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The effect of multi-combination freight vehicles in urban traffic

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Abstract

The use of heavy vehicles that are capable of carrying increased loads has continued to increase rapidly. Such vehicles, such as B-Doubles, Road-Trains and other large sized vehicles, are termed here as Multi-Combination Vehicles (MCV). Significant economic benefits result from the use of such innovative vehicles, which are able to carry up to twice the payload of standard semi-trailers. Those benefits, however, need to be traded-off against the potentially negative impacts on other road users, such as additional delays in urban areas.

The research detailed here will deliver an increased understanding of some of those impacts by investigating models which can be used to estimate delays to other road users. Preliminary results from adding small numbers of MCV for a freeway section and an intersection demonstrated a significant adverse impact on the performance of the network. These results imply higher passenger car equivalent values than those commonly used for MCV. Further research is being conducted, including calibrating the input parameters and performing the same network simulations on other microsimulation packages to compare the results.

Background

Road freight transport plays a major role in the Australian economy. This influence is unlikely to decrease, with freight transport increasing 4% annually between 1970 and 1990 in Australia [1]. Freight movement within urban areas is a very significant part of the total freight task.

In Australia, vehicles meeting current limits of 42.5 tonnes gross vehicle weight, 19.0 metres overall length, regularly operate on major urban routes. Road trains weighing 115 tonnes, 53 metres in length, operate in remote

locations. The trend is for increasing load limits and truck size, with the transport industry continuously seeking to increase productivity through increasing load carrying space, mass or access [2].

This paper is organised as follows: the next section discusses impacts of MCV on other road users and the community, in terms of delays, accidents and environmental consequences. This is followed by a discussion of the use of microsimulation modelling to estimate MCV impacts, including some preliminary results. Finally, some conclusions are given in the last section.

MCV Impacts on Traffic

General

There are two main traffic related issues associated with MCV in urban areas, namely: delays that they may cause to other vehicles and safety related impacts. These are interrelated in urban areas, as accidents involving MCV create delays, while congestion affects the probability of accidents. Other considerations of MCV in urban regions include: efficiency; contribution to the national and local economy; and environmental effects.

Three factors contribute the effect of heavy vehicles on roads: the large size of trucks; the operating capabilities of trucks that are inferior to cars; and the physical impact on nearby cars and psychological effect on the drivers of those cars [3]. It has been suggested by a number of authors that the presence of a truck in front of a passenger car may result in the driver being more cautious due to the large size of the vehicle and the diminished sight distances. Thus, the headways of the cars (not just the headways of the heavy vehicles), in mixed traffic may be larger, effecting congestion, delays and capacity [4] [5]. Other research has concluded the reverse, that the average headways of passenger cars and heavy vehicles in mixed traffic are independent of the type of vehicle immediately ahead [6] [7].

The issue of MCV accidents and incidents on urban freeways is a vital concern, with public awareness is heightened because of the rise in MCV volume, the interaction of these large vehicles with the traffic and the publicity given to major MCV accidents [8]. Crashes involving heavy trucks also tend to have more severe consequences for the other involved road users, as a result of the size and mass difference [9]. Urban crashes represent a significant proportion of truck crashes, with 50 to 75 percent of all serious rigid truck crashes and 25 to 50 percent of serious articulated vehicle crashes occurring in urban areas [10].

Before implementing a MCV management strategy, investigation should be conducted on the current effects of the MCV, to allow the most cost-effective and efficient solution to be implemented. Despite this, a field survey showed that the majority of the 15 states in the US that implemented lane restrictions for trucks, applied these restrictions without detailed evaluation plans or before and after studies [8]. In addition, large truck restrictions have been proposed to improve air quality and reduce congestion, however, there is actually little hard evidence as to their impact on either [11].

The costs of large MCV negotiating urban traffic, such as adverse effects on traffic speeds and capacity, need to be weighed against the economic benefits of requiring fewer vehicles to move the same quantity of freight

Congestion Impacts

An approach which has been widely used in analytically modelling traffic with more than one class is to represent the other classes in terms of passenger car equivalents (PCE's) or passenger car units (PCU's).

The extensive research into PCE's for the movement of heavy vehicles at signalised intersections is reviewed by Lake and Ferreira [12]. Recent research aims to incorporate the delays to other vehicles, with Benekohal and Zhao [13] presenting a method for calculating PCE's for heavy vehicles at signalised intersections in under-saturated conditions based not only on headways, but the delay caused to the rest of the traffic stream. The resulting delay-based PCE are not constant and depend on traffic volume, truck type and truck percentage. A large body of research also exists on calculating PCE's for freeway sections, as detailed in Lake and Ferreira [12]. Fisk [14] found that the PCE approximation could lead to erroneous predictions, mainly because for uninterrupted flow, the different performance characteristics of the two classes are not taken into account.

The second approach that has more recently been applied is the use of simulation models to examine actual effects of heavy vehicles on a simulated road network. This method is considered to be superior to the PCE technique, as the different characteristics that cause the effect of the heavy vehicles on the surrounding traffic, such as performance characteristics, size and driver behaviour, can be explicitly modelled. The use of microsimulation models is discussed in a later section of this paper.

Safety Related Impacts

Despite the fact that the public overwhelmingly considers MCV to be unsafe [15], the available evidence does not support this perception for urban environments. The data, internationally and nationally, has shown that heavy vehicle involvement in collisions is more of an issue in rural areas than urban environments. A review of the research in this area can be found in Lake and Ferreira [12]. In addition, in multi-vehicle accidents involving heavy vehicles, the majority are the fault of the other vehicle. This does not mean that the effect of safety should be discounted in urban areas, given the potential loss of life. In addition, all crashes impact on the performance of an urban road network.

Environmental Impacts

Gurney [16] found that the main environmental impacts, as perceived by the local urban community, are lack of safety, noise/vibration and air pollution, with heavy vehicles considered to be major contributors to these impacts. Attributed to air pollution are a number of serious long-term effects on people and the

environment. From the studies, a review of which can be found in Lake and Ferreira [12], heavy vehicles contribute significantly to emissions from traffic. The potential impact of diesel vehicles on health is of particular concern due to the significant contribution of those vehicles to the total amount of particle matter emitted from road transport. Therefore, heavy vehicles are extremely important to predicting or reducing the effects of transport emissions on the environmental and human health. In addition, heavy vehicles also contribute significantly to noise pollution.

Microsimulation Models

A number of commercially available packages have the ability to define different classes of vehicles with different operating and size characteristics. In principle, these models are suitable to examine the effects of heavy vehicles on congestion/delays in urban areas. In addition, as the acceleration and deceleration of the vehicles are simulated, it could be possible to generate the emissions from the vehicles, and therefore determine the environmental effects. Although, crash rates cannot be predicted using a simulation model directly, the areas of conflict that could result in a crash may be identified through simulation. This would highlight the major safety risks with regard to the interaction of heavy vehicles with urban traffic. In addition, an incident could be simulated to view the effect of this on the network.

Model Testing

There is a lack of understanding of how MCV affect traffic flow in individual manoeuvres, in terms of the delays they may cause to other traffic and the link and intersection capacity implications. Micro-simulation models are usually used to evaluate the performance of a general traffic stream made up primarily of passenger cars. This paper reports on a preliminary analysis using the microsimulation model AIMSUN2 (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), which has been selected as one of the most commonly used models. AIMSUN2 is one of a number of microscopic simulation traffic models in common use by traffic engineering professionals world wide. As a microsimulation model, the behaviour of every single vehicle in the network is continuously modelled throughout the simulation period, using several driver behaviour models including car following, lane changing and gap acceptance. Any number of different types of vehicles can be simulated by defining the vehicle in terms of the parameters used by the underlying vehicle behavioural model, such as acceleration, deceleration, and maximum speed.

The degree to which this package can be used to model the interaction between MCV and other traffic is assessed using test data for a section of freeway and for a signalised intersection. These two networks, which are detailed below, are used to investigate the effect of the MCV on the performance of the network, therefore primarily the impact of delays. Future research could

involve examining other effects such as environmental and safety impacts. In addition, future work will involve conducting the same network simulations on different models to compare the results.

Freeway Network

A model of a 13.2km section of the inbound carriageway Pacific Motorway in Brisbane, with five off ramps and 6 on ramps, is used for the initial tests. The section is modelled during AM peak flows from 06:00 to 09:00 when the route is very congested, with much of its length operating in stop start conditions for at least part of this time. The model used is that of the motorway prior to the 2001 opening of a 5km Transit Lane now operating in the section. It should be noted that the operation of this network relied heavily on the operation of the merges, the modelling of which is one of the most difficult challenges for a microsimulation model. While the overall journey time through the network predicted by the model compared favourably with surveyed results, the delay in various sections of the network showed some discrepancies. The model is considered to be calibrated as well as could be expected with the given data and suitable for the purpose of examining the effects of varying the number of MCV.

Intersection Network

A small model of a traffic signal intersection on an arterial road, the intersection of River Road and Brisbane Road in Dinmore, an outer western suburb of Brisbane, was used. As Brisbane Road is the main link between Brisbane and the predominantly industrial town of Ipswich, it was considered to be suitable to test the impact of varying numbers of MCV on the road network. The model consisted of the traffic signal intersection on Brisbane Rd and a closely coupled intersection on River Rd together with associated approach roads. The approaches are modelled for 200-400m to ensure that queues from the traffic signals would be contained in the model. The PM peak hour was modelled, with volumes based on 1999 traffic counts factored to account for growth to 2000. With these flows the intersection was undersaturated with a reserve capacity of about 40%. The saturation flow across a simple stop line was tested with the same parameters used in this model to ensure that the calibration was acceptable.

Initial Results

All results presented are the average of 12 separate simulations. The MCV added are 19m in length, which corresponds to a number of heavy vehicle combinations in Queensland, Australia, including truck-trailers, prime mover semi-trailers and 19m B-Doubles [2].

The performance measures of the traffic for the freeway traffic, with 0, 10, 30 and 100 MCV per hour, are given in Table 1. The results indicate that the introduction of relatively small numbers of MCV has a significant adverse impact on the performance of the network. The additional delay is especially significant as the freeway is quite long, at 13.2 km, with a freeway throughput of

approximately 4,400 vehicles per hour and a total network volume of 9,900 vehicles per hour. The introduction of 30 MCV increased the total delay in the network by approximately 116 vehicle hours per hour. This may be related to the highly congested state of the network used. To investigate the effect of differing levels of saturation on the results, the passenger car volumes in the intersection network are altered.

Table 1: The traffic characteristics with varying numbers of MCV

MCV (vph)	Density (v/km)	Speed (km/hr)	Travel Time (sec/km)	Delay Time (sec/km)	Stopped Time (sec/v/km)
0	33.6	50.7	93.3	52	21.4
10	33.8	50.3	93.9	53	21.8
30	34.6	48.8	96.5	55	22.3
100	35.0	46.0	101.8	60	24.4

To investigate the effect of MCV on a signalised intersection, a single intersection is used, so that signal coordination and other such factors do not affect the results. As the intersection is initially under saturated, the effects of the MCV on the differing levels of intersection saturation are investigated by increasing the passenger cars flows on the arterial road by 25% and 50%. Figure 1 gives the average vehicle speeds on the network for different levels of passenger car and MCV flows. Adding 100 MCV to the base case reduced the average speed by 2.0km/hr, more than adding 650 extra passenger cars (25%), which decreased the average speed by 1.6 km/hr from the base case. This implies the MCV has a PCE of greater than 6.5 in unsaturated conditions, well in excess of the usual estimates for signalised intersections, which show a maximum of 4.5 [12].

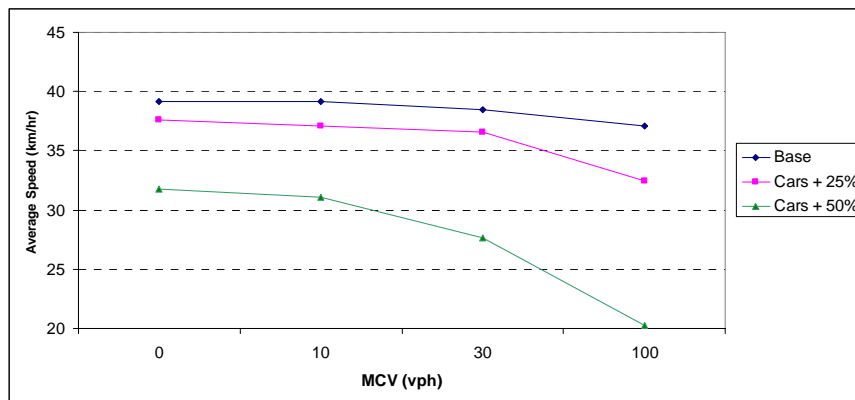


Figure 1: The average vehicle speed varying the passenger vehicle volumes

The effects of the MCV are more pronounced as the network becomes more saturated. The difference in average speed for the additional 100 MCV for the highest level of saturation simulated is 11.5km/hr, which is considerably higher than the 2.0km/hr for the base case. As microsimulation models commonly report the performance of the network in terms of average vehicle speed and average vehicle delay it may be difficult to see the impact of small numbers, for example 30 MCV per hour, of MCV in an undersaturated network. In a saturated network the impact of the same number of vehicle may be more pronounced and thus identifiable in the results reported by the model.

The simulations, however, do imply a high PCE value even at low saturation levels, which could be the result of one of the following:

- The input parameters for the MCV could be incorrect;
- The microsimulation model may not be representing the MCV accurately;
- The values of PCE commonly used underestimate the effect of MCV.

To examine the first of these options, that is the sensitivity of the microsimulation model to the input parameters, a number of the characteristics of the MCV were altered for the intersection. Sensitivity analysis also indicates the importance of obtaining the actual values versus using estimates or default parameters for the microsimulation model. Changing the acceleration of the MCV produced the largest impact on the network, but only at the highest level of MCV simulated, as shown in Figure 2. The values simulated in m/sec^2 were 0.75, 1 and 1.25, in contrast to the acceleration of passenger cars at $2.20 m/sec^2$.

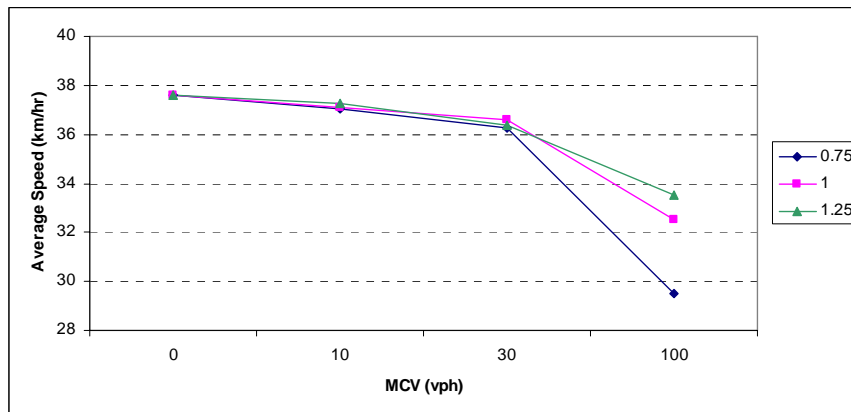


Figure 2: The average speed with varying MCV acceleration

The length of a MCV was increased to 25m (equivalent to a B-Double) and decreased to 12m (a rigid truck) for alternate simulations. Adjusting the length of the MCV, as for the acceleration, only had an effect for the highest level of MCV simulated (100 vph). The average speeds in the network are shown in Figure 3. The normal and maximum deceleration values for MCV were also

simulated at $\pm 0.25 \text{ m/sec}^2$, however, these did not produce any significant effect on the performance of the network.

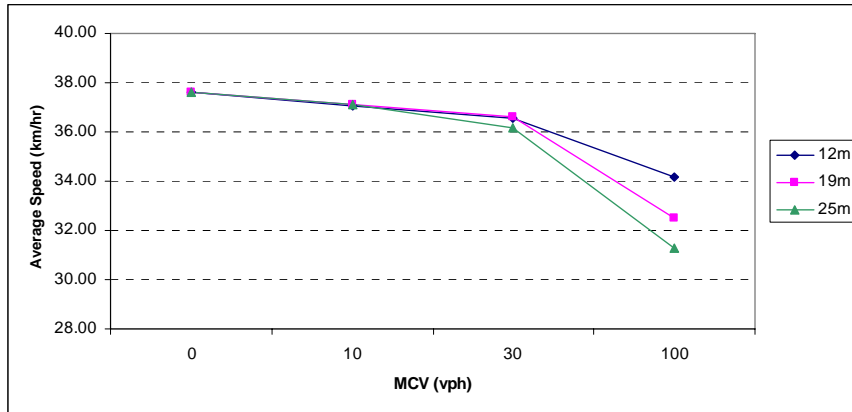


Figure 3: The average speed with varying MCV lengths

The results for the analysis indicate that the model is only sensitive to certain input parameters, and only at higher saturation levels. This indicates that incorrect input parameters are not likely to be the cause of the implied PCE values at low saturation levels. To ensure that the values used are accurate, however, research is being performed in another project at QUT to calibrate the MCV input parameters. To examine whether representation of the MCV and the surrounding traffic network by AIMSUN2 is accurate, different microsimulation models will be used to compare the results for the same networks and input parameters.

Conclusions

There are two main traffic related issues associated with MCV in urban areas, namely: delays that they may cause to other vehicles and safety related impacts. Other considerations of MCV in urban regions include: efficiency; contribution to the national and local economy; and environmental effects.

The degree to which a microsimulation package (AIMSUN2) can be used to model the interaction between MCV and other traffic was assessed in this paper using test data for a section of freeway and for a signalised intersection. These networks were used to investigate the simulation of the effect of the MCV on traffic congestion, however, future research could involve examining the other effects such as environmental and safety.

Preliminary results imply a higher PCE value even at lower saturation levels for an intersection than the values commonly used for MCV. Further research is being conducted to establish the causes of this, including calibrating the input parameters and performing the same network simulations on other microsimulation packages to compare the results.

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