MANAGEMENT OF TRAFFIC-RELATED EFFECTS OF HEAVY VEHICLES ON URBAN FREIGHT CORRIDORS

Euan D. Ramsay, Jonathan M. Bunker and Les Bruzsa

Postgraduate Research Engineer, Queensland University of Technology
Senior Lecturer, Queensland University of Technology
Principal Engineer, Queensland Transport/National Transport Commission

Presenter

Les Bruzsa
Floor 8, 230 Brunswick Street
Fortitude Valley, QLD 4006 Australia
+61 7 3253 4205
les.z.bruzsa@transport.qld.gov.au

ABSTRACT

Increasing demand for road freight has lead to a greater adoption of more-productive multi-combination vehicles on roads that are generally also used as major arterial corridors for non-freight traffic. This paper reports on a study into the effects that these vehicles, such as B-doubles, have on the traffic performance of urban traffic corridors and offers a number of strategies having the potential to minimize their impacts.

A computer-based microsimulation traffic model was created of a multi-lane arterial corridor, including coordinated traffic signals. Individual vehicles progressed along the corridor, with each vehicle following its leader and changing lanes when advantageous and safe to do so. The longitudinal vehicle dynamic behavior of each vehicle was modeled in detail, with heavy vehicles accelerating at a lower rate that light vehicles. The model was calibrated with data collected from GPS-equipped chase car surveys conducted on an urban corridor in Brisbane, Australia. Corridor performance was reported in terms of intersection capacity and delays as well as travel speeds and stop rates for each vehicle type.

The performance of the corridor was found to be sensitive to traffic control measures including the speed limit and traffic signal controller settings such as cycle time and progression design speed. A range of freight policy scenarios were examined, including the effects of increasing freight volumes, freight vehicle mode choice, and vehicle type-specific lane restrictions. Some policies having the potential to improve corridor traffic performance and freight efficiency were able to be identified. Advance detection of heavy vehicles approaching a traffic signal and extension of the green signal until their passage was found to offer benefits to all vehicles on the corridor.

MANAGEMENT OF TRAFFIC-RELATED EFFECTS OF HEAVY VEHICLES ON URBAN FREIGHT CORRIDORS

Euan Ramsay, Jonathan Bunker and Les Bruzsa

Postgraduate Research Engineer, Queensland University of Technology
Senior Lecturer, Queensland University of Technology
Principal Engineer, Queensland Transport/National Transport Commission

1   INTRODUCTION

The limited road space in Australia's urban areas services continually increasing volumes of both private and commercial traffic. These two are often considered to be in competition, with high-capacity urban corridors frequently also serving as major freight routes.

Additionally, there is an increasing disparity between vehicle types. Large freight vehicles (LFVs), such as B-doubles, are becoming more popular due, in part, to their accessibility to urban areas. The Survey of Motor Vehicle Use (ABS, 1999-2005) has recorded a steady increase in the use of B-doubles, from 14 per cent of total freight tonne-kilometers carried in 1998 to 25 per cent in 2004. Despite the fact that fewer vehicles are required for a given freight task (Haldane and Bunker, 2002), individual vehicles have a greater effect on corridor capacity and the delay experienced by all vehicles on the corridor. It is this effect of an individual vehicle on the surrounding traffic that is most noticeable by the motoring public.

2   BACKGROUND

The concerns of an increasing freight volume being carried on urban arterial roads have lead to a number of strategic measures being identified as having the potential to manage these competing demands. Several of these strategies, such as geometric constraints or route or area bans serve to discourage freight movements on a particular route, potentially moving the problem elsewhere and imposing additional costs for enforcement, operators, and ultimately the consumer.

The alternative approach is to manage, rather than limit freight movements on a particular route. Strategies may be able to be developed to continue to cater for a range of road user requirements, reducing overall transport costs without disadvantaging any particular group.

One of the most cost-effective traffic management options is to ensure that traffic signal settings are appropriate for the prevailing conditions. On a major freight route, it may be worth placing a greater emphasis on the needs and requirements of trucks at signalised intersections. To examine the effectiveness of some of these freight policy and traffic management measures, a range of simulations were conducted using the model described in the next section.

3   MODEL DEVELOPMENT

Although existing commercially available microsimulation packages were considered for use in this project, it was generally found they did not adequately characterise both the vehicle dynamics (important for slowly-accelerating heavy vehicles) *and* traffic behaviour and control.

3.1   Model Framework

The model was developed from first principles, considering the behaviour and interaction of individual vehicles moving along the corridor. The model makes extensive use of random numbers to determine the characteristics, headways and lane assignment for each vehicle. A large number of simulations, each using a different random number seed, are typically conducted. The results of these simulations are accumulated and tabulated at the completion. Typically, five vehicle types are used in each simulation – corresponding to passenger cars, 4-wheel drives or light commercial vehicles, rigid trucks, articulated trucks, and B-doubles. Proportions of each vehicle type typically are specified as found in a traffic survey conducted on an urban arterial corridor.

3.2   Longitudinal and Lateral Vehicle Behavior

At each time step, all vehicles move forward along the corridor a distance dependent upon their current speed and acceleration. Each vehicle's maximum acceleration depends on the vehicle type, its current speed, and the grade at its current position. Additionally, each vehicle is prevented from getting closer than the safe stopping distance to the preceding vehicle.

The model enables vehicles to change lanes only when it is both advantageous and safe to do so. The decision for a vehicle to consider changing lanes requires both a disadvantage in remaining in the current lane, and an advantage in moving to an alternative lane. In addition to considering the vehicle's current speed and that of vehicles in adjacent lanes, when approaching the back of an intersection queue the decision is based on the expected queue discharge time of the current and adjacent lanes. A longer queue consisting of cars may be more attractive than a shorter queue behind a large truck. The lane change is only executed if there is no chance of colliding with either the leading or trailing vehicle in the adjacent lane.

3.3   Traffic Control

Traffic signals in the model operate on a common cycle time, with user-specified offsets between adjacent signals. Vehicle detectors are placed upstream of the stop line, and the controller logic determines the length of the green time to be allocated to the main corridor through movement, following the description given in Austroads (2003). Vehicles respond to traffic lights by stopping if safe to do so if the signal is not green. Vehicles form a horizontal queue back from the stop line, and discharge at an appropriate rate after the signal turns green.

3.4   Model Calibration

Model calibration is covered in detail in a previous paper (Ramsay and Bunker, 2004). A traffic counter was used to provide an estimate of the traffic flow patterns typical of an urban arterial traffic corridor. This was used to calibrate the traffic generation component of the model. The performance capabilities of individual vehicles were determined from a GPS-equipped chase car survey, in which a number of vehicles were followed along an urban arterial traffic corridor, recording their in-service speeds and accelerations.

To alleviate concerns that instrumentation fitted to a chase car would not be as accurate as fitting it to the subject vehicle itself, a laden B-double fitted with a GPS receiver was driven along the corridor whilst a chase car fitted with another GPS receiver followed it. Near-identical results in estimating the speed and acceleration profile of the B-double were obtained.

3.5   Model Implementation

Two versions of the corridor model have been developed – a Windows-based application which produces a trajectory diagram of a simulation, as shown in Figure 1; and a console-based application which can run a large number of simulations in rapid succession. The Windows version is useful in identifying features of a particular simulation, whereas the console version is useful for batch processing a number of lengthy simulations.
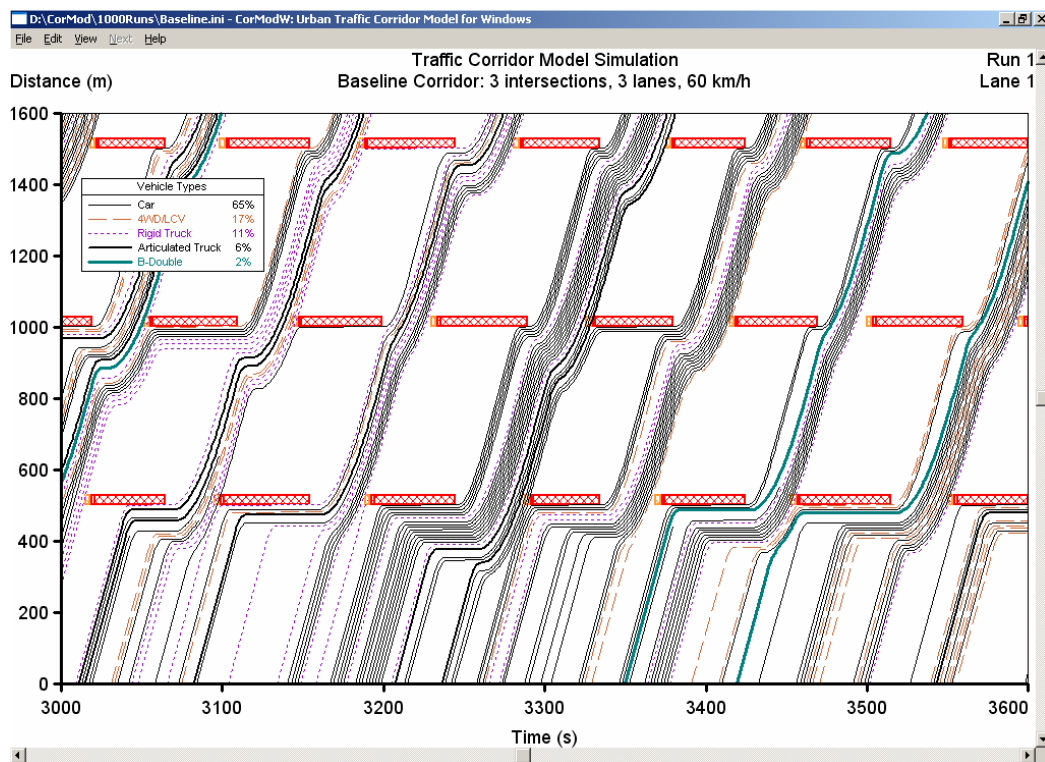

Figure 1. Typical corridor model trajectory diagram

4 FREIGHT POLICY AND TRAFFIC MANAGEMENT ISSUES

A range of simulations of a three-lane, three-intersection urban traffic corridor were conducted using the model, in which the freight volume was varied from 60% through to 200% of the current value. A steady decrease in travel speeds, increase in delay and reduction of intersection capacity was found as the freight volume was increased. Decreases in speed were slightly greater for cars than trucks, trucks being less likely to be significantly impeded by other trucks than cars. A number of freight policy and traffic management scenarios were considered to minimize these unfavorable effects on traffic performance.

4.1 Freight Vehicle Mode Changes

An increased freight volume could be carried by a greater number of existing freight vehicles, or a similar number of larger freight vehicles. The following scenarios were examined:

- Existing composition of cars, LCVs, rigid trucks, articulated trucks and B-doubles
- Car-only, in which all freight is diverted to an alternative route
- No-B-doubles, with their freight being carried by increased numbers of smaller trucks
- More B-doubles, carrying some of the freight which was on smaller trucks
- Some B-triples, carrying some of the freight which was on other freight vehicles

Figure 2 shows the travel speed of vehicles on the corridor under each of these scenarios (as well as the lane utilization scenarios covered below). Of the four scenarios in which freight is carried on the corridor, an increased use of B-doubles offers a slight increase in speed on the corridor for all vehicle types. Introduction of B-triples (comprising 3 trailers, about 33 meters long and weighing up to about 80 tonne) appears to reduce speeds on the corridor, their assumed poorer performance impeding traffic more than the greater number of vehicles they replace. The performance of B-triples was only estimated since they could not be tested in urban areas.
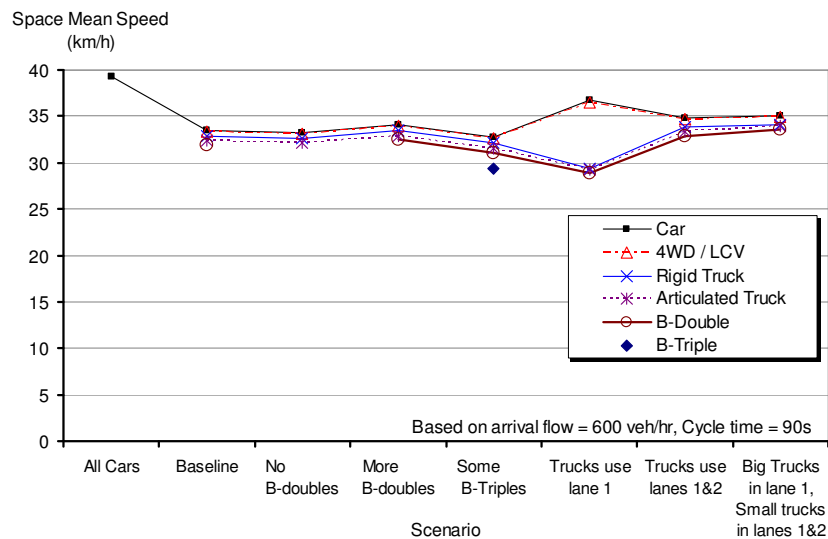

Figure 2. Speeds under various freight and traffic management scenarios

4.2   Lane Utilization

A number of simulations were conducted in which specific vehicle types were restricted to particular lanes. The following cases were considered:

•   All cars and trucks may use any of the three lanes
•   All trucks (except light commercial vehicles (LCVs)) must use lane 1. Cars, 4wds and LCVs may use any of the three lanes
•   All trucks (except LCVs) may use lanes 1 or 2. Cars, 4wds and LCV may use any lane
•   Large Trucks (articulated and B-double) must use lane 1, small trucks may use lanes 1 or 2. Cars, 4wds and LCVs may use any lane.

Results of these scenarios are presented in Figure 4, together with the freight mode scenarios. Restricting all trucks to lane 1 gave the greatest travel speed to cars, however the speeds of trucks was lower than for any other scenario. Further examination revealed the truck lane to be very congested, whereas the car lanes were both free-flowing.

Permitting trucks to use two of the three lanes relieved the congestion, whilst still leaving cars free to pass unimpeded in their own lane. The greatest benefit in terms of travel speed for all vehicle types occurred when the large and small trucks were separated.

Al-Kaisy and Jung (2004) conducted a similar investigation on a non-signalized corridor, using the same lane utilisation scenarios. They also found that having each vehicle type relatively unencumbered by other types gave the greatest travel speeds.

4.3   Progression Design Speed

Trucks can be disadvantaged by linked signals if the offsets between signals are based on car travel times, which slower-accelerating trucks cannot match (Ogden, 1999). In the worst case these slower vehicles may face a 'red wave', arriving at every signal just as it turns red. Following vehicles are also disadvantaged.

A number of simulations were conducted on a corridor consisting of three intersections, spaced 500 meters apart, and varying the progression design speed (PDS) from 20 km/h to 70 km/h. Larger vehicles speeds were lower than for cars at all PDS values, and the optimum PDS (giving the highest space mean speeds) was found to be the same for all vehicle types (Figure 4).

The number of stops per vehicle also was found to be dependent upon PDS, however different optimum speeds occurred for different vehicle types. As shown in Figure 4, trucks had fewest stops on a corridor with a PDS of 40 km/h, compared to cars and 4wds / light commercial vehicles having fewest stops at a PDS of 45 km/h. This was attributed to trucks being more likely to arrive at the rear of a queue and not having to stop at the lower PDS, whereas cars would have arrived there earlier and would have had to stop.

Although the 'red wave' phenomenon could be produced under carefully controlled conditions, it was very rare to see it amongst the general simulations. This was attributed to lane-changing and car-following interactions between individual vehicles and the use of vehicle-actuated signals.
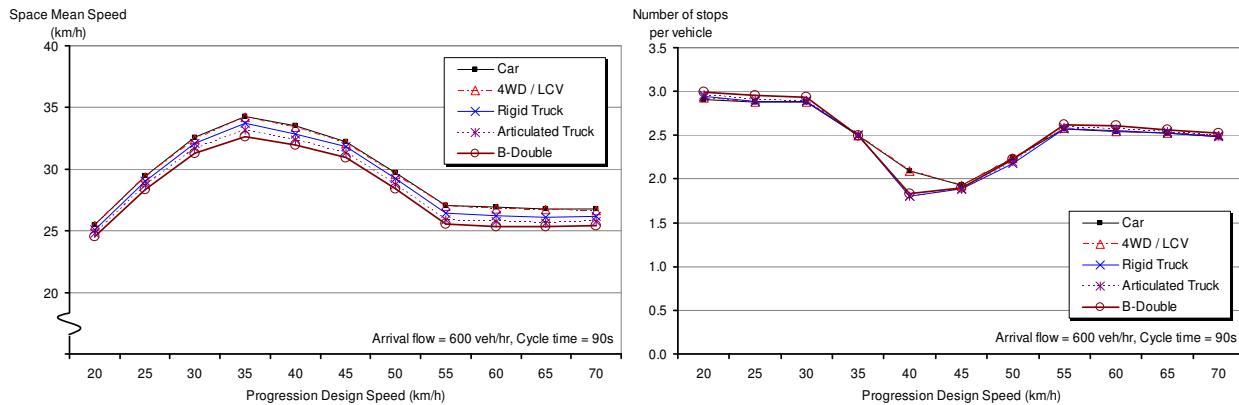

Figure 3. Effect of Progression Design Speed on Space Mean Speed and Stop Rate

4.4 Heavy Vehicle Detection and Green Time Extension

An examination of the composition of vehicles at the front of intersection queues in the baseline simulations found an over-representation of heavy vehicles. Articulated trucks comprised 5.9% of all vehicles used in the baseline simulation, and B-doubles comprised 1.5%. At the front of intersection queues, 6.6% of vehicles were articulated trucks and 2.0% were B-doubles. This was attributed to the greater headway in front of a heavy vehicle leading to an increased probability of the traffic light changing as the heavy vehicle approaches it.

Changing a traffic light from green in front of an approaching heavy vehicle will delay the progress of the heavy vehicle, as well as subjecting following vehicles to a slower acceleration rate when the signal changes to green. Often the heavy vehicle driver is reluctant to stop when confronted with a changing traffic light, and may still be passing through the intersection when a conflicting traffic movement starts.

Detection of an approaching heavy vehicle, and holding the green signal until it has passed is a possible means of reducing these delays and risks. Sunkari *et al.* (2000) developed a truck priority detection algorithm, implementing it at an isolated rural intersection in Texas. The benefits in reduced pavement maintenance costs (through reduced truck braking and acceleration) were said to outweigh the cost of implementing truck detection. In a congested urban corridor scenario, additional benefits may be realised in terms of reduced delays and accident rates.

The simulation model was modified to include additional detectors located 150 meters before the stop line of each intersection, and only activated by articulated trucks or B-doubles. The green time is extended for a sufficient time to permit the heavy vehicle to safely pass through the intersection on a yellow signal, with the next vehicle (generally being a car) appearing at the front of the queue and the queue able to discharge faster than otherwise. To ensure that the

conflicting traffic movements are not disadvantaged, the next green period for the main corridor through movement is shortened by same time that the green had previously been extended by.

To test the effectiveness of heavy vehicle detection and green time extension, a number of simulations were conducted with and without the detection enabled. The proportion of articulated trucks at the front of the intersection queues decreased from 6.6% to 5.7%, and the proportion of B-doubles from 2.0% to 1.6%. It was not possible to completely eliminate heavy vehicles from the front of the queues, since some required more than the maximum permitted green time extension, some were following other heavy vehicles which had already used the green time extension, and some were impeded by other vehicles and had to stop at the intersection.

This reduction in heavy vehicles at the front of the intersection queues had a beneficial effect for all vehicle types at low traffic flows. There may be some disadvantages in using heavy vehicle detection at higher arrival flows – possibly due to the shorter green time being available for the subsequent signal cycle.

## 5   LINKAGES TO OTHER POLICY DEVELOPMENTS

The National Transport Commission is developing a national set of performance based standards to encourage and better assess proposal for new and innovative heavy vehicle combinations that can provide improvements in safety and freight efficiency.   Table 1

Performance standard	Performance measure	Performance level for each road type				Test Specification
		Level 1	**Level 2**	**Level 3**	**Level 4**	
Acceleration capability	Ability to accelerate either from rest or to increase speed on a road (no grade).	Acceleration no worse than specified by the distance-time curves in Fig 2(a) of NRTC (2003a) (shown below)				By simulation or field test.

Figure 5 Acceleration capability requirements in PBS
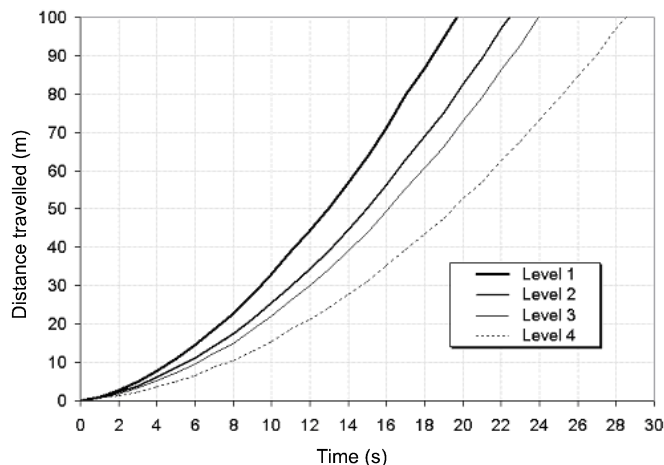
There are 16 safety standards and 4 infrastructure standards proposed for the assessment and regulation of heavy vehicle performance. The current PBS requirement for acceleration capability has been designed to ensure that a PBS vehicle is able to accelerate from a stationary start to a specified distance (100m) over a given time frame or to increase vehicle speed on a road (no grade).

Acceleration capability emerged as an alternative specification to the performance measure intersection clearance time. Sufficient clearance time and distances should be available in the direction of travel for different PBS vehicle classes at signalised intersections and railway crossings. *Acceleration capability* covers a much wider range of conditions (intersection widths and vehicle lengths) and situations (railway level crossings), taking the form of distance/time curves as shown in the Figure 5. The PBS vehicle must demonstrate that it can accelerate with performance 'above the line' within the class of intended operation throughout the acceleration period from stationary to 100m travelled. Concerns have been raised by manufacturers and transport operators that the acceleration requirements are too demanding and might lead to the specification of larger engines. This would also have a negative effect on both the capital and operational cost of a PBS combination and might also affect the environmental outcomes.

The acceleration performance of a heavy vehicle combination depends on the kinematic characteristics of the vehicle such as engine power, driveline, the vertical load on the drive group, gross combination mass of the combination (GCM), aerodynamic and mechanical losses and the achievable maximum friction between the tyres and the road surface. However, it would also be significantly influenced by the actions or driving style of the driver such as technics of acceleration, time used for a gear change and the usage of the engine power available.

Queensland Transport has conducted a practical assessment of the acceleration performance of a number of heavy vehicle combinations which illustrated that most of the vehicles could achieve the overall desired acceleration target but not always for the complete acceleration sequence. This would result in a failure in meeting the PBS requirement. It has been established that there is a difference between the computer simulation methods used by manufacturers and the operation of heavy vehicles under 'normal' driving conditions. It has been decided that a review the standard would be necessary and amendments would be needed that the performance measure can be achieved both in theory and in testing procedures under normal operating conditions.

As a result of these discussions, the need for the vehicle to achieve the acceleration curve for the entire distance-time curve has been removed and the performance standard parameters have been modified. Table 2 illustrates the details of the interim proposal.

Table 2

PBS Road Class	Time To Travel 100m Free Rest (secs)
1	20
2	23
3	26
4	29

Additional work is needed to evaluate the risk implications of difference in the acceleration capabilities of heavy vehicle combinations and relate this to real life on-road performance. The development of a generally acceptable assessment method for this performance measure is necessary to overcome uncertainties of PBS certification. It is also proposed to review the relationship between the longitudinal PBS performance measures such as gradeability, startability and acceleration capability.

6   CONCLUSIONS

A model has been developed to predict the traffic-related effects of large freight vehicles in urban traffic. Some benefits can be achieved by implementing appropriate freight policy and traffic management options, such as active detection of heavy vehicles. In addition to explicitly setting out to keep freight moving through an urban road network, overall gains in traffic efficiency may be realised through the reduction of moving bottlenecks on the network.

7   ACKNOWLEDGEMENTS

8   REFERENCES

ABS, 1999-2005. Survey of Motor Vehicle Use. Catalog No. 9208.0, Australian Bureau of Statistics.

Al-Kaisy, A. F. and Jung, Y., 2004. Examining the effect of heavy vehicles on traffic flow during congestion. Road & Transport Research, 14(4), pp. 3-14.

Austroads, 2003. Guide to traffic engineering practice: Part 7 - Traffic signals. AP-11.7:03, Austroads, Sydney.

Haldane, M. J. and Bunker, J. M., 2002. Examining the impact of large freight vehicles on signalised intersection operation. AITPM National Conference, Perth, Western Australia, pp. 255-268.

Ogden, K. W., 1999. Planning and designing for trucks. In Traffic engineering and management, eds Ogden, K. W. and Taylor, S. Y., pp. 387-411. Institute of Transport Studies, Monash University.

Ramsay, E. D. and Bunker, J. M., 2004. Progression of different vehicle types in a signalised urban arterial corridor - Model development and calibration. 26th Conference of the Australian Institutes of Transportation Research.

Sunkari, S. R., Charara, H. A. and Urbanik, T., 2000. Reducing truck stops at high-speed isolated traffic signals. Project Report 1439-8, Texas Transportation Institute, Texas A&M University.