Freeway capacity, saturation flow and the car following behavioural algorithm of the VISSIM microsimulation software

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1 Introduction

Freeways represent the best example of an unconstrained traffic flow system with high speed operations, limited access and egress opportunities and few factors to inhibit traffic flow. This road type can typically achieve the highest throughput of traffic per hour per lane across most metropolitan networks. As most regular limitations to free flow traffic conditions are removed from freeways, the achievable throughput is subject to regulatory constraints such as speeds and societal limitations such as headways between vehicles.

Historical traffic volumes indicate that hourly throughputs per lane are generally increasing over time. This reflects a reduction in headways between vehicles as motorists' acceptable and safe gaps between vehicles become smaller. As a direct consequence, the capacity of freeways has been observed to increase over time. The most recent edition of the US Highway Capacity Manual indicates a ceiling value significantly higher than that applied fifteen years prior.

This paper has set out to identify the changing values of capacities over time as applied to freeway traffic conditions. The paper examines capacity in the context of observed volumes to date from both an Australian and International experience. This paper then examines the car following algorithm in the VISSIM microsimulation software to benchmark the similarity of the maximum freeway capacity against these observed volumes.

This review of existing literature was initially undertaken when developing a VISSIM microsimulation model to examine the application of forecast future year traffic volumes on a motorway network. Initial discussion queried the method that microsimulation software packages such as VISSIM use to determine capacity. Microsimulation packages are capacity oriented rather than demand focussed. For this reason, microsimulation models are regularly applied to capacity constrained transport situations such as town centre and urban design studies. Existing publications exploring the research behind VISSIM examined the appropriateness of components in the algorithm to recreate traffic operations. However, there was little documentation to identify the midblock capacities represented with the car driver following model to simulate freeway conditions. This paper sets out to explore the maximum capacities that can be achieved when simulating freeway operations for both current and future year conditions.

1.1 Definitions

1.1.1 Freeways

In the Highway Capacity Manual, a freeway is defined by the following characteristics

> *"A divided highway with full control of access and two or more lanes for the exclusive use of traffic in each direction. Freeways provide uninterrupted flow. There are no signalized or stop-controlled at-grade intersections, and direct access to and from adjacent property is not permitted. Access to and from the freeway is limited to ramp locations. Opposing directions of flow are continuously separated by a raised barrier, an at-grade median, or a continuous raised median."*
> *(Transport Research Board, 2000, Chapter 13)*

For the purposes of this paper, a freeway represents an unconstrained traffic flow network, be it referred to as a motorway, tollway, tunnel or a freeway. The affects of tolls on the road network is not relevant and therefore not considered within this analysis.

1.1.2 Capacity

The definition of capacity varies depending on the context applied. Two distinctly different definitions are attributed to the terms "flow rate" and "maximum number of vehicles". The Highway Capacity Manual (2000) defines capacity as the following:

> *"The maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour."*
>
> *(Transport Research Board, 2000, Chapter 5)*

This definition presents an idea of throughput while accounting for the various factors of friction that inhibit vehicles. By comparison, the literature in the VISSIM manual (PTV, 2007) refers to flow rates as a "saturation flow". The term of saturation flow in the Highway Capacity Manual specifically refers to signalised intersections and available green time (Transport Research Board, 2000, Chapter 5). Throughout this paper, the term saturation flow as identified in the VISSIM manual is applied as the maximum traffic flow volumes that can be achieved over an hour long interval. Capacity will be referred to as the maximum achievable throughput given the constraints that limit the traffic flow, such as weaving, grade, traffic composition and geometric bottlenecks. The variation between the two terms is that saturation flow refers to potential hourly flow volumes if the inhibiting factors were not present (under ideal conditions). The other definition reflects an achievable throughput that is subject to the constraints in the network. The capacity of a section of freeway could therefore be significantly less than the saturation flow.

2 Capacity

2.1 Existing standards of capacity

2.1.1 Highway Capacity Manual

The Highway Capacity Manual represents a default document examining capacity and traffic flow characteristics, based on research and observed conditions in North America. The most recent edition of this manual is dated from 2000. Previous editions were released in 1985, with updates in 1994 and 1997.

A review of the successive releases of Highway Capacity Manuals indicates that ceiling values of freeway capacities have increased over time. Capacity calculations in the 1985 edition were in the order of 2,000 vehicles per hour per lane. This flow volume allowed for an average headway between vehicles of two seconds. The 1994 edition of the Highway Capacity Manual identifies that freeway capacity under ideal conditions is 2,200 vehicles per hour per lane. The Highway Capacity Manual 2000 identifies capacity as:

> *"Under base traffic and geometric conditions, freeways will operate with capacities as high as 2,400 pc/h/ln. This capacity is typically achieved on freeways with FFS of 120 km/h or greater. The capacity of a basic freeway segment with a FFS of 90 km/h is expected to be*

approximately 2,250 pc/h/ln."
(Transport Research Board, 2000, pp13-4)

This is further supported by Fellendorf and Vortisch (2001) who observe that US freeway conditions become unstable at a saturation rate of approximately 2,400 vehicles per hour per lane.

Freeway capacity thresholds have continued to increase over subsequent editions of the manual. This is attributable to improved road design elements, improved motor vehicle performance and motor vehicle safety measures as well as the smaller vehicle sizes travelling throughout the urban environment.

Any one of these factors or a combination of factors may have led to contemporary drivers maintaining smaller headways between vehicles while on freeways. However, it may also be due to changes in societal driving patterns rather than engineering improvements in infrastructure or vehicle specifications. Nonetheless, the reduction in headways between vehicles over time appears to have transpired. A detailed description of ideal conditions for maximum achievable capacity is provided in **Appendix A**.

2.1.2 Australian Standards

The current Australian benchmark on freeway capacity (Austroads, 1988) is based on the work undertaken in the 1985 version of the Highway Capacity Manual. This document categorises freeway capacity of 2,000 passenger car units per hour per lane for freeway sections with a design speed of 100km/ hr or greater. A capacity measure of 1,900 passenger car units per hour per lane is provided for freeway sections with design speeds of 80 km/hr.

Given the updates to the freeway standards over time, there is now a significant disparity in freeway capacities between the current release of the Highway Capacity Manual (2000) and the Austroads (1988) documentation.

2.2 Observed Flow volumes

2.2.1 Highway Capacity Manual

The 1994 edition of the Highway Capacity Manual identified a number of North American freeways and average volumes per lane during the peak hour. These flow volumes indicate actual observed traffic volumes and the number of lanes. A summary of this table is reproduced in **Table 1**. The data indicates that there are a number of US freeways with observed traffic flow greater than the saturation flow rate. All of the traffic volumes listed in **Table 1** exceeds the capacity threshold in the publication they are quoted from. The table also indicates that additional lanes reduce the average saturation flow throughput achieved. Freeways with a larger number of lanes generally have lower average observed throughput than freeways with fewer lanes. Furthermore, five of the freeways listed in **Table 1** have an observed throughput from the 1994 edition that exceeds the capacity figure applied to the 2000 edition of the Highway Capacity Manual. All observed freeway traffic volumes listed exceed the current saturation flow volumes applied to Australian road networks.

Table 1: Sample reported maximum hourly one-way volumes on selected freeways

Location	Number of Lanes (Two Directional)	Average Volumes Per Hour Per Lane (One Directional)

I-66, Fairfax, Virginia	4	2650
U.S. 71, Kansas City, Missouri	4	2628
I-59, Birmingham, Alabama	4	2401
I-35W, Minneapolis, Minnesota	4	2345
I-225, Denver, Colorado	4	2336
I-287, Morris Co., New Jersey	4	2312
I-495, Montgomery Co., Maryland	6	2498
U.S. 6, Denver, Colorado	6	2459
I-5, Portland, Oregon	6	2396
I-35W, Minneapolis, Minnesota	6	2303
I-635, Dallas, Texas	8	2272
Garden State Parkway, New Jersey	8	2228

Source: Transport Research Board, 1994:Table 2-2

The data was published in Table 2-2 of the 1994 Highway Capacity Manual (Transport Research Board, 1994) and reprinted as Table 8-19 in the 2000 Edition (Transport Research Board, 2000).

It is acknowledged that capacity should not be recognised as an absolute figure, but as a generic guideline that has been developed based on observed traffic throughputs. As identified in **Table 1**, it is not impossible to exceed the hourly per lane flow volume on freeways.

It is suggested that saturation flows provide an acceptable threshold for many freeways, but this is not an absolute maximum on a number of road networks. The reasons behind these higher observed volumes may be related to circumstances associated with ideal conditions. However, this may simply be an indication that high demand networks respond with reduced headways between vehicles when infrastructure provision is limited on freeways.

2.2.2 Australian Experience

One of the best examples of freeway conditions within the Sydney motorway network is the Sydney Harbour Tunnel. The northbound direction is particularly useful to examine driver performance in response to limited infrastructure arrangements and regular high volume throughput. The suitability of this road for study purposes is in part due to the limited number of downstream bottlenecks upon leaving the tunnel. The Sydney Harbour Tunnel continues in the northbound direction to the Warringah Expressway, ensuring that similar conditions are experienced immediately upon exiting the tunnel. However despite these conditions when leaving, there is significant grade descending in to and ascending out from the tunnel. Grade is a constraint on the potential saturation flows that can be achieved at this location. There are also relatively low signposted speeds in this tunnel of 80 km/ hr.

Traffic volumes for the Sydney Harbour Tunnel in the northbound direction are published on a three year cycle by the New South Wales Roads and Traffic Authority. The most recent published data for this location is for a sample week from the year 2002 (NSW Roads and Traffic Authority, 2003). The data indicates that weekday evening traffic volumes regularly achieve a traffic flow of 4,200 vehicles for the two lanes. By comparison, the equivalent location in 1999 achieved a flow volume of 3,500 vehicles per hour (NSW Roads and Traffic Authority, 2000). This recent traffic throughput is an average lane volume of 2,100 vehicles per hour, which exceeds the current Australian capacity benchmark at this design speed of 1,900 vehicles per hour, before examining further constrains such as grade. The data also suggests that traffic volumes can exceed the saturation flow if downstream bottlenecks can be engineered out from the system.

3 VISSIM and the Wiedemann Car Following Behavioural Algorithms

3.1 The VISSIM Microsimulation Software

VISSIM is a microsimulation modelling software for assessing complex traffic and transport operations where a multitude of factors can constrain capacity. This simulation modelling utilises a time step based approach to identifying opportunities for each vehicle (object) within a network (Wiedemann and Reiter, 1992). Microsimulation modelling incorporates the elements of traffic demand with the road geometry and signal operations together to appropriately reflect traffic operations. The models incorporate significantly more detail than traditional metropolitan wide models. This modelling approach provides value in assessing congested traffic conditions, by incorporating the numerous factors of friction that limit throughput including signal coordination between intersections, signal arrangements, interaction with pedestrians and on-street parking.

VISSIM is a German microsimulation product, developed by PTV AG as part of the transport modelling suite. VISSIM is a trajectory based (rather than node based) microsimulation software that utilises a psycho-physical driver behavioural model as developed by Wiedermann (PTV, 2007). The software was calibrated with field research from the Technical University of Karlsruhe, Germany.

3.2 The Wiedemann Car Following Behavioural Model

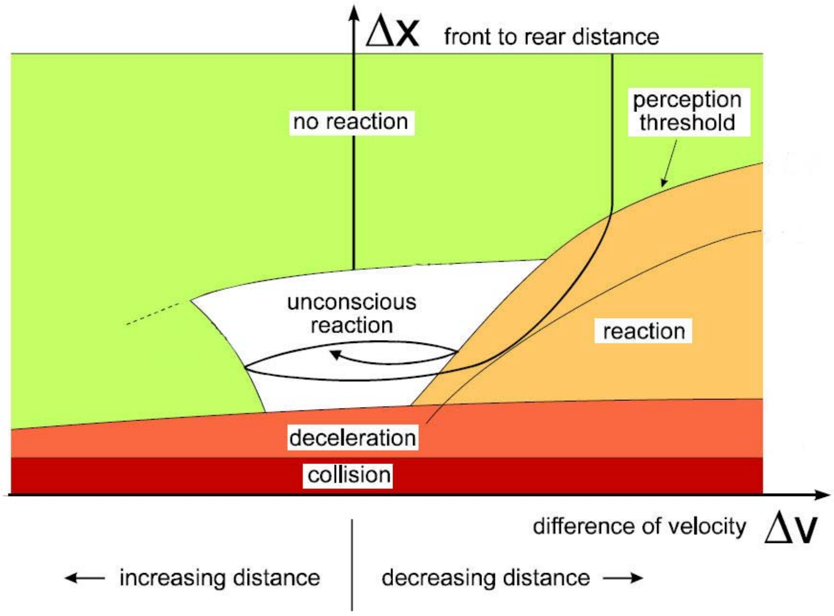
The car following algorithm in VISSIM is derived from research undertaken by Wiedemann in 1974 (PTV, 2007). The car following model considers the changes in vehicle speeds in response to the performance of those vehicles immediately in front. The model incorporates changes in driver conditions from free flow speeds to congested networks.

The model, as shown in **Figure 1** has been developed to assess each individual vehicle in regard to the relative distance and speed of the vehicle immediately in front. There are four stages to the model, identified by Fellendorf and Vortisch (2001) as the following:

1. Free driving
2. Approaching
3. Following
4. Braking

The first stage of the car following model identifies a vehicle in a free driving arrangement that does not need to respond to the performance of other vehicles - only to regulatory measures (eg signalised intersections). At a point while driving the distance is reduced so that the rear vehicle acknowledges the existence of the leading vehicle that it is approaching. Once the trailing vehicle has caught up to the leading vehicle, the trailing vehicle drives in a responsive manner to the performance of the vehicle in front. A distance from the leading vehicle is maintained but does continue to oscillate due to subtle changes in speed, acceleration and deceleration. A desired safe distance is preserved between the leading and the trailing vehicle. However, if the trailing vehicle moves too close to the leading vehicle, it enters the “Braking” stage. It is at this stage where accidents are more likely to occur.

Figure 1: Wiedemann Car Following Model



Source: PTV, 2007

Where:
ΔX is the change is distance between the leading and the trailing vehicle; and
ΔY is the change in velocity between the leading and the trailing vehicle.

There are two algorithms within the VISSIM microsimulation software to represent the driver behaviour described in the Wiedemann car following model. The first algorithm was developed in 1974 (Wiedemann 74) and is now applied to urban and arterial roads. The second algorithm was developed in 1999 and is applicable to freeway conditions (Wiedemann 99).

The car following model is one of three primary equations applied during the simulation of a VISSIM model. The other two models include the lane change algorithm which is applied to assess upcoming opportunities and requirements to change lanes for each vehicle, as well as a route choice algorithm to determine the origin-destination path building process.

3.3 Capacity in VISSIM

Capacity in VISSIM is not reflected by an arbitrary number to indicate potential high volume throughput. Rather, the car following algorithm maintains elements of headways (and safety distances). For this reason, the capacity of a roadway in VISSIM is subject to the performance of the vehicle immediately in front of any trailing vehicle, given the operational and regulatory constraints of the road network. From a purist microsimulation perspective, capacity in microsimulation software is directly constrained by the performance of the leading vehicle.

As a result of this approach to capacity, there is no literature to benchmark the maximum saturation flow that can be simulated in VISSIM for a freeway. There is also no documentation to discuss the proximity of the default calibration parameters to resemble the capacity figures documented in the 1985, the 1994 or the 2000 editions of the Highway Capacity Manual

There is discussion in the VISSIM manual (PTV, 2007) to indicate a number of scenario tests that were applied to determine the saturation flow. However, there is limited information regarding the characteristics of the scenarios and no information to describe the model development or application for which these simulation results apply.

By comparison, there are numerous studies that document freeway management and the amelioration of bottlenecks within networks. However, each of these studies are undertaken to review existing operational constraints, or develop numerous inhibitors to hinder maximising the saturation flow. None of the studies identified attempt to determine the maximum achievable saturation flow to indicate what the VISSIM microsimulation software can achieve under ideal conditions.

Brilon and Bressler (2003) applied VISSIM to examine the impacts of traffic flow conditions on upgrades to a German freeway. The emphasis of this paper was the impact of heavy vehicles with increases in freeway gradient. Speed-flow curves indicate a maximum throughput achieved towards 2,000 vehicles per hour per lane. Tian *et al* (2002) benchmarked the performance of VISSIM and other simulation software against the Highway Capacity Manual (2000) with a focus on delay rather than saturation flow.

Gomes *et al* (2003) simulated an extensive freeway network in VISSIM to examine recursive bottlenecks within the system. This paper examined calibration of parameters to match existing conditions rather than examining capacity as part of the problem. This is a frequent application of microsimulation models to assess freeway conditions where the study focus is to resolve congestion at interchanges in order to improve throughput. Such studies aim to resolve issues at the access and exit locations to the freeway where the flow is often limited rather than maximising the utility of the midblock sections.

3.4 The Wiedemann 74 Model

The initial car following algorithm developed by Wiedemann in 1974 to represent the model was relatively straight forward and comprised three calibration components. The algorithm included a standstill distance, plus an additive and a multiplicative element (calibration parameters) to the safety element of the equation. The algorithm has since been categorised to apply to urban traffic operations.

The equation is developed on the basis that distance between vehicles is the sum of the standstill distance plus the safety distance while travelling. The Wiedemann 74 equation is as follows:

$$\text{Distance} = \alpha x + bx$$

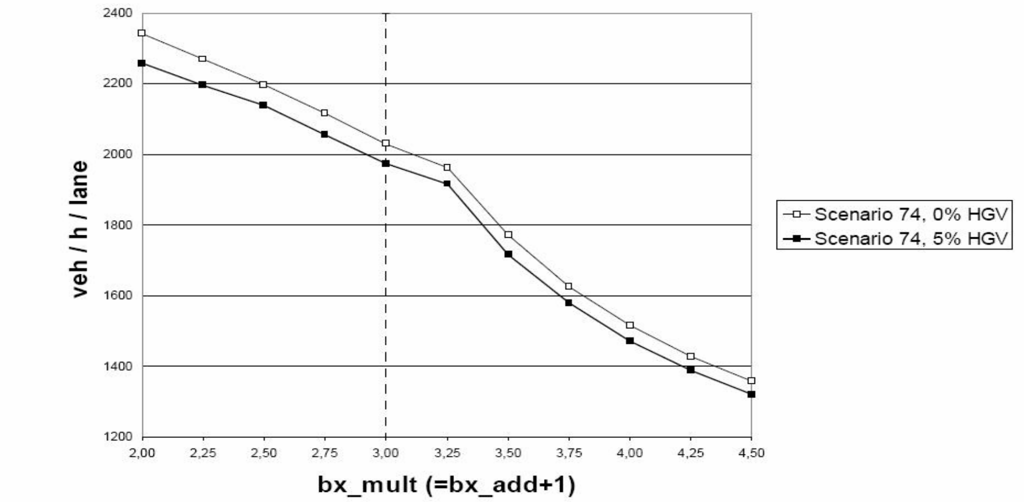
Where αx is the standstill distance (in metres) and bx is

$$bx = (bx\_add + bx\_Multi * z) * \sqrt{v}$$

Where:
v is is the vehicle speed [m/s];
bx_add is the additive component of the safety distance;
bx_Multi is the multiplicative element of the safety distance; and
z is a value of range [0,1] which is normally distributed around 0.5 with a standard deviation of 0.15.

A capacity measure has been estimated for a number of applications of the additive and multiplicative parameters (PTV, 2007) as shown in **Figure 2**. However there is no description outlining the simulation model applied, nor the geometric features. Although there are two scenarios displayed in this graph (both with and without HGVs) data indicates that the simulation has been run using a desired speed (signposted speed) of 48-58 km/hr. For this reason, there is a suggestion that saturation flows in VISSIM could potentially be higher than as applied in this model.

Figure 2: Saturation Flows on simulations applying Wiedemann 74 algorithm



Source: PTV, 2007

3.5 The Wiedemann 99 Model

The Wiedemann 99 algorithm is a more complex representation of the car following model and contains ten calibration components. This algorithm was specifically developed for application to freeways and motorway conditions.

The ten calibration parameters of the Wiedemann 99 algorithm are discussed in significant detail in Lownes and Machemehl (2006) and in Gomes et al (2003). The parameter labelling system and a short description are tabulated in **Table 2**. All parameters are named as a Calibration Component followed by a singular digit. Although there are a number of significant parameters in this algorithm, the Vissim manual confirms that “CC1 is the parameter which has a major influence on the safety distance and thus affects the saturation flow rate” (PTV, 2007, pp: 120).

Table 2: Calibration Components of Wiedemann 99 algorithm

Calibration Component Number	Calibration Component Description
CC0	Stopped Condition Distance
CC1	Headway Time
CC2	‘Following’ Variation (Oscillation)
CC3	Threshold for Entering ‘Following’
CC4	Negative Speed ‘Following’ Thresholds
CC5	Positive Speed ‘Following’ Thresholds
CC6	Speed Dependency of Oscillation
CC7	Oscillation Acceleration
CC8	Stopped Condition Acceleration
CC9	Acceleration at 80 km/h

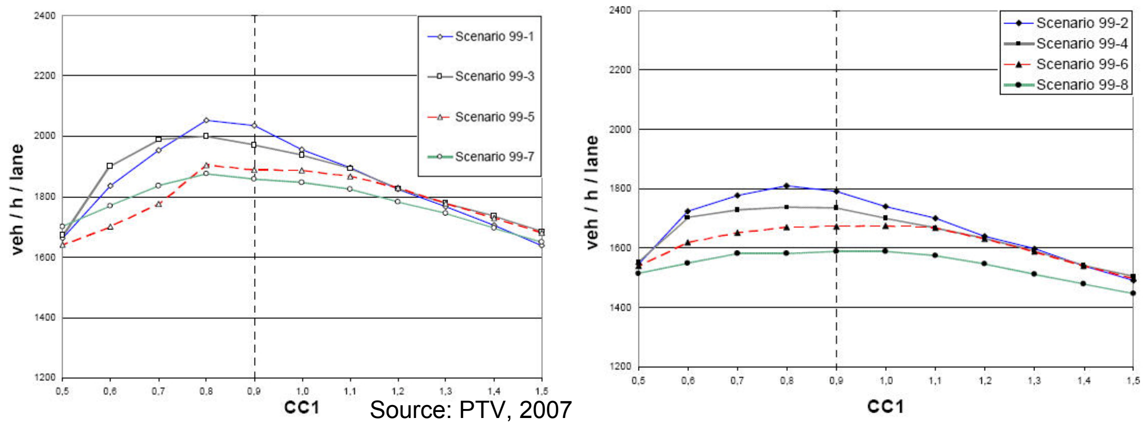
Source: Lownes and Machemal (2006)

The VISSIM manual also indicates that some sensitivity analysis has been undertaken to determine the saturation flow of this algorithm. Half of the eight model runs included a component of Heavy goods vehicles, while the other half of the model runs omitted this vehicle class from the traffic composition. A number of the parameters applied in these scenarios are provided in **Appendix B**. The results of the simulations are presented in **Figure 3** and indicate varying saturation flows using this algorithm of between 1,600 vehicles per hour per lane and 2,000 vehicles per hour per lane in response to an adjustment of the CC1 parameter. However, there is a limited description of the simulation model that was used to generate these results.

One element that is documented in the simulation runs examining saturation flow from the Wiedemann 99 algorithm is the number of time steps applied. This time step element identifies the number of times per second simulated that the algorithm recalculates the vehicles speed and distance in regard to the preceding vehicle. The simulation results displayed in **Figure 3** were run utilising a single time step per second (ie vehicle specific calculations were undertaken once every second). While this may seem to be quite thorough compared to the process applied to strategic area wide modelling, this rate is quite limiting amongst microsimulation software. Most simulation runs in VISSIM are undertaken with at least five time steps (five calculations) for every second simulated within the model.

Figure 3: Saturation Flows on simulations applying Wiedemann 99 algorithm

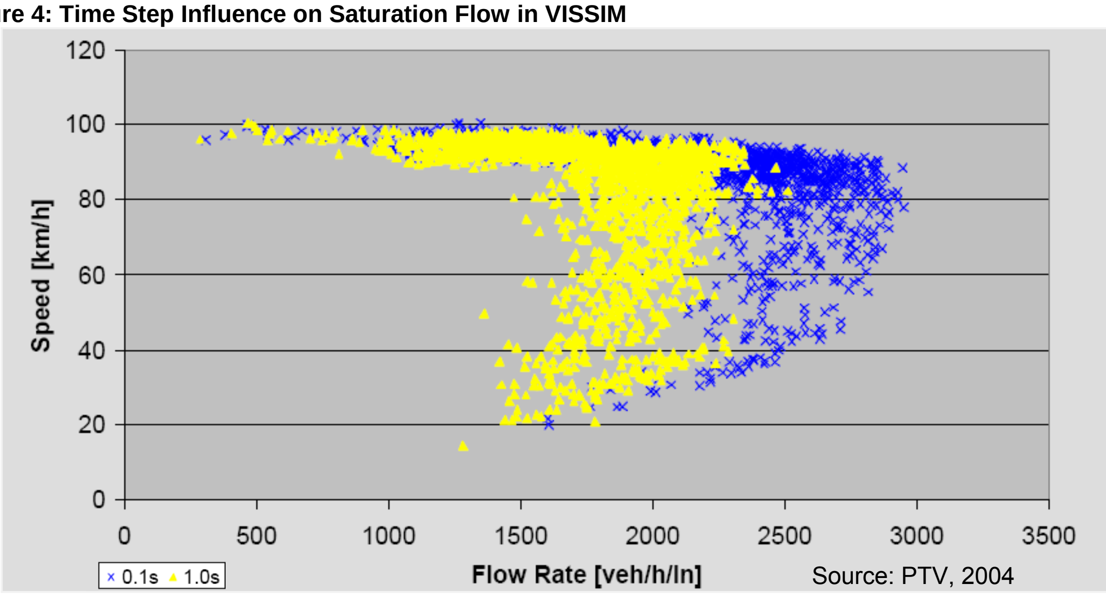
(without HGV's) (with HGV's)



Source: PTV, 2007

By comparison, **Figure 4** identifies that the application of a single time step per second simulated can produce a saturation flow rate of 2,000-2,500 vehicles per hour per lane. The same application at ten time steps per second can produce a much higher flow rate – achieving a saturation flow rate of up to 3,000 vehicles per hour per lane. This diagram indicates that the additional number of time steps, although adding computation time and energy can represent a higher saturation flow. This mechanism may suggest another calibration parameter for modelling high volume freeways. The process of simulating at a rate of ten time steps per second could also be applicable for assessing future year freeway operations.

Figure 4: Time Step Influence on Saturation Flow in VISSIM



Source: PTV, 2004

As a cross reference to this diagram Fellendorf and Vortisch (2001) note that when one time step per simulated second is applied, the saturation flow rate of traffic becomes unstable at approximately 2,000 vehicles per hour per lane.

4 Model Development

4.1 Introduction

In order to determine the maximum saturation rate that can be achieved in the VISSIM microsimulation software, Maunsell has developed a model that emphasises the complex decision making of the Wiedemann car following model. Although this model appears to be of a simple nature, there is significant complexity in the input parameters that have been applied as an attempt to minimise variation in model performance and analysis.

As the model is specific to freeway conditions, the Wiedemann 99 car following algorithm has been applied to all links within the modelling.

The emphasis of this model development is to try to determine the maximum saturation flow rates, as a comparison for the changing freeway flow volumes experienced over time. By achieving a high saturation flow within these models, any subsequent variation in inputs can be factored to reduce the capacity. However, suboptimal saturation flows cannot be increased to the same extent against improvements in traffic operations. All elements of this microsimulation modelling were designed to maximise the saturation flow rate achievable from the simulation.

4.2 Model Characteristics

A total of seven traffic models have been developed to identify a profile of saturation flows under optimal conditions. Each of the seven models is geometrically isolated from each other. There is no interaction between any of the seven models displayed in **Figure 5**. The seven models have the same vehicular, geometric behavioural characteristics except for the headway time (CC1) in the Wiedemann 99 car following algorithm. Headway factors range between 1.2 and 0.6 seconds, varying in 0.1 s increments. The default value in the software is 0.9 seconds.

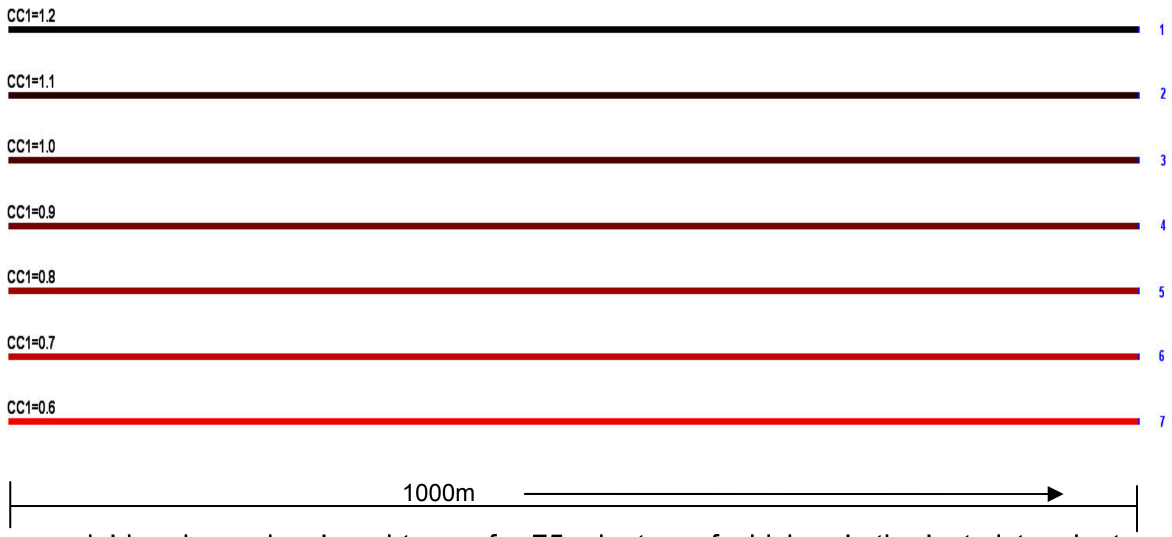
The models have been built to represent a single lane of 1 km (1000m) of road. This approach has been developed to remove the components of route choice and the lane changing algorithm to examine maximum throughput achievable from the car following model. The network design ensures that two of the three key microsimulation algorithms are removed from the simulation and do not inhibit on the traffic flow conditions. For this reason an uninterrupted single lane network provide a useful examination of the maximum capacities achievable in VISSIM due to the Wiedemann car following model. However, the utilisations of the lane changing and route choice algorithms are critical when assessing the limitations of designs in simulated applied networks. Under such conditions each network is subject to the complexity of operations from all three algorithms at the specific location. With the removal of the route choice and the lane changing algorithm, this paper has sought to examine how the CC1 parameter in the Wiedemman car following model can affect the number of vehicles that traverse these networks.

This model was developed and simulated using version 4.10 of the VISSIM microsimulation software. The simulation was modelled at ten time steps per simulated second. A maximum of 4,000 vehicles per hour was generated on each link.

The vehicle composition was designed to ensure a homogenous vehicle type on each of the seven models. This does not simply exclude commercial vehicles and public transport vehicles, but ensures that car vehicle class does not vary. Within the VISSIM microsimulation software, vehicles within a class can be heterogeneous. The vehicle components are not required to be identical. Consequently there can be a number of different vehicle models to represent one vehicle class within the model structure. Such variation between the vehicle models can include length, height, power to weight ratios and speed profiles. To ensure simplicity within this model, the car vehicle model that was most common in the default profile was applied as a homogenous vehicle in this simulation.

Desired speed profiles were developed in this model to minimise the variation of vehicle performance between the behavioural tests. Twelve specific desired speed profiles were developed and simulated in consecutive order to allow a speed profile to be developed against the throughput for each run. The desired speeds range between a maximum speed of 20km/hr and 130 km/hr. For each model run, the speed distribution developed was limited to 0.1km/hr. This effectively removed any further randomness in desired speeds of traffic flow between the simulation runs and the links assessed. The process limited the variation of this parameters when examining the impacts of changing the headway parameters within the Wiedemann 99 car following algorithm. The desired speed distributions were applied both at the start of the link and applied to the vehicle composition structure.

Figure 5: Parallel Vissim network developed to examine capacity



The model has been developed to run for 75 minutes, of which only the last sixty minutes of throughout is used for evaluation purposes. Grade has not been applied to any of the links within the modelling as this would inhibit the flow of traffic and produce a suboptimal saturation flow.

Data collection points were developed at the end of the link to determine the volume and speeds of the vehicles that complete traversing the link. These markers can be seen in blue at the end of the links in **Figure 5**. The models were run on a computer using Dual Core 4200+ AMD Processors with one gigabyte of RAM and a 256 MB video card.

A script was developed using Visual Basic for Applications (VBA) in Excel to simulate a number of seed runs with adjustments made to the desired (signposted) speeds. A total of ten seed runs were simulated for each of the twelve signposted speeds designated. Therefore a total of 120 simulations were automated and run. Due to the high number of simulation runs, the application of a VISSIM COM programming script was deemed to be the most suitable measure to develop multiple data outputs. The ten seed runs were determined at random from another Excel script to generate ten seed values from a range of 10,000 integers.

Another script was developed to rename, format and collate the numerous data measurements files for evaluation purposes. These files were loaded into an Excel workbook and assessed within this structure.

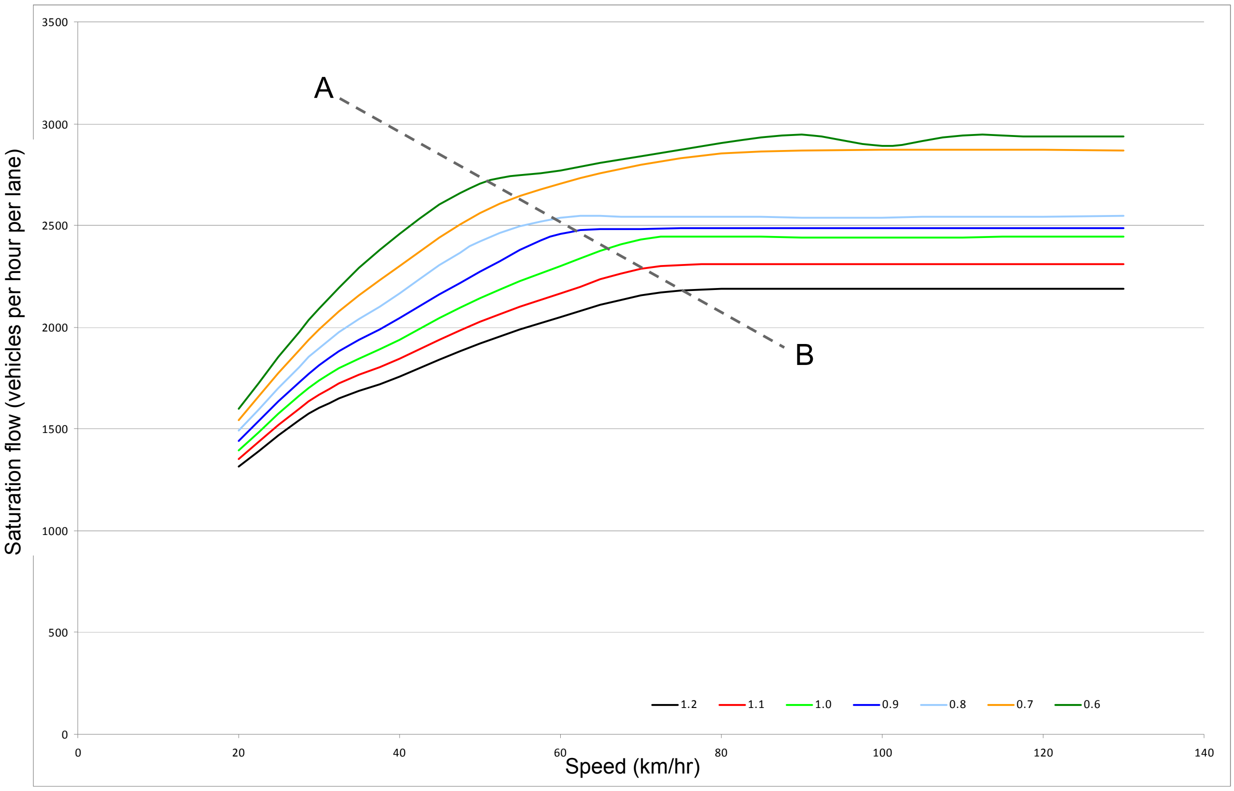
For evaluation purposes, the two outlying data runs at either end were omitted from analytical discussion. This ensures that any discrepancy in throughput, potentially from a sporadic break down in traffic flow conditions was removed from the analysis. The process was undertaken in line with regular microsimulation operations whereby potential outliers are removed from the analysis. The performance of the six central seed runs were used to determined the saturation flow of the VISSIM microsimulation software.

5 Simulation Results

The VISSIM microsimulation modelling has produced the speed flow curves displayed in **Figure 6**. Each point on the curve represents the average throughput achieved from the six seed runs, having excluded the four outlying values.

Figure 6 indicates that there is a notable difference in model performance with the adjustment of the headway time parameter (CC1). At desired speeds above 100 km/hr all of the model runs achieve saturation flow that is greater than the current Australian standard of 2,000 vehicles per hour per lane (Austroads, 1988). The default headway value of 0.9 seconds achieves a saturation flow rate of up to approximately 2,500 vehicles per hour per lane. The saturation rates of simulations with a headway factor of 0.7 and 0.6 seconds are close to achieving a rate of 3,000 vehicles per hour per lane. As a comparison, initial testing of saturation flows in VISSIM without the removal of a number of the parameters discussed above produced a throughput of 2,200 vehicles per hour.

Figure 6: Modelled freeway throughput in VISSIM microsimulation



At the higher speed distribution of 130 km/hr there is a variance in saturation flow in the order of 700-800 vehicles per hour per lane. As would be expected, when the simulation is run at lower speeds, the variation in performance between the model runs is marginalised.

Although the saturation flows displayed in **Figure 6** appear to be high and do not represent more conservative measures of freeways capacities, these curves do indicate the sensitivity of the car following algorithm in the VISSIM microsimulation software. The very purpose of this study was to identify an upper limit that the driving behaviour parameters can represent. This has been undertaken by removing a number of factors that constrain or inhibit traffic flow, including grade, traffic composition, traffic fleet and driver awareness or familiarity with regard to route choice.

Despite this performance, there are a number of additional points to note with regard to the speed flow curves in **Figure 6**. All of the saturation curves plateau at a unique flow rate whereby an increase in desired speed is not associated with an increase in throughput. The line AB in **Figure 6** represents the point across higher CC1 value curves where this plateau commences. However, curves for lower CC1 values that have achieved a higher volume of throughput approach a threshold value at higher speeds of approximately 80 km/hr. At lower thresholds, the default safety headway between vehicles is greater than the headway parameter. For this reason changes in speeds do not affect the saturation rate achieved in the modelling. Initial simulation modelling external to this paper that has moved away from the default safety distance confirms this statement.

6 Conclusion

This paper investigates the revised capacities on freeways and the applicability of the VISSIM microsimulation software to reflect these changes. The thresholds of capacity have changed over time which may be related to changing societal driving conditions, especially with regard to headways between vehicles. However, it may also be associated with improved vehicle performance or vehicle safety over this timeframe.

It is noted that the changes in capacities appear to be based on observed throughputs, rather than clearly defined flow rates. Subject to this, a number of examples have been provided where the throughput exceeds the value of capacity. A number of these observations from North American freeways are in excess of the capacity volumes from the 2000 edition of the Highway Capacity Manual. For this reason, capacity should not be viewed as an absolute threshold, but rather as a benchmark where supplementary parameters (such as headways) change.

Previous attempts to examine freeway capacity in VISSIM were dismissed for their representation of existing conditions rather than examining performance thresholds. Much of the VISSIM literature focuses on ameliorating existing bottlenecks and congestion on freeways. A number of papers further examined the refinement of the Wiedemann 99 car following algorithm to adjust the modelled throughput. A review of saturation flow tests in the VISSIM manual found limited information of the scenarios used on the simulation details.

A high end saturation flow rate has been achieved using the VISSIM microsimulation software when numerous constraints are removed from the modelling. These constraints include homogenous vehicle type, limited range in the desired speed range, no grade, no route choice and no lane changing opportunities. The modelling identified that a saturation flow rate of up to 2,500 vehicles per hour per lane was achievable for the default headway time parameter. A flow rate approaching 3,000 vehicles per hour was achieved with the smaller headway values of 0.6 seconds. All speed profiles greater than 80km/hr were able to achieve a saturation rate equivalent of the current Australian standard of capacity.

One of the largest inhibitors on saturation flow at high speed and high volume simulations appears to be the safety distance in the Wiedemann 99 car following algorithm. This has the affect of causing saturation flow curves to plateau when headways are shorter than the safety distance in the car following algorithm.

This paper has examined how the changing capacities on freeways can be reflected through the VISSIM microsimulation software. The simulation modelling undertaken indicates that calibrating the parameters of the Wiedemann 99 car following algorithm can represent the capacities presented in the 2000 edition of the Highway Capacity Manual. The range and extent of the simulation results indicate that any further enhancement in capacities over time could be simulated in the VISSIM microsimulation software through the refinement of the parameters in the car following algorithm.

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Appendices

Appendix A: Base Conditions for Basic Freeway Segments

The base conditions under which the full capacity of a basic freeway segment is achieved are good weather, good visibility, and no incidents or accidents. For the analysis procedures in this chapter, these base conditions are assumed to exist. If any of these conditions fails to exist, the speed, LOS, and capacity of the freeway segment all tend to be reduced.

Base conditions for freeway

The specific speed-flow-density relationship of a basic freeway segment depends on flow prevailing traffic and roadway conditions. A set of base conditions for basic freeway segments has been established. These conditions serve as a starting point for the methodology in this chapter:

- Minimum lane widths of 3.6 m;
- Minimum right-shoulder lateral clearance between the edge of the travel lane and the nearest obstacle or object that influences traffic behaviour of 1.8 m;
- Minimum median lateral clearance of 0.6 m;
- Traffic stream composed entirely of passenger cars;
- Five or more lanes for one direction (in urban areas only);
- Interchange spacing at 3 km or greater;
- Level terrain, with grades no greater than 2 percent; and
- A driver population composed principally of regular users of the facility.
- These base conditions represent a high operating level, with a free-flow speed (FFS) of 110 km/h or greater.

(Source: Highway Capacity Manual, 2000)

Appendix B: Characteristics of scenarios applied to capacity tests in Figure 3

Scenario	Right-side rule	Lanes	Speed cars*	Speed HGV*	% HGV
99-1	no	2	80	n.a.	0%
99-2	no	2	80	85	15%
99-3	yes	2	80	n.a.	0%
99-4	yes	2	80	85	15%
99-5	yes	2	120	n.a.	0%
99-6	yes	2	120	85	15%
99-7	yes	3	120	n.a.	0%
99-8	yes	3	120	85	15%

(Source: PTV, 2007)