Simulation Modeling And Performance Standards For Combination Vehicles

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ABSTRACT

This paper provides examples of the use of AUTOSIM in developing custom models for investigating the dynamic performance of combination vehicles in Australia. Custom models have been developed for aspects of the trailing fidelity of combination vehicles on non-planar surfaces and examples of model outputs for combination vehicles operating on road shoulders and over roadway depressions are given. Examples of the application of dynamic performance standards related to stability and control in a number of performance attributes are given, and an example of an innovative vehicle combination is compared with currently-operating conventional trucks. Some recent experience with model-based performance assessment of limited-access vehicles in Australia is described.

INTRODUCTION

Heavy vehicles are currently required to meet a range of regulations which affect their on-road performance. These regulations include braking, length, width and height, "internal" dimensions, turning circle and mass limits; together with industry practices with respect to selection of vehicle configuration and components, plus the characteristics of loads carried, these regulations indirectly define the dynamic performance of heavy vehicles using Australian roads. The dynamic performance of vehicles making up the national fleet in turn affects traffic safety and interaction with the road system.

There is a current drive to improve freight vehicle productivity, allow industry room for innovation, and to overcome the problems of non-uniformity between States. One possible approach to allowing productivity improvements while maintaining control over vehicle performance is the use of performance-based specifications for heavy vehicles. Performance-based specifications are being applied initially to vehicles which exceed the weight and dimension limits applicable to general access vehicles. In Australia, these limited-access vehicle configurations are termed Medium Combination Vehicles (MCVs) and Long Combination Vehicles (LCVs). These configurations exceed 19 m in overall length and 42.5 t in Gross Combination Mass (GCM); MCVs are limited to 25 m and 62.5 t, while LCVs are generally limited to 53.5 m and 115.5 t.

PERFORMANCE-BASED SPECIFICATIONS

Performance-based specifications are intended to focus heavy vehicle regulations on desired outcomes (ie. safety and the interaction with other traffic and the road system) and provide a rationale for assessing the implications of design modifications and vehicle innovations.

Performance-based specifications, when combined with quality assurance mechanisms, offer the prospect of significant gains in the productivity of the road freight industry because vehicle design could directly address the needs of a particular transport task, instead of being constrained by generalized configurations and limits. On the other hand, there are perceived difficulties with performance-based standards in that they may be complex, highly-technical and difficult to enforce. For example, it is easier to regulate overall length than to regulate swept path of a vehicle combination.

When applied to limited-access vehicle configurations, performance-based analysis is additional to all other traditional vehicle standards applicable to heavy vehicles, including braking, lighting, mechanical integrity, noise, emissions, etc.

MODELING OF DYNAMIC PERFORMANCE

Simulation modeling provides a convenient means of quantifying the dynamic performance of innovative vehicle configurations and permits the effects of individual vehicle parameters to be investigated and vehicle configurations to be optimized for particular road environments. Such models, when validated against experimental data, offer powerful insights into the dynamic performance of heavy vehicle configurations.

Roaduser Research has carried out a number investigations of innovative vehicle combinations, using the well-established and validated University of Michigan Transportation Research Institute (UMTRI) Yaw/Roll Model and using custom models developed using

AUTOSIM. These custom models allow yaw/roll formulations to be extended to a larger number of trailers and also allow the modeling of a three-dimensional road surface. These custom models have been used to indicate the relative performance quality of various innovative vehicle options and have facilitated negotiation with Australian road managers in order to bring about the construction and trialing of the most promising vehicle configuration options. Arrangements are in hand to carry out tests with these new vehicle configurations as they are commissioned, and this data will be used to validate the custom simulation models for future simulation projects.

PERFORMANCE ATTRIBUTES MODELED

The Roads and Transportation Association of Canada (RTAC) Weights and Dimensions Study [1] broke new ground by integrating a useful set of performance attributes into a size-and-weight decision process. These performance attributes were modeled using UMTRI simulation programs, including Yaw/Roll. Recent work by Roaduser Research has utilized a number of the RTAC performance attributes and has developed some additional attributes in the area of trailing fidelity performance.

RTAC Performance Attributes The RTAC performance attributes considered are as follows:

- steady-state roll stability
- rearward amplification
- load transfer ratio
- high-speed dynamic offtracking
- high-speed offtracking
- low-speed offtracking.

Trailing Fidelity AUTOSIM has been used to model certain aspects of trailing fidelity. When a combination vehicle is travelling at highway speed, the rear unit of the combination tends to exhibit more lateral movement than the hauling unit. This may be caused by external disturbances such as road roughness, changes in crossfall, wind effects, etc. The ability of the vehicle to control and damp out such motions is termed trailing fidelity. Alternatively, the total excursion of the rear unit is sometimes called the swept width of the vehicle.

Trailing fidelity has received little research and there are no comprehensive models currently available for complete assessment of trailing fidelity performance (although the Australian Road Research Board is currently carrying out research into the trailing fidelity of road trains).

The following specific aspects of trailing fidelity have been simulated, using custom models generated with AUTOSIM:

- response to the vehicle suddenly encountering a depression in one wheel path (see Fig 1)

- response to the vehicle steering over a 50 mm shoulder drop-off on a cross-fall of 5%, including steering off the shoulder and back over the shoulder (see Fig 2)

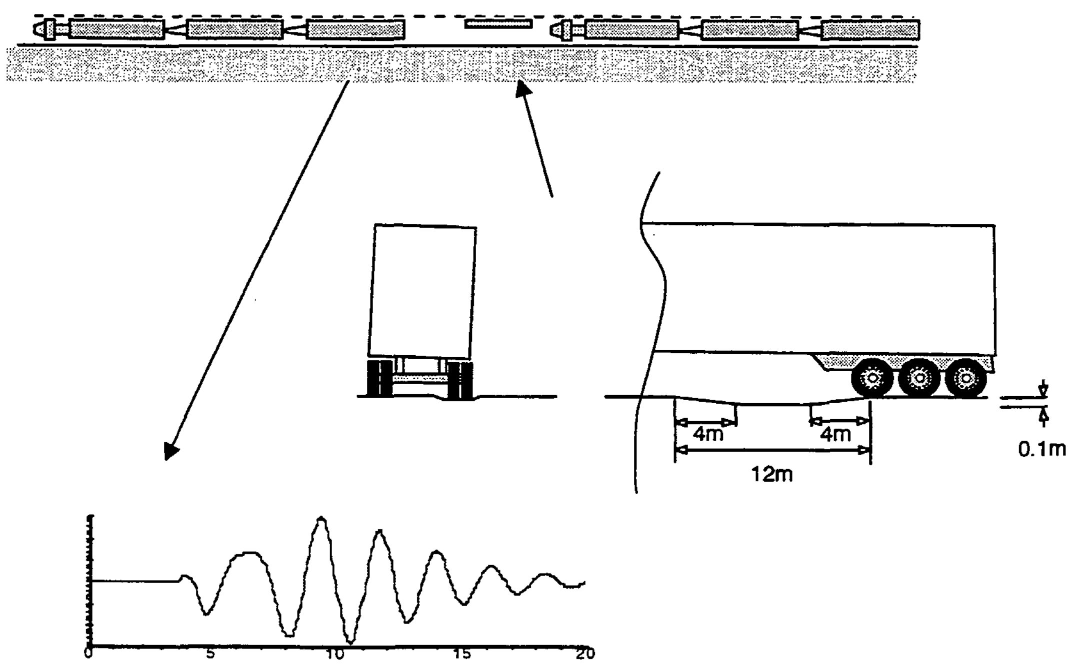

Figure 1. Trailing fidelity on road depression.

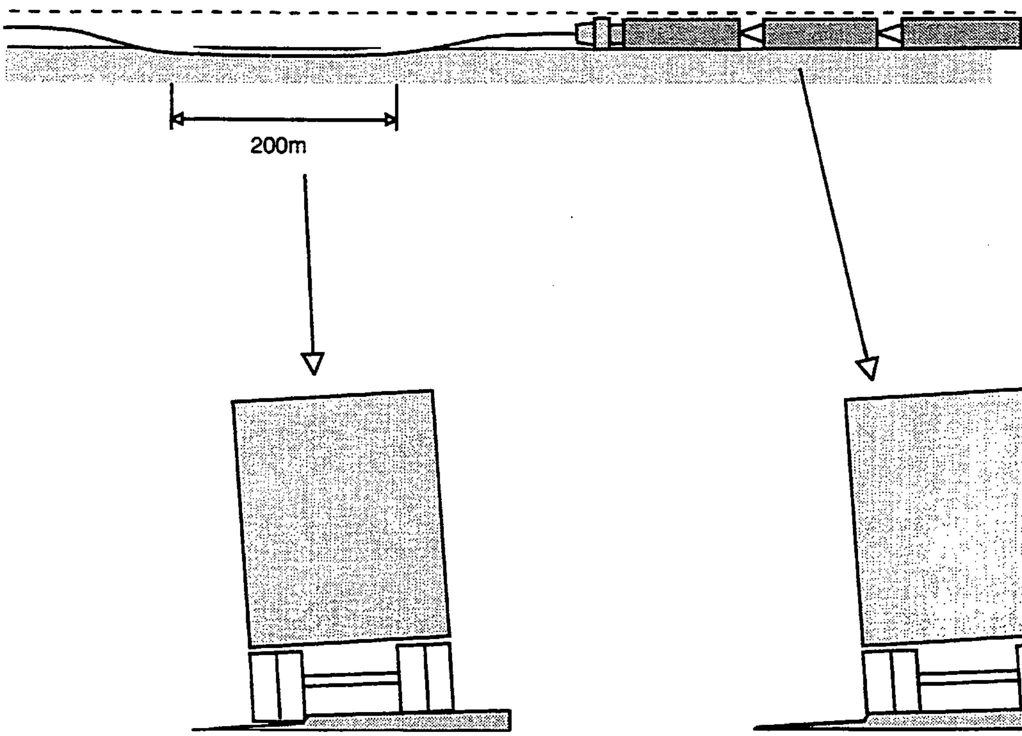

Figure 2. Trailing fidelity on road shoulder.

The peak lateral motion of the rear trailer has been computed for both these situations, at a speed of 90 km/h. The lateral motion of the rear trailer is asymmetric in both these situations, so peak movement was computed for both inboard and outboard movements. In the case of the road depression, the motion of the rear trailer was also characterised in terms of (i) the time required to damp the trailer motion to 10% of its peak value and (ii) the number of cycles of motion required for the amplitude of the trailer motion to reduce to 10% of its peak value.

EXAMPLES OF PERFORMANCE EVALUATION USING SIMULATION

Trailing Fidelity Performance Consideration of the use of larger, more productive road trains on specific routes is often dependent on the ability of the combination vehicle to track well on narrow seals. The additional road width required to accommodate sway at the rear of the combination vehicle is of concern to road managers in relation to the interaction of the combination vehicle with oncoming traffic. The innovative vehicle configurations shown in Fig 3 were evaluated for potential trailing fidelity performance. It should be noted that the GCM of these configuration options is 103.5 t, as compared to 79 t for the doubles currently operating on the route in question.

The results in Fig 4 show the maximum outboard movement after the vehicle has travelled through the depression in the road. The result for the A+B is better than the baseline doubles, while the B+DOG result is worse than the baseline doubles.

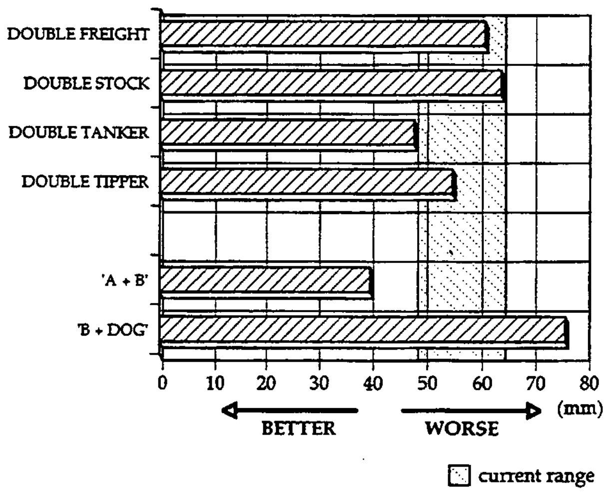

Figure 4. Maximum outboard movement after travelling through depression in the right wheel path

The results in Fig 5 show the number of cycles for the motion generated at the rear of the vehicle to decay to 10% of the peak value. The results give an indication of the amount of damping present in the yaw motions of the vehicle. It is apparent from the results given in Fig 5 that the yaw damping of the B+DOG and A+B is as good as, or better than, the baseline doubles.

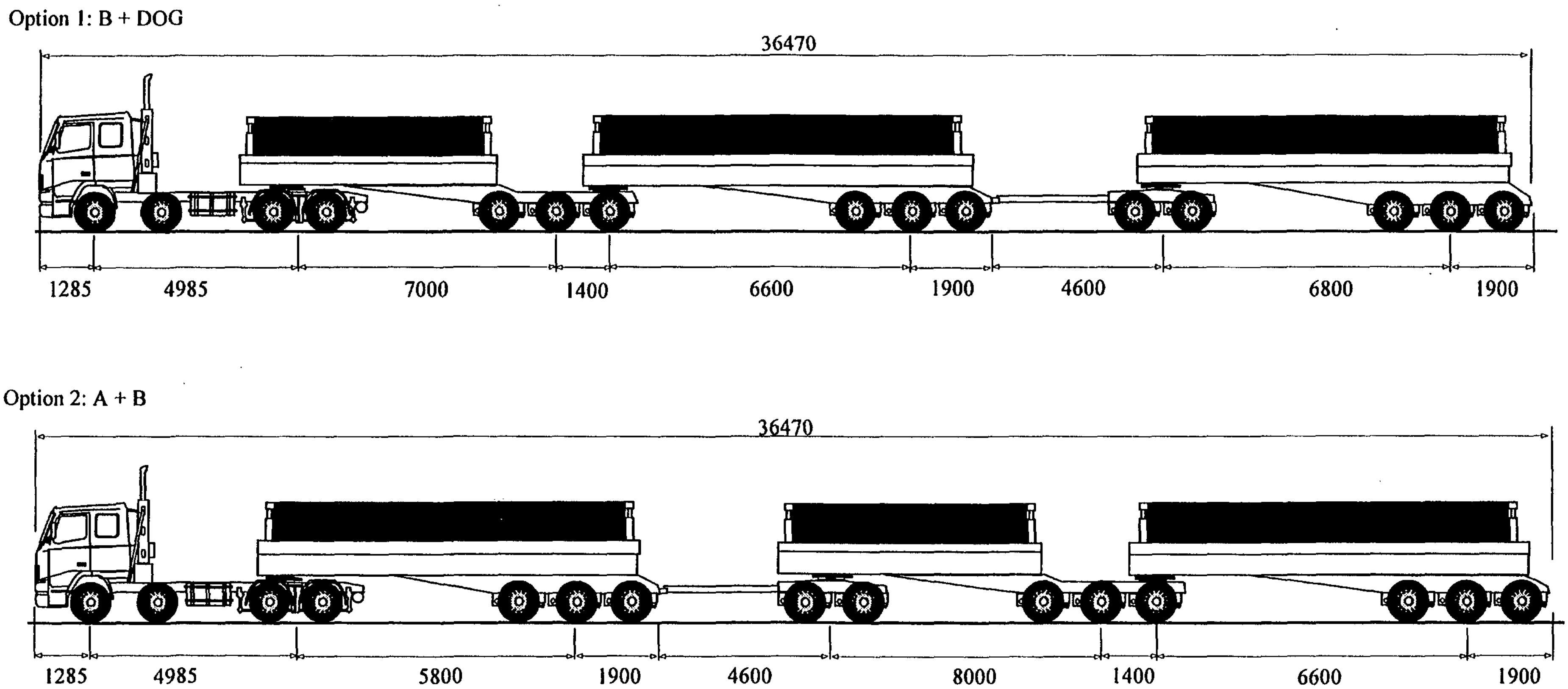

Figure 3. Example innovative vehicle configurations.

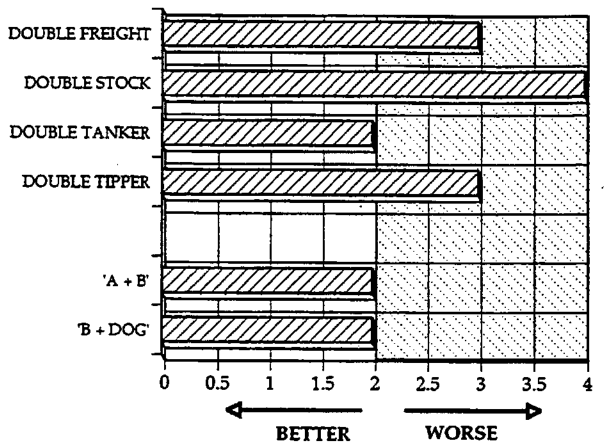

Figure 5. Number of cycles to below 10% of maximum excursion after passing through a depression in the right wheel path

Fig 6 shows the peak lateral motions of the rear of the vehicle combination in the shoulder drop-off situation. Again, the tracking of the A+B and B+DOG are is good as, or better than, the tracking of the baseline doubles.

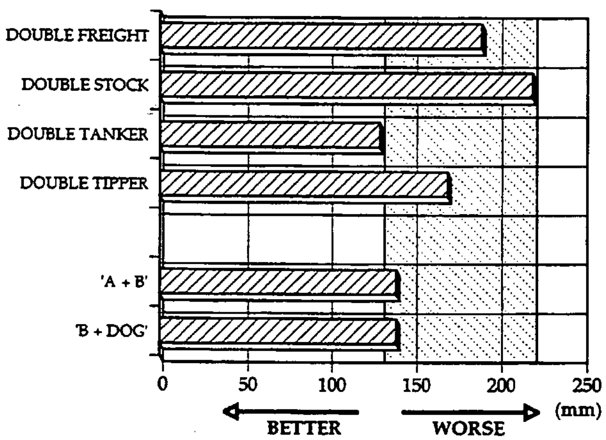

Figure 6. Trailing fidelity (outboard movement)

Total Performance & Productivity In some applications, it is necessary to compare a range of new configuration options against vehicles currently permitted on a particular route, to include consideration of the efficiency of the vehicle configuration in terms of pavement wear and to recommend the optimum configuration. In such cases, certain configurations perform well in certain performance attributes, but perhaps not in others. Fig 7 shows a performance profile for a configuration similar to the A+B shown in Fig 3. The performance targets against which this vehicle was assessed are given in Tables 1&2. These performance targets were considered appropriate for a "Type I" road train route, where conventional doubles are permitted at a length of 36.5 m and GCM of 79 t.

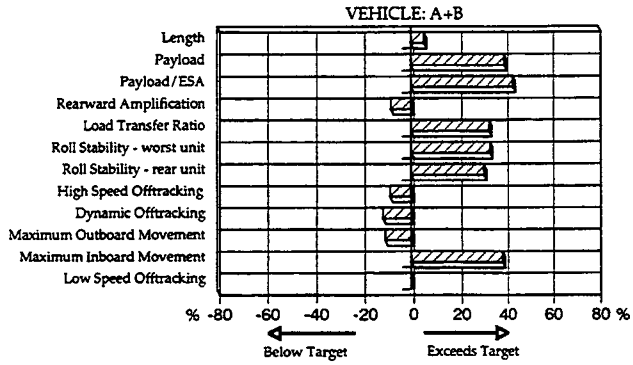

Figure 7. Example performance profile - A+B configuration.

Table 1. Example performance targets - "Type I" regime.

PERFORMANCE ATTRIBUTE	PERFORMANCE TARGET
REARWARD AMPLIFICATION	1.85 max
LOAD TRANSFER RATIO	0.70 max
ROLL STABILITY worst leading unit rearmost unit	 0.33 g min 0.36 g min
HIGH SPEED OFFTRACKING	350 mm max
HIGH-SPEED DYNAMIC OFFTRACKING	580 mm max
TRAILING FIDELITY outboard movement inboard movement	 170 mm max 70 mm max
LOW-SPEED OFFTRACKING	4.2 m max

Table 2. Size, weight and efficiency benchmarks - "Type I" regime.

CONFIGURATION CHARACTERISTIC	TARGET
OVERALL LENGTH	36.5 m max
PAYLOAD	49.8 t min
PAYLOAD/ESA	5.80 t/ESA min

The total performance of the A+B configuration, along with a number of other configuration options, was assessed using weighting factors applied to each performance attribute, as illustrated in Table 3. This analysis resulted in the following overall assessment of the A+B option:

- total performance 10% above target
- total efficiency 39% above target
- total performance and efficiency 25% above target.

Table 3. Example relative weightings of performance attributes - "Type I" regime.

PERFORMANCE ATTRIBUTE	RELATIVE WEIGHTING
PAYLOAD	0.9
PAYLOAD/ESA	1.0
STEADY-STATE ROLL STABILITY	
worst leading unit	0.6
rearmost unit	0.9
REARWARD AMPLIFICATION	0.8
LOAD TRANSFER RATIO	1.0
HIGH-SPEED OFFTRACKING	1.0
HIGH-SPEED DYNAMIC OFFTRACKING	0.9
TRAILING FIDELITY	
outboard movement	0.6
inboard movement	1.0
LOW-SPEED OFFTRACKING	0.5

CONCLUDING REMARKS

This paper has attempted to demonstrate the use of performance assessment and specifications in the controlled introduction of new configurations of limited-access vehicle in Australia.

Simulation modeling has gained some acceptance as an indicator of the relative performance quality of new proposals for innovative vehicle configurations. Use of models has indicated that such configurations could result in significant gains in transport efficiency and productivity as well as dynamic performance equal to - or better than - currently-permitted combination vehicles. In arriving at recommended configurations, consideration has been given to the relative significance of different performance attributes for particular routes.

Trailing fidelity performance is often a key indicator for high-productivity, limited-access vehicle configurations in Australia and testing of these configurations is planned as part of the commissioning process. This will provide valuable input and validation data for custom models developed using AUTOSIM.

REFERENCE

[1] ERVIN, RD & GUY, Y (1986) The influence of weights and dimensions on the stability and control of heavy trucks in Canada. Roads and Transportation Association of Canada. Ottawa.