# CUSTOMISING VEHICLE ATTRIBUTES FOR ROAD TRAFFIC MICROSIMULATION MODELLING

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**Abstract**

Vehicle classification including their proportions, physical and kinematics attributes is a necessary step when building a microsimulation model of any road network. Microscopic simulators are based on modelling individual vehicle/driver units and their interaction which points to the importance of having a proper vehicle attributes specified in order to achieve the modeling results that match real-life conditions. The substitution of default vehicle attributes that are usually built into microsimulation software by a locally customised vehicle fleet will allow for more accurate estimation of traffic performance indicators, such as speeds, travel times, capacity, fuel consumption etc. In particular, the accurate classification of vehicles is essential for reliable vehicle emissions predictions, since the type and fuel used by vehicles has a significant effect on their emissions level. Vehicle data that is being collected around the world may vary in its form and detail but single databases very rarely will contain all the information needed for microsimulation tasks. Therefore, main sources of vehicle registration data will need to be supplemented by other sources. This paper describes the development of vehicle fleet profiles and their attributes suitable for modelling Australian road networks. It describes the development of the customised vehicle fleet to be used in Paramics microsimulation modelling package by Quadstone in the United Kingdom (UK) but it can easily be extended to any other traffic microsimulation software.

**Keywords: Microsimulation, Vehicles, Roads, Kinematics.**

## Presenting Author's biography

Branko Stazic is a Regular Member of Eastern Asia Society for Transportation Studies (EASTS) with ten years of experience as a Transportation Engineer working for both, the University of South Australia (UniSA) and the State Government Transport Agency. For last seven years he has been working as a Research Associate at the UniSA and is involved in research, teaching and supervision of postgraduate students working on Transport Modelling projects. He holds a Master's Degree in Transport Systems Engineering from University of South Australia and he is currently undertaking a PhD research degree course at the same University. His involvement in research projects has resulted in the publication of a number of recent conference papers in the area of Transport Microsimulation modelling.

 

## 1 Introduction

Traffic modelling is a very useful and cost effective method when assessing real life traffic network performance and when comparing alternative scenarios. It is important to stress that microscopic simulation does not refer to simulation of small networks but the simulation of networks on an individual vehicle level. This means that this type of simulation can be applied on a large size networks in great detail. Because of these characteristics the microsimulation is very often the only tool available in assessing driver reaction to certain road conditions and technologies (e.g. incidents and Intelligent Transport Systems (ITS) technologies).

One of the very important parts of microsimulation modeling involves the specification of vehicle profiles. Vehicle physical characteristics have a potential to impact on road capacity and level of service, especially in urban areas. For instance, the length of the vehicles will have an impact on the back of the queue location at junctions. Also, different vehicle types will have different performance characteristics (e.g. acceleration, deceleration, crawl speed on a slope) that can affect traffic flow rate. Unless the proper vehicle attributes are used in transport modelling the results could represent a significant mismatch with the real-life traffic conditions resulting in insufficiently calibrated models.

There are a number of systems in use that are capable of collecting traffic volume data but only some of them are capable of gathering fleet profile data. Very often the data available when conducting microsimulation comes from more than one of such systems.

To this end there are a number of Australian databases that can be used for vehicle classification, these include but are not limited to: Australian Bureau of Statistics (ABS) Motor Vehicle Census Data (MVC); Austroads Vehicle Classifications; Fleet composition models produced by Bureau of Transport Economics. Vehicle fleet profiles were developed for South Australian urban and rural conditions based on Australian Bureau of Statistics' Motor Vehicle Census data and supplemented with other sources of vehicle kinematics and physical characteristics

Customised vehicle fleet, including vehicle mix and attributes, was developed to be used in Paramics microsimulation modelling package by Quadstone in the UK for South Australian urban and local road networks. The development was based on Australian Bureau of Statistics' Motor Vehicle Census but due to some attributes missing or only partially recorded data was supplemented with other sources of vehicle kinematics and physical characteristics.

## 2 Traffic simulation

The ever increasing power of personal computers has allowed the development of the powerful traffic simulation software that can be used as an extension to traditional analytical models and be of a great help when analyzing complex traffic systems. 'They [microsimulation models] are the only modelling tools available with the capability to realistically examine certain complex traffic issues such as Variable Message Signs (VMS), closely linked traffic signals, effects of incidents, parking and road works or the impact of trams on the network.' (Transport for London 2003, p.3).

Microsimulation models are capable of simulating random nature of the traffic system elements due to use of probability distributions rather than relying on fixed values that are very often unable to properly represent real-life conditions. An example of the probabilistic behavior of traffic system element would be the random vehicle arrival which is modelled through the use of some type of the probability function based on random seed values. The use of random seed values means that every modelling run could potentially produce slightly different results. In order to achieve the repeatability of the runs microsimulation packages allow users to lock the seeding value that was found to be appropriate.

In microsimulation each vehicle and its interaction with other vehicles and the physical constraints of the network is modelled throughout the whole trip. All the calculations are done for short simulation steps (usually one second) indicating a need for powerful personal computers. Many modelling packages are also capable of running on Personal Computers (PC) with multiple Central Processing Unit (CPU) setting enabling faster model running especially in the case of large and complex networks being modelled. Driver behaviour factors are also modelled that usually include aggression, awareness, network familiarity, etc. Also, data about traffic conditions ahead (e.g. congestion) is updated in user-specified intervals (known as dynamic feedback period) which allows for dynamic route selection.

As Bell (1998, p.4) suggested, that simulation will continue to play an important role in transport research but it is not perfect and comes with a number of pitfalls due to model complexity. For instance, complex models may: obscure their assumptions; compound error; have an increased chance of chaotic behaviour; may yield results that are difficult to interpret, and therefore are difficult to translate into policy.

Some recent software developments have resulted in the creation of the link between traffic modelling packages and modern adaptive traffic signal control systems like SCATS (Sydney Coordinated Adaptive Traffic System); see Sims and Dobinson (1979, pp.9-42). This link has allowed data to be exchanged between modelling software and the real-life traffic control systems. This is an important add-in since none of the major microsimulation packages has traffic signal optimization module incorporated in the core of the program.

## 3 Mathematical models in traffic microsimulation

'Underlying operational research in transport (or any other field for that matter) is a mathematical model, consisting of a system of equations quantifying the relationships between the key variables.' (Bell ed 1998, p.1). The mathematical models used in microsimulation are combined with driver reasoning and are usually calibrated against data generated by real-life experiments. The basic models used are car-following, lane changing, gap acceptance and route choice models.

The example is so called car-following models developed by General Motors more than fifty years ago that explain how drivers react when following another car without a chance to change the lane. These models take into account vehicle speeds, acceleration, deceleration, reaction time, vehicle lengths and spacing between vehicles. Many of the current car-following models are based on the second General Motors model that is given in equation 1. The equation [1] suggests that the interaction of the vehicles will be higher as the spacing between them decreases.

$$a_n(t+\Delta t) = \Lambda_n \frac{v_{n-1}(t) - v_n(t)}{x_{n-1}(t) - x_n(t) - l_{n-1}} \quad [1]$$

where,

$a_n(t+\Delta t)$ is the acceleration of the nth vehicle

$\Delta t$ is a reaction time

$\Lambda_n$ is a sensitivity coefficient

$v_i(t)$ is the speed of vehicle i at time t

$x_i(t)$ is the position of vehicle i on the road at time t

$l_{n-1}$ is the effective length of vehicle (n-1)

Lane changing process is more complex than car-following since it requires drivers to make more decisions. According to Taylor, Young and Bonsall (1996, p.61), 'The demand for lane changing is at minimum when all drivers desire to travel at about the same speed. As the relative differences in vehicle speeds increase, so does the frequency of demand for lane changing.' Lane changing can be compulsory and optional. Compulsory lane changes occur when vehicles are forced to change lanes due to road conditions or traffic control instructions (e.g. lane closure ahead, lane merging, lane discipline, etc). Optional lane changes are made at the drivers' discretion usually as a result of drivers having desired speeds higher than the vehicles in front of them or as an anticipation of the road conditions ahead (e.g. short lane at the downstream side of an intersection).

Even more complicated behaviour than a lane changing would be an overtaking maneuver. It is important to note that current microsimulation software packages are not yet capable of modelling overtaking maneuvers. There have been some recent attempts to add this functionality to some of the software but the modules have still not been fully implemented. Research work undertaken by Fry (2004) on a development of an overtaking module for two-way two-lane roads for Paramics Quadstone has shown that this is possible and it will probably be implemented in not so distant future.

An important characteristic of the simulation models is the ability to model gap acceptance behaviour for different network conditions. This ranges from stop signs to filter turning movements at the signalized intersection.

Microsimulation models are capable of modelling dynamic traffic assignment technique that takes into account delays that drivers are experiencing during the trip when calculating shortest routes through the network. According to Heydecker and Addison (in Bell ed 1998, p.35), 'Dynamic traffic assignment provides a valuable means to investigate congested road networks and hence to develop traffic managements for them.'

## 4 The importance of vehicle specifications in microsimulation

The vehicle attributes can vary significantly between individual vehicle and even more between vehicles belonging to different vehicle categories. For instance, heavy vehicles have much lower traffic kinematics performance than passenger vehicles. Although, the development of detailed vehicle profiles can be data intensive it is necessary to develop groups of vehicles with similar characteristics if the microsimulation models are to properly mimic the real life conditions.

Since both, car-following and lane-changing models, contain parameters related to vehicle kinematics and physical attributes it is important that proper vehicle specifications are used. It is quite possible that vehicle fleet and vehicle performance specifications will vary between countries and even between networks within same country. Thus, the use of improper attributes could lead to an error that could influence many traffic performance indicators generated by the modelling software resulting in incorrect representation of the real life transport system.

According to HCM (2000) 'The characteristics and performance of motor vehicles play a major role in defining the fundamentals of traffic flow and capacity.'

Although all the microsimulation modelling packages contain few default vehicle types (e.g. passenger vehicles, light commercial, heavy trucks, buses, etc.) having default vehicle attributes, the importance of the proper customised vehicle profiles should not be neglected.

The specification of vehicle profiles is of particular importance if emission modelling is to be performed. This type of modelling would not only require some extra vehicle attributes (e.g. fuel type) but also vehicle kinematics and engine data (acceleration, deceleration, engine size, engine temperature, etc.). According to Akcelik and Besley (2003, p.1), 'Estimation of operating cost, fuel consumption and pollutant emissions for evaluating intersection and mid-block traffic conditions is useful for design, operations and planning purposes in traffic management.'

## 5 Paramics microsimulation software and its default vehicle specifications

PARAMICS (Parallel Microscopic Simulation) is an advanced suit of software capable of modelling complex traffic networks by mimicking the behaviour of individual vehicles on urban and highway road networks. It has been originally developed at the University of Edinburgh in the UK and since it became commercially available it has been maintained and distributed through Quadstone Ltd.

Movement of the vehicles through the network can be stochastic, based on random variations and dynamic, where vehicle behaviour is changed according to conditions during the trip. According to Paramics Modeller Reference Manual (Quadstone 2004, p.17), 'Feedback Period – This sets the period at which link times are fed back into the routing calculations. At the beginning of each feedback period route cost tables are calculated for each viable network node to each destination zone for each routing table.' Paramics also uses feedback smoothing factor (delay averaging across calculation periods) and feedback decay factor (when there are no new costs of travel available) that can influence route table calculations.

Paramics is capable of modelling private and public transport vehicles in urban and highway environment. Private vehicle demand is specified through the origin-destination (OD) matrix and due to random nature of vehicle release the number of vehicles specified may not match the actual number of vehicles released into the network. On the other hand, public transport vehicles are specified as fixed-route vehicles with the release frequency or the exact schedule released times used rather than random release. A number of other attributes is also used when coding public transport vehicles including associated stops, dwell time, vehicle occupancy, fleet size, etc.

Paramics has a powerful 2D/3D visualization engine for displaying vehicle movements during the simulation. An example of Paramics 3D network visualization capability is illustrated in Figure 1.

Figure 1 Paramics 3D visualization of Adelaide CBD area

Once the vehicles are released into a network they will move from the origins towards their destinations according to a number of behaviour rules, vehicle and driver characteristics and network attributes.

The movement of vehicles through the network is dynamic since driver vehicle units (DVU) have only partial information on their route to the destination (small number of nodes ahead). The route choice decisions are based on travel costs (distance, time, and toll) and network restrictions. The costs of travel can be link or network-wide based and the user has a choice of selecting how these costs will be used and which weighting coefficient will be applied for each of them. It should be noted that in Paramics, unlike some other equilibrium based models, the vehicle journey times will vary for each vehicle even if they follow the same route since the traffic conditions may be different when journeys were made.

Also, it is possible to model the variation in the cost perception by different drivers through the use of cost perturbation. Furthermore, by specifying the proportion of familiar drivers the route selection can be influenced allowing only certain percentage of drivers to use minor roads when looking for alternative routes.

Default vehicle types and their attributes used by Paramics that can influence modelling results are summarized in the Table 1. There are also few other attributes that do not have any influence on modelling like vehicle shape and colour and are there only to enhance the visual display. Furthermore, a number of trailers and associated physical attributes can be specified in a similar manner to vehicles with the exception of trailer age.

Table 1 Default vehicle attributes

| Type | Length (m) | Height (m) | Width (m) | Weight (tonne) | Top Speed (km/h) | Acceleration (m/s/s) | Deceleration (m/s/s) |
|---|---|---|---|---|---|---|---|
| Car | 4.0 | 1.5 | 1.6 | 0.8 | 158.4 | 2.5 | 4.5 |
| Lgv | 6.0 | 2.6 | 2.3 | 2.5 | 126.0 | 1.8 | 3.9 |
| Ogv1 | 8.0 | 3.6 | 2.4 | 15.0 | 104.4 | 1.1 | 3.2 |
| Ogv2 | 11.0 | 4.0 | 2.5 | 38.0 | 118.8 | 1.4 | 3.7 |
| Coach | 10.0 | 3.0 | 2.5 | 12.0 | 126.0 | 1.2 | 3.7 |
| Minibus | 6.0 | 4.0 | 2.5 | 8.0 | 61.2 | 1.1 | 3.2 |
| Bus | 10.0 | 4.0 | 2.5 | 12.0 | 61.2 | 0.9 | 3.2 |

 

# 6 Australian vehicle classification schemes

As a starting point in the development of the vehicle fleet profiles two existing Australian schemes were used. Each of these schemes uses different vehicle type description as can be seen from the following chapters.

Motor Vehicle Census (MVC) data represents vehicles recorded by state and territory motor vehicle registration authorities at the census date or had registration expire less than one month before that date. Census date for data used in this thesis was 31 March 2003 and it includes passenger vehicles, light commercial vehicles, trucks and buses. In total there were 13.2 million motor vehicles registered in Australia including motor cycles of which 1.1 million were registered in South Australia.

Austroads 94 vehicle classification has been in use in Australia since 1994 as a replacement to previous NAASRA (National Association of Australian State Road Authorities) scheme. AustRoads94 scheme classifies vehicles according to spacing of first three axles and total number of axles and axle groups.

# 7 New fleet profiles and vehicle attributes developed

Vehicle fleet consists of a variety of different vehicle types that can perform quite differently when responding to network geometry and basic behaviour models built in microsimulation software. It is unrealistic to model each individual vehicle with its specific attributes but rather to classify them into vehicle groups that have similar vehicle characteristics. Vehicle shapes are excluded from this paper since they are there mainly for the visual effect and do not influence the simulation results.

## 7.1 Vehicle fleet

Using the ABS data vehicles were grouped into two sets according to the area of the registration, with vehicles registered outside the state disregarded. This has lead to a broad grouping of vehicles into urban and rural classes that were split further according to vehicle body type as follows:

- Passenger vehicles
- Light Commercial Vehicles
- Light rigid trucks
- Heavy rigid trucks
- Articulated trucks

Public transport vehicles (e.g. buses) were excluded from the calculations since in microsimulation they are modelled as fixed route vehicle and are not part of the origin-destination matrix.

## 7.2 Vehicle physical attributes

In order to determine the physical attributes of the passenger vehicle fleet six most common vehicle models were selected as per MVC database which made around 44% of total passenger vehicle fleet.

Table 2 Passenger vehicle physical attributes

| | Length [m] | Width [m] | Height [m] | Weight [t] |
|---|---|---|---|---|
| Holden Commodore Executive Sedan 1988-1993 | 4.865 | 1.813 | 1.406 | 1.310 |
| Ford Falcon GLi Sedan | 4.811 | 1.857 | 1.399 | 1.418 |
| Mitsubishi Magna SE Sedan | 4.746 | 1.775 | 1.430 | 1.370 |
| Toyota Corolla CSi liftback | 4.210 | 1.655 | 1.360 | 1.045 |
| Ford Laser GL Hatch | 4.270 | 1.695 | 1.375 | 1.005 |
| Toyota Camry SE Sedan | 4.500 | 1.710 | 1.400 | 1.205 |
| Mean Vehicle Attributes | 4.675 | 1.779 | 1.400 | 1.275 |

Table 2 clearly shows the difference in default Paramics vehicle parameters when compared to South Australian fleet. South Australian fleet seems to be consisting of much larger cars than the cars described using default Paramics values that could be more suitable for European conditions.

Following the same procedure as for passenger vehicles physical attributes were developed for other vehicle classes. Top six most common light commercial vehicles made up around 59% of total light commercial vehicle fleet in the registry database indicating lower vehicle diversity than passenger vehicle fleet as expected.

Vehicle attributes for all three truck classes (light and heavy rigid and articulated) were also developed. Furthermore, public transport vehicle profiles have been developed although they are not modelled as a part of OD matrix travel demand specification it is still necessary to develop the proper vehicle attributes for such vehicles.

## 7.3 Vehicle Kinematics

Maximum acceleration and deceleration rates of the vehicles were determined using maximum performance figures. It should be noted that the values were determined only for vehicle accelerating from/to a stop and not from any other speed.

One of the attributes used by Paramics that can influence vehicle behaviour on slopes is mean vehicle age. Mean vehicle age data was recorded as a part of MVC data and it was used in the determination of this attribute for all vehicle types developed in the previous step. This data is summarized in Table 3.

 

Table 3 Mean vehicle age

| Cars [years] | Light Comm. Vehicles [years] | Light rigid trucks [years] | Heavy rigid trucks [years] | Artic. trucks [years] |
|---|---|---|---|---|
| 11 | 12 | 12 | 14 | 10 |

Net horse power for vehicles that are representative of the developed vehicle classes was taken from vehicle manufacturers' websites and the mean value determined according to the proportion of the vehicles in each class as per MVC data.

### 7.4 Comparison of vehicle lengths with the field data

In order to verify that MVC data on registered vehicles reflects the actual vehicle fleet characteristics on the road, the vehicle wheelbase dimensions for the vehicles used in the previous steps were compared against MetroCount classifier vehicle wheel-base distributions for three different locations in Adelaide Metropolitan area.

It was shown that mean vehicle wheelbase for vehicles (passenger and light commercial) selected in the determination of the vehicle physical characteristics matches closely (within 10 cm) the real-life figures.

## 8 Conclusions

The use of locally customised vehicle fleet instead of default fleet that is usually built into modelling packages will lead to more credible modelling results.

Since microsimulation modelling is done on an individual vehicle level, it is important to have vehicle attributes specified as close as possible to the real world in order to achieve more accurate mimicking of vehicle impact on road capacity. Furthermore, proper vehicle characteristics will increase accuracy in individual vehicle interaction when traveling through a network allowing for better representation of the lane-changing, car-following and gap-acceptance algorithms.

Vehicle fleet profiles described in this paper were developed specifically for Paramics modelling package but with the small changes they could be adjusted for use by any other transport modelling software. This may only involve changes to the file format that particular software is using. Also, the vehicle fleet could be developed for other Australian and overseas towns using the same data sources and following the similar approach as presented in this paper.

Proportion of different vehicle classes was determined together with the vehicle physical and kinematics attributes. It should be noted that the proportion of different vehicle types may vary throughout a day and between different days of the week, which may require some extra analysis for the particular modelling period.

It was shown that the proportion of vehicles in the fleet varies significantly between urban and rural areas. Also, the mean values for some of the attributes were found to differ significantly from Paramics default values that seem to match European fleet better due to fleet consisting of much smaller cars than in Australia.

Vehicle mean wheelbase dimensions for passenger and light commercial vehicles were checked against the real-life data collected by the MetroCount traffic classifiers. It was shown that vehicles selected from the MVC database represented a good match with the data collected on the road.

Due to possible shift towards smaller/larger cars the vehicle profiles developed may require updating in the future. Also, a few other vehicle characteristics could be added to the profile list, for instance fuel type, which would enable fuel consumption and emission modelling to be conducted.

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