, turning radii, gradient, lane position (nearside / offside), number of lanes and speed limits.

These have been explored by various practitioners, resulting in several formulations relating geometric attributes and adjustments of environmental locations. One of the formulations is TRRL RR67 (Kimber et.al.), which is incorporated in software such as TRANSYT and LINSIG and is based on additive formulation (refer **Equation 1**). Another is the HCM2010 formulation, which uses a multiplicative set of factors (refer **Equation 2**).

Equation 1
TRRL - RR67 (1986) – Kimber et.al.

$$S = \frac{2080 - 140\,d_n - 42 d_g\,G + 100\,(w_i\ - 3.25)}{1 + 1.5\left({}^{f}/_{r}\right)}$$

Where

S = saturation flow (passenger car units / hour)

d_n = dummy variable (1 for nearside lane, 0 for all others)

d_g = dummy variable (1 for uphill and 0 for downhill)

G = gradient (per cent)

w_l = lane width at entry (metres)

f = proportion of turning vehicles in a lane

r = radius of turn path (metres)

Equation 2
HCM 2010

Metropolitan Areas (population > 250,000):

$S = 1900\ f_w\ f_{HV}\ f_g\ f_p\ f_{bb}\ f_a\ f_{LU}\ f_{LT}\ f_{RT}\ f_{Lpb}\ f_{Rpb}$

Other areas (population < 250,000):

$S = 1750\ f_w\ f_{HV}\ f_g\ f_p\ f_{bb}\ f_a\ f_{LU}\ f_{LT}\ f_{RT}\ f_{Lpb}\ f_{Rpb}$

Where:

f_w = adjustment factor for lane width

f_{HV} = adjustment factor for heavy vehicles in traffic stream

f_g = adjustment factor for approach grade

f_p = adjustment factor for parking lane and parking activity

f_{bb} = adjustment factor for blocking effect of local buses that stop within intersection area

f_a = adjustment factor for area type

f_{LU} =adjustment factor lane utilisation

f_{LT} = adjustment factor for left turn vehicle presence in lane group

f_{RT} = adjustment factor for right turn vehicle presence in lane group

f_{Lpb} = pedestrian-bicycle adjustment factor for left turn group

f_{Rpb} = pedestrian-bicycle adjustment factor for right turn group

The HCM2010 equation incorporates a range of geometric and operational activities such as parking, bus operation, pedestrians and bicycles. In addition, the scale of the study area population has an impact of reducing saturation flow by 8%; and there is an adjustment factor for area, which recommends a value 0.9 should be applied on an area by area basis but is primarily intended for CBD areas.

The TRRL and HCM2010 formulations have common variables of lane width, gradient and turning movements. The impact of these parameters on saturation flow as recommended by TRRL and HCM2010 are illustrated in **Figure 3** to **Figure 5**.

Figure 3 – Impact of lane width on saturation flow (TRRL and HCM 2010)

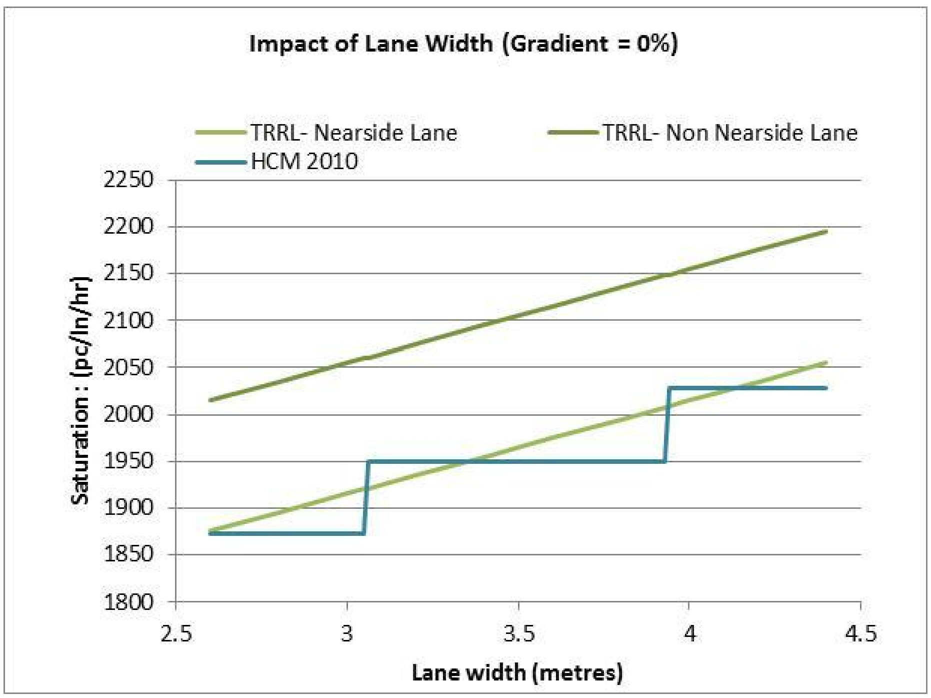


Figure 4 – Impact of gradient on saturation flow (TRRL and HCM 2010)

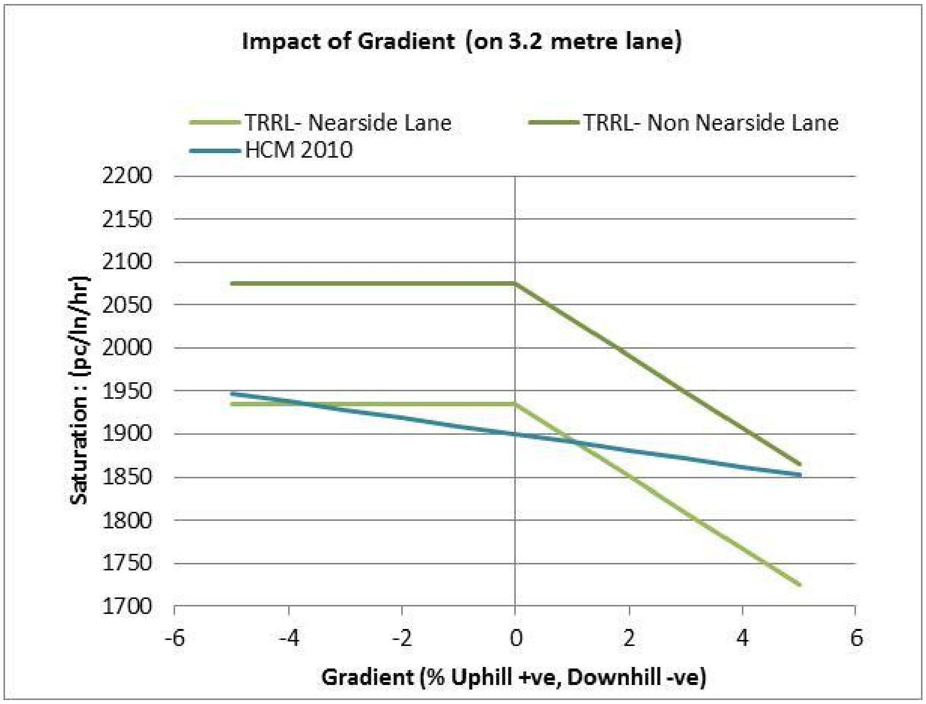
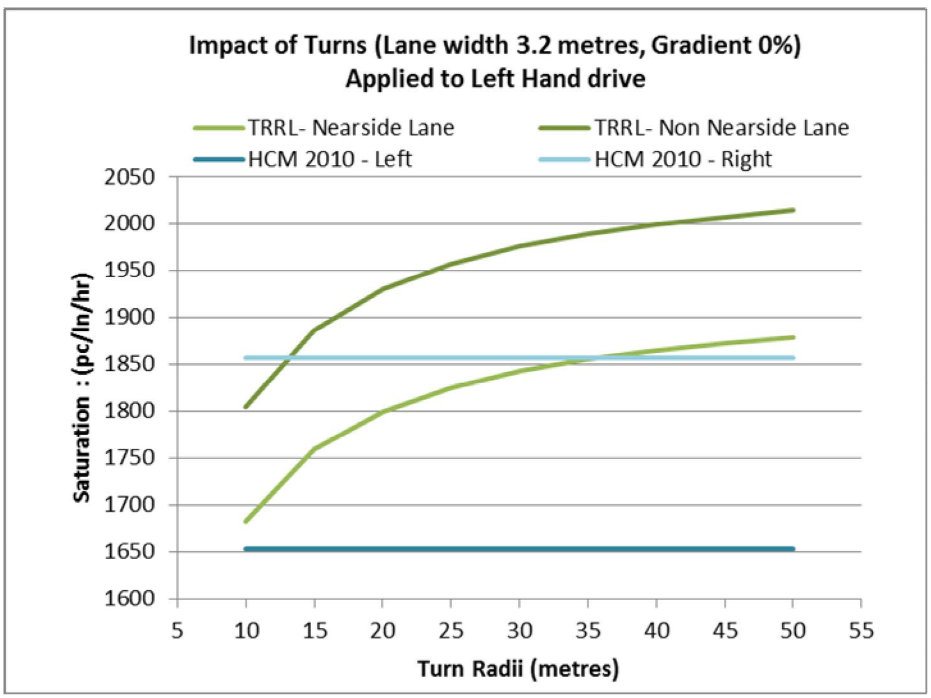


Figure 5 – Impact of turn radii on saturation flow (TRRL and HCM 2010)



The TRRL approach was further clarified in the TRRL Food for Thought Article 97 (2005) with the view that sites could be categorised into three designations – good, average and poor; and that adjustments to the geometric based saturation flows could be applied on this basis (refer **Table 1)**.

Table 1 – TRRL Food for Thought Article 97 (2005) saturation flow adjustment recommendations

Site designation	Description of characteristics	Adjustment to TRRL RR67
Good	Dual carriageway intersections. No noticeable interference from pedestrians, parked vehicles, right –turning traffic (either owing to their absence of because special provision is made for them). Good visibility and adequately large turning radii. Exit of adequate width and alignment. Good quality road surface.	+10%
Average	Some characteristics of good sites and poor sites.	-5% to 10%
Poor	Average speeds low. Some interference from standing vehicle, pedestrians and right turning traffic. Poor visibility and or poor alignment of intersection. Busy shopping street with pedestrian activity. Poor road surface. Traffic calming measures on either/both entry and exit. Congestion or downstream queueing discouraging drivers from pulling away cleanly.	15% to 25%

Both the TRRL and HCM2010 formulations are based on generalisation and simplification; and therefore provide a guide to an intersection’s likely operation. The formulas point to local conditions such as road width, gradients, turn traffic proportions, pedestrian/cyclist activity; and location with the road network can all contribute to higher and lower than typical performance. Considering these factors can aid and justify the calibration of specific site observations on queues, delays and throughput; and can be used to refine traffic model operations.

The background and formulas outlined above demonstrate the importance of saturation flow rate in traffic modelling and analysis.

2.3 Micro vs. Meso simulation in Aimsun

Micro simulation in Aimsun utilises the Gipps car-following model (Gipps 1981 and 1986b), which includes (but isn’t limited to) parameters such as driver behaviour, speed limits (on sections and turns) and the influence of vehicles in adjacent lanes. Key elements of the model are acceleration and deceleration, which represent the intention of a vehicle to achieve a desired speed and reproduces the limitations imposed by the preceding vehicle when trying to drive at the desired speed (TSS Aimsun 8.1.4 User’ Manual 2016).

Another important element is lane changing. In Aimsun, lane changing is represented in micro simulation using the Gipps lane-changing model (Gipps 1986a and 1986b). The model represents a decision making process that incorporates the necessity of changing lanes; the desirability of changing lanes and the feasibility of changing lanes (TSS Aimsun version 8.1.4 User’s Manual 2016). The feasibility of changing lanes is governed by gap acceptance calculations.

Aimsun meso simulation is based on discrete-event simulation (Law and Kelton 1991) and adopts a simplified version of the Gipps car-following model in terms of vehicle movement, lane changing and gap acceptance. Whereas vehicle movements and decision making can occur in all locations and times in micro simulation; such changes only occur in meso simulation during discrete events such as vehicle generation, vehicle system entrance and vehicle node movement (TSS Aimsun 8.1.4 User's Manual 2016).

Consequently, the following key differences exist between Aimsun micro and meso operation (TSS Aimsun 8.1.4 User's Manual 2016):

- Vehicle acceleration and deceleration are not represented in meso simulation – vehicles are assumed to be either stationary or travelling at free flow (posted) speed.
- Simplified lane changing – vehicles in meso can only change lanes at the entrance/ exit to sections.
- Simplified gap acceptance – signal, yield and stop delay is linked to down-stream section capacity.

Vehicle acceleration/ deceleration and lane changing behaviour can have a significant impact on network operation and saturation flow, so it is important to robustly calibrate meso operation to make sure that this behaviour is accounted for in some way.

Anecdotally, an industry general rule of thumb suggests that reaction times in meso simulation should be around 1.5 times that of the reaction times in micro simulation; however this recommendation has not been documented clearly in previous research or guidance documents.

2.4 Saturation flows in Aimsun

In Aimsun meso and micro simulation (and many other car-following software packages), lane widths and other geometrical parameters do not significantly impact saturation flow rates. Instead, saturation flow rates can be impacted using the following parameters:

- Vehicle reaction times (including Reaction Time, Reaction Time at Stop)
- Vehicle kinematics.
- Speeds on turns.
- Section Jam Density.

Jam Density represents section capacity in meso simulation and governs the number of vehicles that can stay at the same time in a section (refer **Equation 3**).

Equation 3

TSS Aimsun 8.1.4 User's Manual 2016

SectionCapacity = JamDensity * Length * NumberLanes

where

- *JamDensity* is the Jam Density parameter defined in Aimsun sections
- *Length* is the section length considering 3D coordinates
- *NumberLanes* is the total number of lanes in a section considering on and off ramps.

The "Reaction Time at Traffic Light" parameter can also be adjusted in microsimulation assignment; however this parameter only impacts the first vehicle at the intersection stop line and so may be considered inappropriate to impact constant saturation flow and queue discharge.

3. Analysis

The analysis undertaken for this paper has focussed on the impacts of vehicle reaction times, turn speeds and section jam density in the calibration of saturation flow rates in Aimsun (using Aimsun version 8.2.0); with the aim of achieving comparability between micro and meso simulation for hybrid assignment.

3.1 Methodology and assumptions

Calculation of saturation flow rates in Aimsun can be achieved by taking visual measurements from micro simulation using the TRRL and HCM2010 recommended methods commonly used for on-site measurement. This approach ensures that accelerating and arriving (non-queued) vehicles are not included in the saturation flow rate calculation.

Individual vehicle movements cannot be easily visualised in meso simulation in Aimsun version 8.1, so direct measurement of saturation flow rates is not achievable using this method. To robustly calibrate saturation flow in meso simulation it is recommended to firstly calibrate the operation in micro to provide target operation outputs to calibrate against in meso.

The methodology for calibrating meso saturation flow rates used in this paper followed the process outlined below:

1. Calculate saturation flow rate in micro using software default reaction time and turn speed values.
2. Undertake iterative refinements to the reaction time and turn speed parameters in micro to achieve a typical saturation flow rate of around 1,900-2,000 vehicles per hour per lane.
3. Calculate the average delay across a two hour period for the intersection approach using the preferred reaction time and turn speed parameters.
4. Calculate the average delay across a two hour period for the intersection approach using meso simulation with software default meso reaction time and turn speed parameters.
5. Undertake iterative refinements to the reaction time, turn speed and section jam density parameters in meso simulation to produce intersection approach average delay comparable to the levels achieved in the micro assignment.

To maintain consistency between the micro and meso comparisons, the following assumptions were incorporated into the analysis:

- Single lane intersection approach to eliminate impacts of vehicle lane changing.
- Assignment of car vehicle type only.
- Consistent signal timings and operation.
- Consistent approach volume and vehicle arrival profile.

Impacts of turn speed were tested by applying varying values to the automatic turn speed for the approach through movement. Impacts of section jam density were tested by applying varying values to the jam density parameter for the approach section. Impacts of variances in vehicles reaction times were analysed by making adjustments to the global and approach section parameters.

Calibration of saturation flow rates were assessed separately for each of these adjustment methods, not in combination.

3.2 Results

Saturation flow rates and average delay outputs using the software default and preferred parameters for the reactions times and turn speed in micro assignment are summarised in **Table 2**.

Table 2 – Micro assignment preferred calibration parameters

Method	Turn speed (kph)	Time step (s)	Reaction time (s)	Reaction time at stop (s)	Saturation flow rate (vph)	Average delay (s)
Default parameters	70	0.8	0.8	1.2	2,250	26.42
Preferred turn speed	28	0.8	0.8	1.2	2,000	27.82
Preferred global reaction times	70	0.5	1.0	1.4	1,963	28.40
Preferred section reaction times	70	0.8	0.8	1.5	1,928	28.29

Results of the meso simulation calibration to achieve the average delays produced by the microsimulation assignment are summarised in **Table 3**.

Table 3 – Meso simulation calibration outputs

Method	Turn speed (kph)	Jam density (veh/km)	Reaction time (s)	Reaction time at stop (s)	Saturation flow rate (vph)	Average delay (s)
Default parameters	70	200	1.2	1.6	N/A	13.08
Preferred turn speed	28	200	1.2	1.6	N/A	13.08
Preferred section jam density	70	40	1.2	1.6	N/A	27.79

Preferred global reaction times	70	200	2.12	1.6	N/A	28.13
Preferred section reaction times	70	200	2.06	1.6	N/A	28.69

The outputs in **Table 3** indicate that the turn speed did not have any impact on the approach delay in mesoscopic simulation. Iterative adjustments for the approach section jam density and global/ section reaction time values were able to re-produce levels of approach delay comparable to the delay achieved in the micro assignment.

It should be noted that changes in the Reaction Time at Stop parameter did not seem to have a significant impact on approach delay in meso, so this parameter was maintained at the default value for all of the tests.

3.3 Other calibration considerations

The analysis presented in the sections above are intended to demonstrate how typical saturation flow rates can be produced for use as a starting point in intersection calibration and to achieve a level of comparability between meso and micro assignment for hybrid simulation. Other important site specific factors to consider in the calibration process include:

- *Vehicle lane changing on approach to, at and beyond the signal stop line* – Vehicle lane changing can have a significant impact on intersection throughput. This behaviour can be managed by making changes to the section Look-ahead Distance parameters, although this approach is challenging in mesoscopic assignment due to the simplified representation of mesoscopic lane changing in Aimsun mesoscopic simulation.
- *Impacts of reaction time parameter changes on angled turn movements* – The analysis presented in this paper has focussed on calibration of saturation flow rates for through movements. Impacts of refinements to reaction times (either globally or locally) on angled turn movements should be reviewed on a site by site basis to ensure that the desired saturation flow rate is produced. Localised adjustments to angled turn speeds may be required.
- *Lane utilisation* – Early tests undertaken as part of the analysis for this paper originally assumed three lanes along the intersection approach. It was discovered, however, that comparable lane utilisation across the three lanes could not be achieved between the microscopic and mesoscopic simulation. The mesoscopic simulation tended to favour utilisation of the kerb-side lane by default, whereas the microscopic simulation assumed a fairly even distribution of traffic across the three lanes. Application of the “Penalise Shared Lanes” and “Penalise Slow Lanes” did not help to achieve better comparability in lane utilisation.
- *Impact of section speed, lane widths and gradient on saturation flow* – These parameters do not seem to have a significant impact on saturation flow calibration in micro or meso simulation.

4. Discussion and conclusion

This paper has investigated the parameters that impact saturation flow as determined by industry research. It has underlined the importance of saturation flow calibration in relation to traffic operation and traditional traffic modelling approaches. Two of the most widely used methods for predicting saturation flow (developed by TRRL and HCM2010) are based primarily around geometrical inputs such as lane widths, turn radii and gradient. Research has also suggested that saturation flow can be impacted by other factors such as location (CBD vs rural) and associated driver behavioural differences.

Prediction and calibration of saturation flow in Aimsun presents a challenge to practitioners as the micro and meso simulations of the software are based around a car-following model; so saturation flow in Aimsun is not governed by the geometrical factors outlined in the TRRL and HCM2010 research. Instead, saturation flow can be impacted by vehicle reaction times, turn speeds and jam densities (meso simulation only).

For hybrid simulation it is important to produce a level of comparability between saturation flow in micro and meso simulation as the two assignment methods interact and influence route choice calculations and vehicle arrival patterns across a common network. The aim of the analysis presented in this paper was to determine a set of parameters in Aimsun micro and meso simulation that could be used (with caution) as a starting point to produce the required level of comparability.

The analysis has indicated that the software default parameters adopted in Aimsun version 8.2.0 appear to produce a saturation flow rate that is significantly higher than typical maximum values. It is recommended that saturation flow rates are reviewed as part of model development processes and calibrated as required.

Saturation flow in micro simulation can be measured visually using the on-site method recommended by TRRL and HCM2010; however this approach cannot be adopted in meso simulation as it is not currently possible to view each individual vehicle using this assignment method. It is recommended that saturation flow is calibrated firstly in micro simulation to produce a calibrated approach delay output. The micro-based approach delay output can then be used to calibrate the approach delay in meso; and thereby the meso saturation flow.

The analysis in this paper has indicated that in micro simulation, a vehicle Reaction Time value of 1.0 and Reaction Time at Stop value of 1.4 can result in a (typical) saturation flow rate of around 1,900-2,000 vph per lane when applied. It has been determined that a Turn Speed value of 28kph can result in a similar saturation flow rate.

In meso simulation, Turn Speed was not found to impact saturation flow rate. Reaction Time and Reaction Time at Stop values of 2.12 and 1.6 respectively resulted in a similar approach delay to that of the micro simulation; as did a Jam Density value of 40. This suggests that reaction times in meso simulation should be around twice that of the reaction times in micro (rather than the anecdotal industry recommendation of 1.5 times).

It is recommended that these values could be used with caution as a starting point for the calibration of saturation flow in Aimsun for meso, micro and hybrid simulation; with further refinement to site-specific conditions as necessary. Other factors such as lane changing and lane utilisation are important considerations; and should be reviewed and calibrated against as required.

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John is a chartered engineer and traffic modeller with experience from across the UK and Australia. He has a particular interest and expertise in operational traffic modelling using meso and micro simulation; and has developed and managed medium to large scale models for a range of major road and public transport infrastructure planning and design projects. John has advanced capabilities in a range of mainstream industry software packages, including PTV Vision software, Aimsun and Paramics.

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Brian is a consultant who has led numerous transport planning and modelling projects in the United Kingdom, Ireland, Kuwait, Kazakhstan and most recently Australia. Brian specialises in delivering strategic multimodal and highway modelling studies, scheme appraisal and economic assessment in support of business cases. Brian is experienced in formulating improvements to improve operational performance / efficiency, promote economic growth, integration and sustainability of the transport sector. Brian has lead projects that have used various software suites including SATURN, CUBE, EMME, VISSIM, VISUM, Paramics and since 2013 projects which have utilised Aimsun.