# TRAFFIC FLOW MODELLING FOR AN URBAN ARTERIAL ROAD IN BRISBANE CITY

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## ABSTRACT

This paper presents the development and calibration of a simulation model for interrupted traffic flow condition on a Brisbane urban arterial road with signalised intersections. VISSIM software was used to develop the model using the actual data collected by the Brisbane traffic control system and from the field observations. The model developments focus on key elements and concepts to incorporate the road network and lane configuration features, available signal timing and coordination, and vehicle and driver behaviour characteristics. The notable difficult task in the process was the calibration of actual saturation flow rate at each intersection to represent actual conditions. Statistical tests have been used to identify the required number of simulation runs and subsequently to validate the results. The results revealed that model is compatible with field data measurements. The results demonstrate that a model for simulating interrupted traffic flow conditions is possible with actual data and reasonable calibration and validation efforts. This study's considerable efforts to develop the model were devoted to investigate the effect of future ITS applications to urban arterial roads.

*Key words: Traffic Simulation, Urban arterial road, Interrupted traffic flow, Traffic Modelling*

## 1. 0 INTRODUCTION

Traffic congestion and delay are well-known phenomena in almost any urban area. During traffic congestion the interactions between vehicles slow the speed of the traffic stream and subsequently reduce the road capacity. There are several traffic demand and system based attempts which have been adopted aiming to reduce and/or resolve those problems. The Department of Transport and Main Roads (DTMR), Queensland tries to ease Brisbane's traffic congestion by applying various traffic control strategies such as application of variable speed limits, signs for route guidance and traffic incidents and others applicable for a congested road network.

Over the last three decades, traffic simulation techniques have been used to predict the effect of any remedial measure before its application. Currently, several traffic engineering software programs are available which are found to be applicable to simulate and/or visualize the real situation flow condition in a road network. These packages include TRANSIT- 7F, EMME3, SATURN, AIMSUN/2, PARAMICS, CORSIM, and VISSIM. When using simulations it is vital to be able to generate real scenarios which represent actual traffic flows.

Urban traffic systems are complex systems composed of vehicles, pedestrians, traffic control devices, and a road network, along with some other sub-systems such as Urban Traffic Management and Vehicle Generation (López-Neri, Ramírez-Treviño, López-Mellado 2010). Therefore developing a simulation model representing a real traffic flow condition is not an easy task, and all processes need several input parameters related to the traffic characteristics induced from various traffic controls, geometric factors, driver and vehicular behaviours. Collecting the complete required data requires a lot of resources and traffic simulation models therefore frequently assume some traffic parameters to simplify the simulation process. Additionally, each software program has its own limitations in incorporating the traffic characteristics to simulate the various real-life scenarios (Boxill & Yu, 2000). VISSIM, a time step stochastic behaviour model, was developed initially in the 1970's at the University of Karlsruhe, Karlsruhe, Germany. The aim was to model urban public transportation systems and the program was then developed to model freeway and highway traffic behaviour.

In the current study, a simulation model has been developed using VISSIM to investigate the possibilities of employing variable speed limit (VSL) for upstream traffic management of a target arterial road link. The aim is to control the traffic flow through critical intersections by maintaining flow rather than having the flow fully congest. This study outlines the main steps in developing a simulation model to identify the critical parameters that are involved when congestion is developing and to find ways to reduce the effect.

## 2.0 SITE SELECTION AND DATA COLLECTION

The Griffith Arterial Road (U20) is part of the Brisbane Urban Corridor. This section of road is about 11.5 km in length, between the Gateway Motorway and the Ipswich Motorway, and is part of the National Land Transport Network (Department of Transport and Regional Services, 2007). The operation of this arterial is under jurisdiction of Department of Transport and Main Roads, Queensland (QDTMR). This study selected a segment of this road (Figure 1) containing six signalised intersections: Granard Road- Beatty Road (intersection 1 "Beatty"); Granard Road - Beaudesert Road - Riawena Road (intersection 2 " Beaudesert"); Riawena Road - Perrin Place (intersection 3 "Perrin"); Riawena Road - Orange Grove Road (intersection 4 "Orange"); Kessels Road - Troughton Road (intersection 5 "Troughton"); and Kessels Road - Mains Road (intersection 6 "Mains").

Traffic signal management for the road is undertaken using the STREAMS system which controls the signal cycle times, splits and offsets to suit changing traffic conditions. In addition traffic data is collected continuously using 30 second time periods. A pilot survey and preliminary statistical results showed that the Beaudesert and Mains intersections experienced high traffic flows during the evening peak period for both Eastbound (EB) and Westbound (WB) directions. The traffic data from 35 detectors supporting the STREAMS operation, plus data from manual counts, were used to calibrate the traffic condition in a VISSIM model of the road segment.

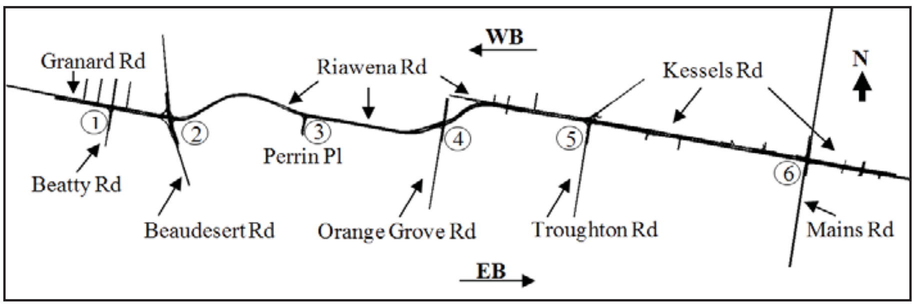


**Figure 1. Griffith arterial road (U20), Brisbane**

Manual counting revealed that the flows in both EB and WB directions along the arterial road represent the major traffic flows in the study area, except at the Beaudesert and Mains intersections where the four approaches at each intersection could be considered major flows. Over a 2 hour evening peak period, little fluctuation was noted in the EB flow whereas the WB flow exhibited greater fluctuation. The study area land use was predominantly industrial and commercial services. The percentage of heavy vehicles was found to fluctuate between 3% and 18% from link to link along the arterial.

## 3.0 DEVELOPMENT OF TRAFFIC FLOW MODEL

Microscopic modelling allows for tracing of individual vehicles from entry into the network until departure and for assigning to each vehicle type specific performance capabilities such as maximum speeds and acceleration and deceleration rates (Oketch & Carrick 2005). VISSIM allows the input of these and other parameters into the model (Moen at el 2000). The VISSIM program uses the psycho-physical driver behaviour model developed by Wiedemann (PTV 2011) in the calculation of vehicle movements through the road network.

### 3.1 Road network and signal timing

The initial step in creating the VISSIM model for this study was drawing up the study area using the interface screen. This required knowledge of the geometric layout of all road features. Features of the network were identified in Google Earth and an unscaled aerial photo of the selected area was saved. The photo file was uploaded as a screen background, then as detailed in PTV (2011) the photo was scaled to match with real measurements. In this manner, whole geometric condition of the network, lane configuration, and the intersection locations were setup by tracing the background using the VISSIM links and connectors. The lane width of roads were obtained from using the toolbox of Google Earth and compared with field measurements. Speed regulations over the network were also checked from the field observations. Geometric features incorporated included link type (behaviour type), number and widths of lanes, lane change parameters (which include the lane change distance and the emergency stop distance), priority signs for merging lanes, reduced speed areas for left and right turn movements at intersections, turning curvatures, and conflict areas at intersections which could be blocked by vehicles in oversaturated conditions.

The second stage after developing the road network was allocating the real-world traffic control systems to the traffic signals. The six signalised intersections were created using the Traffic control signal and signal ahead tool of the software. Each individual signalised intersection was designated separately in order to take advantage of the offset feature. The study was concerned with the evening peak period and so the model was created to focus on a near congested condition. Traffic signal operational patterns were therefore adopted which were close to fixed timing plans. The signal timing information and the traffic phase sequences were decided after analysing data collected from the traffic signal sites using video cameras. Some of the signal phasing incorporates a special phase of permitted right turn, but VISSIM modelling doesn’t include this option. Thus signal priority with signal ahead was used to imply the permitted option in a fixed timing plan, and a signal control mode for intersection 1 is shown Figure 2.

### 3.2 Traffic characteristics

Traffic flow characteristics including volume, vehicle compositions, vehicle lane distribution, and required speeds, were incorporated for each road section to progress the model construction. Traffic characteristics are inserted using a window pop up menu environment. First the actual peak traffic volumes through each entrance point of the network were loaded to the model. VISSIM modelling allows a variety of vehicles types that reflect the diversity of vehicles in reality. Editable futures include vehicle type (i.e. length and width), functions (i.e., acceleration, deceleration), and distribution (i.e. weight and power). Two vehicle types were selected for this study, namely private vehicles (car) and trucks (heavy vehicles). Average field observed dimension and classifications were used in the modelling. The percentage of each vehicle type as a proportion of the entire flow was inserted for each entrance point or source of generation for the network. Different percentage of heavy vehicles and desired speed were defined according to the observed traffic data.

Generated traffic for each source needed to be distributed over the network. Routing decisions and routes command in the model allowed assigning two input options: static route and dynamic assignment route. In this process, an O/D traffic matrix was established to facilitate assigning traffic routes in the selected area. The static option was used to configure the traffic flow, and route decision (origin and destination) points which were required to create the traffic distribution. One origin point route decision may have multiple destination routes so the model was assembled in a method analogous to a tree with several branches. Finally, the number of vehicles traversing each route in a specific time period was fed into the model.

### 3.3 Driving behaviour

The VISSIM program uses the concept of car following theory developed by Wiedemann in 1974 (PTV2011). The basic concept of this model is that the driver of a faster moving vehicle starts to decelerate as they reach their individual perception threshold to a slower moving vehicle. Since the driver is unable to determine exactly the speed of that vehicle, the speed will fall below that vehicle's speed until the driver starts to slightly accelerate again after reaching another perception threshold. This results in an iterative process of acceleration and deceleration (PTV 2011).

The VISSIM parameters controlling driver behaviour, such as average standstill distance ($a_x$), additive part of desired safety distance ($b_{x\_add}$) and multiplicative part of desired safety distance ($b_{x\_mult}$), were used to adjust in a number of calibration runs. The average standstill distance represents the average desired distance between stopped cars with variation ± 1 m, normally distributed around 0.0 m with a standard deviation of 0.3 m. As a default, the additive part of the desired safety distance was set to 2 m and the multiplicative part of desired safety distance was set to 3 m and both affect the computation of the safety standstill distance, d in a link.

The driving behaviours used in four trial calibrations (one default and three adjusted) in Beatty Road EB direction are given in Table 1. The default value of driver behaviour is represented by $a_x$:$b_{x\_add}$:$b_{x\_mult}$ = 2:2:3 (for Trial 1). When calibration used the default parameters the results did not represent the field traffic condition for the road links or for the discharged traffic movements (through, left and right movements) at the intersection. Therefore several combinations of driver parameters were tested to capture the real behaviour over the study area, and the results of 3 adjustment trials are also given in Table 1. The saturation flow providing the best match between simulation and field values was adopted as the saturation flow of the approach.

**Table 1. Parameters tested for model calibration**

| Parameters | Default | Adjusted | | |
|---|---|---|---|---|
| Beatty EB | Trial 1 | Trial 2 | Trial 3 | Trial 4* |
| Driving Behaviour ($a_x$:$b_{x\_add}$:$b_{x\_mult}$) | 2:2:3 | 2:2:1 | 2:1:1 | 2:0.5:1 |
| Average simulated volume from 5 runs | 2068 | 2075 | 2081 | 2089 |
| Field Measurement | 2090 | 2090 | 2090 | 2090 |
| % Relative Error | 1.0 | 0.7 | 0.4 | 0.0 |

* refers to the verified parameters (some results were transferred to Table 2)

In addition, the necessary lane change parameters were set to define conditions where a vehicle changed lanes. These parameters are dependent on the emergency distance available when a lane ends and the gap acceptance value for normal lane changing. In this study, these parameters are set as the default values except for two parameters: safety distance reduction factor and maximum deceleration for cooperative braking (PTV 2011). Higher values have been used and this allowed for more braking and thus increased the likelihood of lane changing. Since the study concentrates on the peak period, with dense traffic for an urban area, a higher value to allow for increased for the driver aggressiveness accurately modelled actual behaviour. An example of VISSUM input parameters for defining driver behaviour is shown in Figure 3.

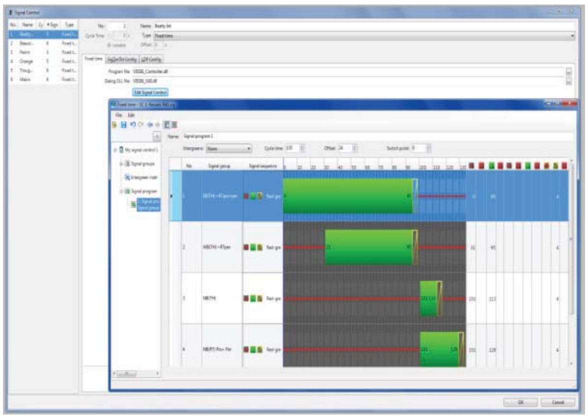

**Figure 2. Traffic control at intersection 1**

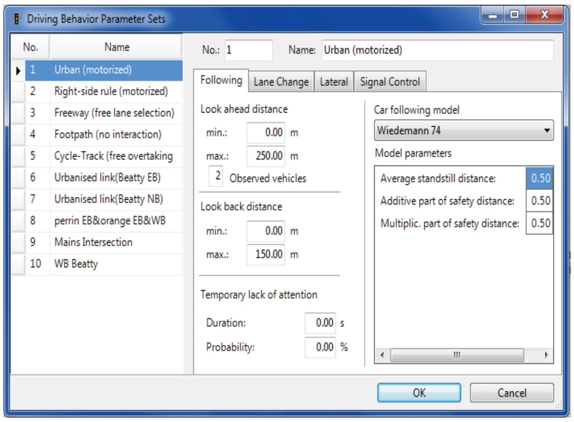


**Figure 3. Input mode for driver behaviour**

## 4.0 MODEL SIMULATION AND VALIDATION

Initially, a 600 second warm-up period for simulation execution was considered to populate the road network with vehicles. The model's outputs vary with the number of runs which is associated with a selected 'random seed'. This 'random seed' parameter initialises the random number generator. Changing the random seed number will change the stochastic nature of many behavioural sub-models that are responsible for generating traffic random distribution over the links (PVT 2011). In using the simulation tools it is possible to use different random seed numbers (e.g. 100, 110, 120, … - see Table 2) to replicate the local traffic conditions.

Determination of the number of simulation runs required to replicate the local traffic condition is a vital step in the modelling. Statistical procedures outlined by Federal Highway Administration (2004) and Abdy & Hellinga (2008) were used to decide the required number of simulation runs to the planned accuracy. Analysis revealed that the maximum of simulation runs required depended on the link characteristics, and varied from 2 to 20.

Adequate calibration is based on statistical tests and the level of acceptable error between the simulated results and the field observations. The Geoffrey E. Havers (GEH) statistic is used widely in traffic engineering, traffic modelling and traffic forecasting [Oketch & Carrick 2005].

The formula for calculating the GEH value is: √ [2(S-F)2/(S+F)] where S is the simulated result and F is the field measurement. According to Oketch & Carrick (2005) the goodness indications for GEH between two sets of data can be classified as a good fit when GEH is less than 5; a fit warranting further investigation when GEH is between 5 and 10; and a poor fit when GEH is greater than 10. As can be seen from Table 2, all the GEH value found were below 5 and the developed model represented the actual interrupted traffic flow conditions.

**Table 2. Results for Model validation**

| Main stream Flow Destination | | Seed number | | 100 | 110 | 120 | 130 | 140 | Statistical Evaluation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Detectors′ group(numbers) | Observed v/h | RUN 1 | RUN 2 | RUN3 | RUN4 | RUN5 | AVG | 5% AVG | STD | GEH |
| Eastbound (EB) | Beatty | 1 (1,2,3) | 2090 | 2089 | 2090 | 2090 | 2090 | 2090 | **2089** | 104 | 0.4 | 0.004 |
| | Beaudesert | 2 (4,5,6) | 1859 | 1881 | 1852 | 1791 | 1875 | 1805 | 1841 | 92 | 40.8 | 0.413 |
| | Perrin | 3 (7,8) | 1550 | 1510 | 1522 | 1452 | 1537 | 1515 | 1507 | 75 | 32.5 | 1.105 |
| | Orange | 4 (9,10) | 1547 | 1500 | 1527 | 1462 | 1538 | 1507 | 1507 | 75 | 29.3 | 1.039 |
| | Troughton | 5 (11,12,13,14,15) | 1824 | 1743 | 1716 | 1722 | 1764 | 1755 | 1740 | 87 | 20.7 | 1.975 |
| | Mains | 6 (16,17,18) | 1735 | 1651 | 1611 | 1623 | 1654 | 1596 | 1627 | 81 | 25.2 | 2.688 |
| Westbound (WB) | Mains | 7 (19,20,21) | 1231 | 1166 | 1180 | 1222 | 1300 | 1229 | 1219 | 61 | 52.4 | 0.331 |
| | Troughton | 8 (22,23,24) | 1050 | 988 | 995 | 1008 | 1025 | 1004 | 1004 | 50 | 14.1 | 1.454 |
| | Orange | 9 (25,26,27) | 1195 | 1109 | 1129 | 1122 | 1189 | 1089 | 1128 | 56 | 37.5 | 1.977 |
| | Perrin | 10 (28,29,30) | 1331 | 1212 | 1233 | 1245 | 1279 | 1192 | 1232 | 62 | 33.1 | 2.742 |
| | Beaudesert | 11 (31,32) | 1357 | 1221 | 1254 | 1256 | 1305 | 1212 | 1250 | 62 | 36.6 | 2.969 |
| | Beatty | 12 (33,34,35) | 1660 | 1463 | 1587 | 1518 | 1533 | 1491 | 1518 | 76 | 46.7 | 3.572 |

The results used to validate the model are given in Table 2. Results show that the actual traffic distribution at the selected signalised intersections and the traffic flow along the arterial links for the study area can be calibrated to local traffic condition using the developed VISSIM model.

## 5.0 CONCLUSION

Traffic flow is a complex phenomenon and the realistic modelling of actual flows requires considerable skill and patience. The creation of a model to study flow along a major urban arterial road involving six signalised intersections has proven to be a challenging exercise but use of VISSIM software has enable this to be achieved. It is intended that the created model will initially be used to study how improved traffic flow may be achieved under conditions near saturation, with an aim of adopting control strategies which will facilitate optimum travelling conditions for the public.

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