USE OF HEAVY RIGID TRUCK-TRAILER COMBINATION VEHICLES IN WESTERN AUSTRALIA

Vic Johnston
Senior Engineer, Plant and Mechanical
Main Roads Department

and

Albert O'Neill
Engineer, Vehicle Limits
Main Roads Department

USE OF HEAVY RIGID TRUCK-TRAILER COMBINATIONS IN WESTERN AUSTRALIA

ABSTRACT

The road transport industry in Western Australia utilises a very wide range of vehicle configurations to maximise transport economies in a very large and sparsely populated State. Whilst the largest combination freight vehicles, roadtrains, are amongst the longest and heaviest in the world there are also other unique features of the State's fleet. Developments have taken place in the use of 17 m truck trailer combinations with a gross vehicle mass of 58.5 tonnes and short 18 m 'B' Doubles at 63.0 tonnes. These vehicles, which operate under special conditions, and have proved very popular with transport operators. The paper details operating conditions and vehicle characteristics and compares several key performance factors for a number of vehicle configurations given a set transport task. The advantages of 'B' Doubles and rigid truck trailers over more common vehicles are confirmed.

Authors' Name : V Johnston and A O'Neill

Authors' Position : Senior Engineer Plant & Mechanical and Engineer Vehicle Limits
Main Roads Department of Western Australia
Waterloo Crescent
EAST PERTH WA 6000

Title of Paper : Use of Heavy Rigid Truck-Trailer Combinations in Western Australia

INTRODUCTION

Western Australia's general freight vehicle fleet is the most diverse in Australia. The largest combination freight vehicles, road trains, are amongst the longest and heaviest in the world.

Medium Combination Vehicles in Western Australia operate in the range from 42.5 tonnes to 64 tonnes gross combination mass and generally are within the regulation length limit of 17.5 metres. This development has resulted from the necessity for large quantities of freight to be transported over long distances efficiently and economically and is possible because of the unique characteristics of the road and bridge network and its environment. The experience Western Australia has gained with this class of vehicle has enabled its use to be permitted extensively throughout the arterial road system and in particular within the Metropolitan Region. This class of vehicle has great versatility and during the last ten years has been gaining increasing popularity and acceptance.

Medium Combination Vehicles and Road Trains offer significant economic advantages due to greater payload per vehicle, but as with all large vehicles there are disadvantages with their use which arise from the interaction with other traffic and the permitted geographical location of the operation of these vehicles. Aspects such as the percentage heavy vehicles in the traffic stream, total traffic volume and geographic considerations (e.g. manoeuvrability, terrain, road formation and pavement width) make it essential for the movement of these vehicles to be strictly controlled.

In practice control is effected by permits issued by the Main Roads Department WA for specified combinations of vehicles to operate on approved selected routes. Whenever possible loading controls are engineered into the vehicle or applied as a condition of the permit to reduce the possibility of overloading enabling greater flexibility of movement and enhancing the overall enforcement strategy.

In Western Australia Medium Combination Vehicles (Truck and Trailer) have been operating for many years. Their use is more widespread in Western Australia than in other States. The controls which are applied to the operations of these vehicles have been progressively evolved in the light of experience.

The 'B' double combination commenced operation on selected routes in the Perth Metropolitan Region in 1983. These early vehicles were designed and constructed in such a way that it is unlikely that

the regulation axle group load limits on any axle group could be exceeded. These early vehicles were designed for specific commodities of known densities and therefore were constructed ensuring regulation axle masses were adhered to on all axle groups. With the introduction of the NAASRA 23 m 'B' Double nationally and the acceptance of general freight a relaxation of guideline in WA is being considered and the carriage of general freight is likely to be approved in the near future.

USE OF HEAVY RIGID TRUCK-TRAILER COMBINATIONS IN WESTERN AUSTRALIA

WESTERN AUSTRALIA - BACKGROUND

The special characteristics of the road transport industry in Western Australia are partly attributable to the particular geography and demography of the State. Western Australia occupies one third of the continent of Australia. It covers an area of over 2.5 million square kilometres. The population of the State is approximately one and a half million people which is only 8.5% of the Australian total. This relatively low figure and the distribution within Western Australia has been greatly influenced by the vast arid country and the unique climatic conditions.

The population is concentrated in and around Perth. About 75% of the State population live within a 50 km radius of the centre of Perth in an area which is 0.2% of the whole State. Almost 87% of the population live within the south west corner of the State, an area of 9% of the State total. The population, area, and population density are shown in Table 1 for the State as a whole. The population density figure is one of the lowest in Australia. Rural areas of the State are even less densely populated. However, the population growth in the Western Australian rural area between 1971 and 1981 was one of the highest in Australia.

TABLE 1 DEMOGRAPHIC INFORMATION

Population ('000 persons)	1.5
Area ('000 km^2)	2 527
Population Density (persons/km^2)	0.6
Population Growth	2.11

Road transport has become and will continue to be the dominant force in the development and servicing of a major portion of the State as the railway system is confined to specific areas and concentrates on a limited range of bulk commodities.

WESTERN AUSTRALIAN VEHICLE FLEET

Approximately 90% of road vehicles in Western Australia are cars and light commercials. These provide the principal demand for

road facilities. However, it is the larger and heavier commercial vehicles which determine the design requirements for roads and bridges. Whilst comprising only 10% of the vehicle fleet they are responsible for some six thousand billion tonne-kilometres of travel on the State's road network annually.

Historically, the development of the road transport fleet has progressed from two horsepower vehicles with gross combination mass of 2 tonnes, to vehicles of 500 horsepower or more with a gross combination mass of up to 138 tonnes. The benefits to be achieved by permitting vehicles to carry greater loads are recognised and have in fact been achieved by carrying increased gross loads over a greater number of axle groups, but with all axle groups loaded to the regulation limits.

Therefore, as shown in Figure 1, a diverse range of commercial vehicles has developed in Western Australia, many of which are permitted to operate well in excess of the regulation gross mass limit of 38 tonnes. For example, combinations consisting of a 4-axle rigid truck plus a 4-axle dog trailers, and having a gross combination mass of 58.5 tonnes, are widely used on a number of approved routes throughout the State. Also permitted to operate on selected routes throughout the State are road trains, consisting of combinations of normal regulation vehicles - either a rigid truck plus two or three trailers, or an articulated vehicle plus one or two trailers.

The most common road train operating in Western Australia is the "double bottom", consisting of an articulated vehicle plus one trailer and operating with a gross combination mass of approximately 72 tonnes, with an overall combination length of up to 33 metres. "Triple bottoms", consisting of an articulated vehicle plus two trailers, with a gross combination mass of approximately 105 tonnes, are also common in northern parts of the State.

ADMINISTRATION OF EXTRA MASS AND OVERDIMENSIONS SYSTEM

Regulation Mass Limits

Legally enforceable mass limits provide a uniform basis for vehicle manufacturers to design vehicles, road designers to design roads and bridges on which vehicles will operate, and give transport operators the opportunity to utilise vehicles which will optimise their operations.

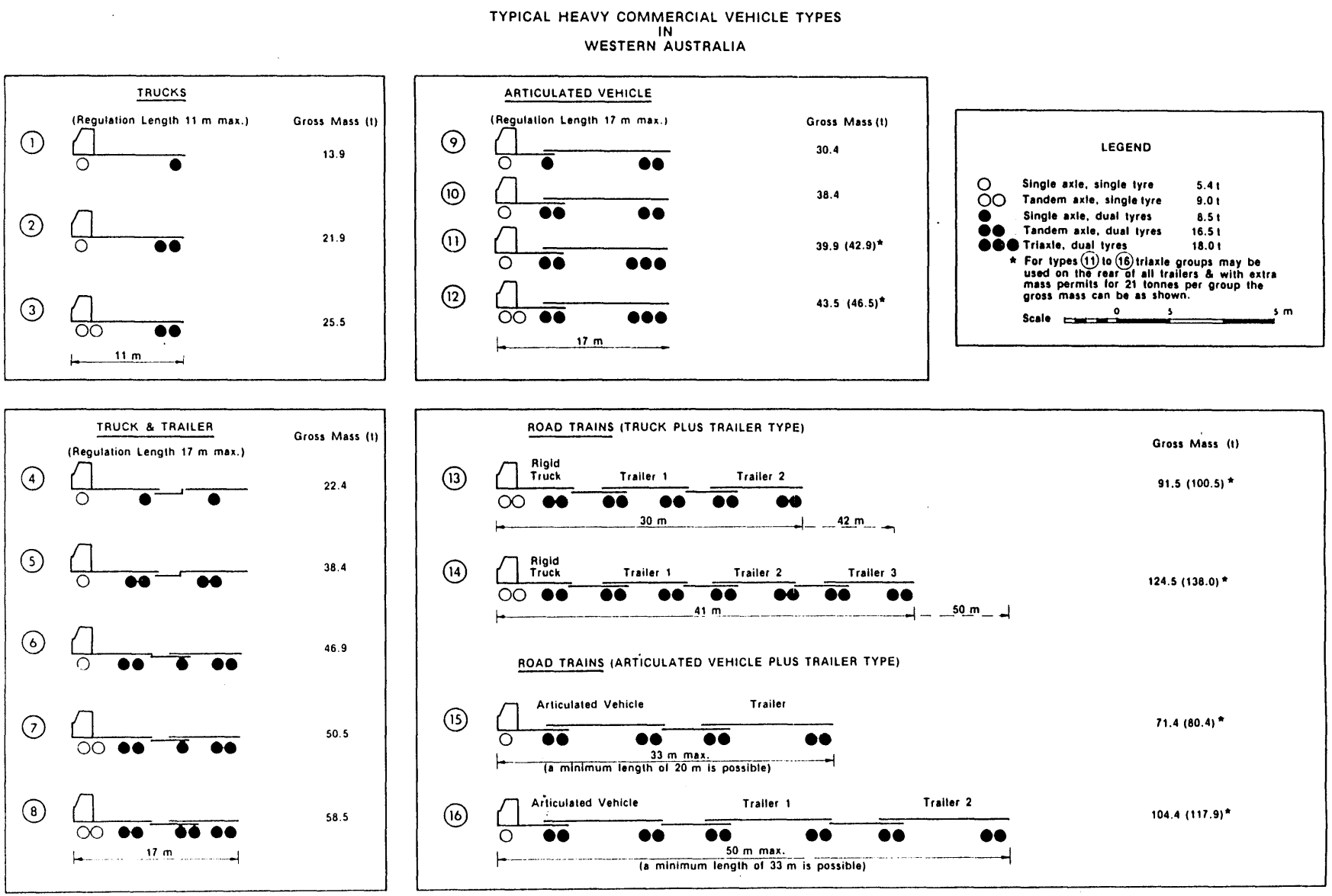


FIGURE 1 TYPICAL HEAVY COMMERCIAL VEHICLE TYPES

All motor vehicles using public roads throughout Western Australia are licensed by the Western Australian Police Department's Licensing and Services Division under powers prescribed in the Vehicle Standards Regulations (VSRs) of the Road Traffic Act 1974-1976. Certain of these VSRs stipulate the mass limits at which a vehicle may operate on any road in Western Australia. These regulation mass limits are shown at Table 2.

It is worth noting that in 1985 a national Review of Road Vehicle Limits (RoRVL) was undertaken by the National Association of Australian State Road Authorities (NAASRA), its purpose being to ... "Review the mass and dimension limits applying to vehicles using Australian roads, with the objective of enabling the Road Transport Industry to improve its economic viability."

TABLE 2
PROPOSED CHANGES TO AXLE AND
GROSS MASS LIMITS - WESTERN AUSTRALIA

AXLE GROUP	MASS LIMIT (Tonnes)	
	EXISTING	PROPOSED
Single Axle, Single Tyres	5.4	6.0
Single Axle, Dual Tyres	8.5	9.0
Twin Steer, Load Sharing	10.0	11.0
Twin Steer, Non-Load Sharing	9.0	10.0
Tandem Axle, single tyres	10.0	11.0
Tandem Axle, Dual Tyres	16.5	16.5
Tandem Axle, single and dual tyres	12.0	13.0
Triaxle, dual tyres	18.0	20.0
Gross Mass	38.0	42.5

SOURCE : Review of Road Vehicles Limits, NAASRA, 1985

The RoRVL study noted that options for increases in mass limits were constrained by the capacity of the community to fund the increased cost of road damage from heavier vehicles. RoRVL recommended minor increases in vehicle mass limits to assist industry

productivity, but which also reflected current financial constraints on road and bridge works. For Western Australia, legislation to increase certain mass limits in accordance with the RoRVL recommendations is under consideration. The changes proposed are shown in Table 2.

The Permit System

Under the Western Australian Vehicle Standards Regulations the Commissioner of Main Roads may issue a permit to allow a licensed vehicle to be operated when it does not comply with the regulation limits for dimension or mass, or both. Extensive use is made of the permit system which enables concessions to be made to the transport industry where conditions allow. The availability of these concessions gives the transport industry a great deal of flexibility in its choice of the type of vehicle for a particular task. It enables the transport industry to respond to the transport needs of the community and whenever possible it allows the most economic transport method to be employed.

Permits are concessions and not rights. They are made available subject to a variety of conditions, and failure to comply with the permit conditions will render a permit liable to cancellation. Loss of permit concessions by an operator will have far reaching effects on his business and this control procedure is very effective in ensuring that operations are conducted in accordance with permit conditions.

Statutory vehicle limitations in effect serve as the lowest common denominator. In certain circumstances special dispensation to exceed this limitation for particular haulage operations can be justified. The indiscriminate issue of permits could however result in financial and social burdens on the community. Therefore permits are only issued after taking into regard all the relevant factors such as safety, likely damage to road and bridges, equitable use of the road system, environmental impact and compatibility with national standards for transport economies. Routes with large traffic volume and percentage of heavy vehicles stand to contribute greater marginal benefits if the road pavement is constructed to withstand these additional loads.

A total of approximately 20 000 permits were issued in 1987/88 of which 460 applied to truck/trailer combinations and 1700 were Road Train Permits. Total permit fees collected from all permits issued amounted to approximately $650 000.

V JOHNSTON AND A O'NEILL

VEHICLE CONFIGURATIONS

Rigid Truck and Trailer Combinations

The various combinations discussed in this section are shown as Vehicle numbers 4 to 8 of Figure 1. In Western Australia the operation of this class of vehicle combination has grown quickly. Their use has been able to be permitted because they perform on the road system very well from many points of view, their turning swept path is better than that of a standard 17 m articulated vehicle as shown in figure 2 and they also offer a dramatic increase in payload over a standard articulated vehicle. Their gross combination masses range from 48.0 to 60.5 tonnes and with only a very limited number of exceptions for very specialised applications confined to timber country, they are within the overall combination length of 17.5 m.

For those operating at gross combination masses of up to 53.0 tonnes, Extra Mass Permits have been issued for many years to operate over a major portion of the road system including the Perth Metropolitan Area. Apart from restrictions of route, there are no limitations applied to the operations of these combinations. The network of routes which these vehicles are permitted to operate is only limited by some weak bridges. As a further condition of operation and permit it is a requirement that these vehicles be weighed at some point of the journey and accessibility to the weighbridge dockets by the Main Roads Department is a permit condition.

In Western Australia a distinction has been drawn between single steer units and twin steer units. Single Steer units with tandem drives are permitted regulation axle loadings, i.e. 5.4 tonne and 16.5 tonne respectively with a total mass of 21.9 tonne. These units however when used in a truck trailer combination are restricted to a maximum of 25 tonnes for the rear trailer permitting a total gross combination mass of 46.9 tonnes for this configuration. The limiting factor being the mass being towed. If no restriction was applied a 50% increase in towed mass could be achieved.

It can be appreciated that as the mass being towed increases significantly above the mass of the towing vehicle the situation arises when the front vehicle behaviour is determined by the rear trailer. In terms of operating in a metropolitan environment with high traffic volumes and high pedestrian activity this type of vehicle performance reduces road safety and introduces unnecessary hazards. For these reasons the gross mass of the rear trailer is restricted to 25 tonnes irrespective of the trailer axle configuration.

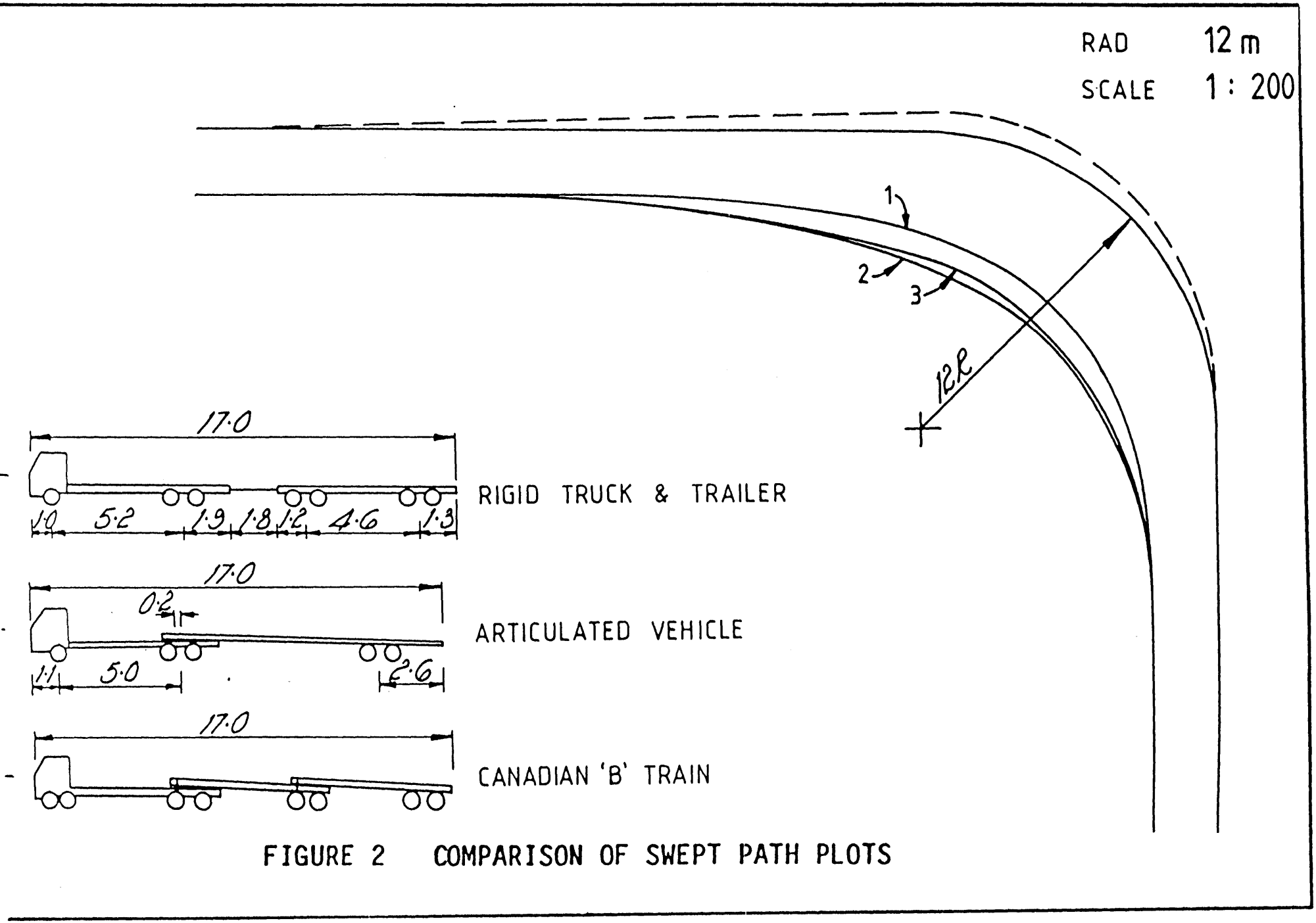


FIGURE 2 COMPARISON OF SWEPT PATH PLOTS

The twin steer vehicle is permitted a gross vehicle mass of 25.5 tonnes with a further allowance of 1 tonne if the front suspension is certified as a load sharing suspension. In this configuration the rear trailer is allowed full axle loadings. It is recognised that the ratio of the towing vehicle to the mass being towed increases however the twin steer unit offers the added safety and security of a tandem front steer system. These vehicle combinations are extensively used throughout Western Australia but are restricted to bridge strength evaluated routes. Each application requires agreement from the relevant Authorities which control the routes over which the vehicle requires approval and a further bridge assessment is carried out to assess any structural inadequacy.

Since 1978 there has been a growth in the issue of Extra Mass Permits for the four axle truck and four axle trailer combination with a gross combination mass up to 60.5 tonnes now allowed on permit. Approximately 460 permits were issued during 1987/88 for truck trailers.

Permits for these vehicles have been issued strictly in accordance with the following guidelines -

. cartage of a nominated commodity between fixed terminal points

. weighing facilities to be used en route for accurate determination of permitted laden masses

. routes to be approved by the MRD, i.e road conditions and bridge capacities to be adequate

. Local Government approval usually required for permit operations outside of the Perth Metropolitan Region.

Where further conditions are imposed by the Local Authorities the permit system is flexible enough to include these requests and endorsements are added to the relevant permits. Currently no maximum road speed is imposed on these units and the only pre-requisite to the issue of a permit is the qualification that the hauling unit be rated with the appropriate gross combination mass.

In addition to the limits outlined above, there are regulation mass limits for axle group loadings. Again, the Commissioner may issue Extra Mass Permits to exceed these limits, but in normal commercial vehicle operations such permits are only issued for triaxle groups. The regulation limit for such groups is 18 tonnes but permits are issued for 20 tonne loadings. The introduction of RoRVL recommendations will supersede the requirement for permits in this case.

The Commissioner has the power to withdraw permits. For example permits can be withdrawn for violation of permit conditions and violation could include the use of unauthorised routes and overloading. Because of this power, the escalation of capital equipment cost of vehicles with increasing capacity and the road transport industry's general view that permits are a concessional privilege (and a means of improving the efficiency of their operations), vehicles operating under permits issued by the Commissioner have a better record for compliance with regulation axle group loadings than normal as of right vehicles. In essence, they are less damaging to the road system. In addition, these higher capacity vehicles are generally operated by the more competent drivers and are better maintained.

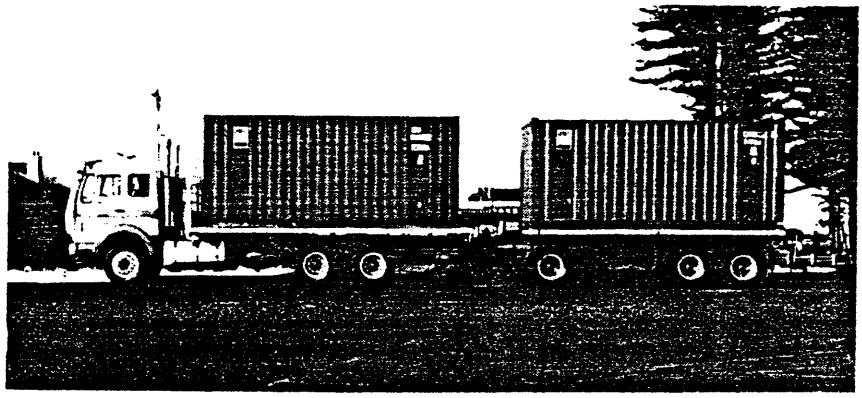
The 'B' Double

During the 1970s, although the ISO rating for the maximum laden mass of 6 m ISO seatainers was 21 tonnes, the majority of seatainers being handled in Western Australia were well below this maximum. The use of rigid truck and trailer combinations as shown at Types A & B, Figure 3, with a permitted gross combination mass of 46.9 and 50.5 tonnes, and to a lesser extent, articulated vehicles as shown at Type C, Figure 3, with a gross mass of 38 tonnes, became more relevant for the movement of 6 metre long ISO seatainers two at a time. However, as the number of seatainers with laden masses of up to about 21 tonnes increased, the incidence of overloading on rigid truck and trailer combinations escalated to the extent that it became a real concern to both the administering authority and responsible transport operators.

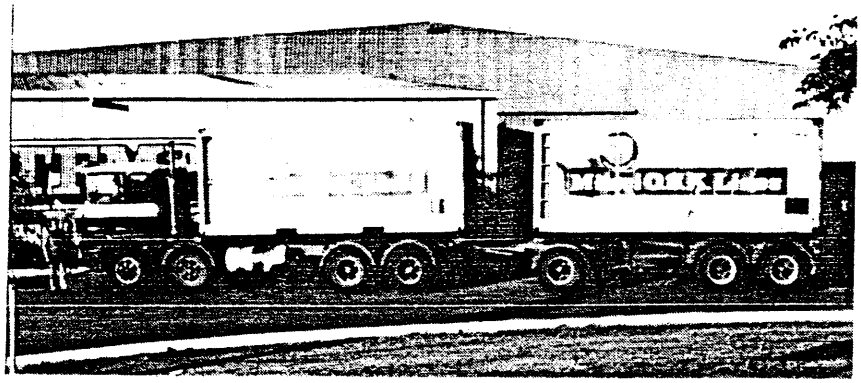
Table 3 shows some typical loading patterns which can result from the use of rigid truck and trailer combinations for the transport of seatainers two at a time. These results demonstrate the inability of this type of combination to equitably distribute loading over the supporting axle groups' this produces a high potential for overloading and a reduction in transport efficiency.

In examining alternative vehicle configurations for this container task a suitable combination type appeared to be the Canadian 'B' Train concept. In April 1983 a permit was issued to a company to operate a Canadian 'B' Train on a trial basis.

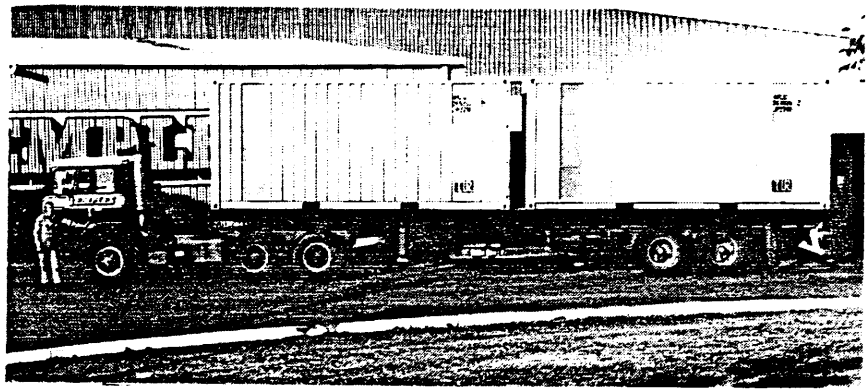
In Western Australia because of the sensitivity of roadtrain activity the terminology 'B' Double has now been promoted instead of 'B' Train.



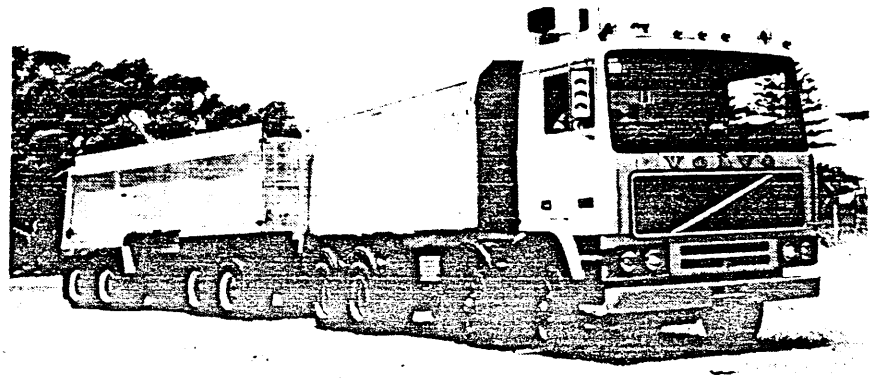
TYPE A - TRUCK & TRAILER COMBINATION WITH PERMITTED GROSS COMBINATION MASS OF 46.9 TONNES.



TYPE B - TRUCK & TRAILER COMBINATION WITH PERMITTED GROSS COMBINATION MASS OF 50.5 TONNES.



TYPE C - ARTICULATED VEHICLE WITH MAXIMUM GROSS COMBINATION MASS OF 38.0 TONNES.



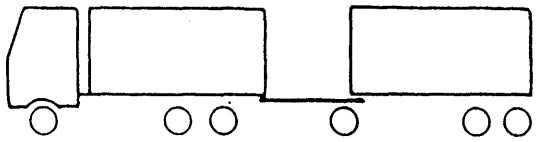
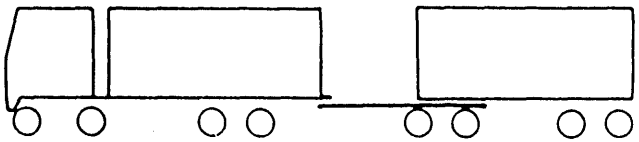
TYPE OF COMBINATION	THREE AXLE RIGID TRUCK & THREE AXLE TRAILER				FOUR AXLE RIGID TRUCK & FOUR AXLE TRAILER			
								
	AXLE GROUP LOADING				AXLE GROUP LOADING			
AXLE GROUP	STEER	DRIVE	FRONT TRAILER	REAR TRAILER	STEER	DRIVE	FRONT TRAILER	REAR TRAILER
REGULATION LIMIT / LOAD	5·4	16·5	8·5	16·5	10	16·5	16·5	16·5
2 x 16 TONNE SEATAINERS	6·1	17·8	7·9	13·4	9·7	16·5	10·8	11·5
2 x 21 TONNE SEATAINERS	6·9	22·1	9·7	16·5	10·8	20·4	13·2	14·1
2 x 24 TONNE SEATAINERS	7·3	24·7	10·8	18·4	11·6	21·6	14·6	15·7

FIGURE 4 TRUCK TRAILER LOADING ANALYSIS

The overall length of this combination exceeded the regulation limit of 17 metres by up to 1 metre thus giving a maximum overall combination length of approximately 18 metres. However, because the swept path characteristics of the combination were better than a regulation 17 metre articulated vehicle, see Figure 2, this slight increase in length was not considered to be of any significance.

In general, routes were confined to major arterial roads connecting ports with industrial areas and major rural centres together with essential access to and within industrial areas. In all cases operations were only permitted on routes approved by the Main Roads Department.

In the initial stages it was considered that the use of these units should not be permitted for other commodities where variability of loading was considered to be a problem however the possibility of relaxing this requirement is currently being investigated and it is likely that the carriage of general freight will be approved in the near future.

In terms of the operational characteristics of the 'B' Double all drivers have reported a feeling of confidence in the stable handling characteristics, particularly when compared with the common rigid truck and trailer combinations. This no doubt is a reflection of the difference in coupling mechanisms through two fifthwheels in the case of the 'B' Double compared with one fifthwheel and a pin type coupling with the rigid truck and trailer. The longitudinal torsional stability imparted through the two fifthwheel connections produces a more direct feel by the driver for the behaviour of the vehicles being towed. In Western Australia these units have an excellent road safety record with no reported accidents.

Acceptance by the general public has been ratified by no complaints being received from other road users or the public concerning the operation of these vehicles. This is not unusual in that 'B' Doubles are very similar to rigid truck and trailer combinations which have been prevalent in both the metropolitan and rural areas of WA for many years.

In regard to overloading, 'B' Doubles are subject to the same field surveillance, risk of detection and prosecution for overloading as other commercial vehicles. Having regard for the generally strict controls over container loadings, particularly the upper limit of 24 tonnes, the risk of containers exceeding a laden weight of 24 tonnes

is not high. Also the 'B' Doubles can more adequately distribute the total payload over the supporting axle groups than the conventional rigid truck and trailer combinations; this feature will considerably reduce the risk of excessive overloads which have become more prevalent with the rigid truck and trailer combinations.

Currently Western Australia has 20 'B' Double configurations at 18 m long and 5 at 23 m long. All vehicles are subject to the National Association of State Road Authorities (NAASRA) Speed and Gradeability assessment.

With the introduction of the new NAASRA 23m 'B' Double specific routes on the outer perimeter of the Metropolitan area have been designated and in this regard because the traffic is generally lighter no distinction has been drawn in respect of the advantages of twin steer versus single steer.

VEHICLE COMPARISON - ECONOMIES OF SCALE

There can be little doubt regarding the economies in road transport costs to be achieved by using large combination vehicles. For example, an analysis of the task of carting 100 000 tonnes of cargo over 160 kilometres (100 miles) in different types of combinations and assuming no backloading, is shown in Table 4.

Included in the performance measures in this table is the concept of Equivalent Standard Axle (ESA) which is a measure of the damaging effect of a Standard Axle. The various other commonly used axle group configurations all have loadings at which they have the same damaging effect as a standard axle, and when they are laden to the regulation limit the damage they inflict on the road can be measured in multiples of standard axles.

It also follows that each axle group when operating at its regulation limit has a different Road Damage Factor (RDF) measured in ESAs/tonne. The relationships between the axle groups, their regulation load limits, their Standard Axle Equivalencies and their Road Damage Factor is shown in Table 5.

TABLE 4 : VEHICLE COMPARISON FOR SET TRANSPORTATION TASK

100 000 TONNES TRANSPORTED OVER 161 KM

VEHICLE TYPE	RIGID TRUCK	SEMI TRAILER	RIGID TRUCK/TRAILER	'B' DOUBLE	ROAD TRAIN DOUBLE BOTTOM
AXLE LOADINGS	5.4 8.5 o o	5.4 16.5 20.0 o oo ooo	9.0 16.5 16.5 16.5 oo oo oo oo	9.0 16.5 20.0 16.5 oo oo ooo oo	5.4 16.5 20.0 16.5 20.0 o oo ooo oo ooo
LADEN MASS	13.9	41.9	58.5	62.0	78.4
UNLADEN MASS	4.9	15.9	19.5	20.0	28.4
PAYLOAD	9.0	26.0	39.0	42.0	50.0
TOTAL TRIPS (LADEN & UNLADEN)	22 224	7 692	5 130	4 762	4 000
ESA/VEHICLE - LADEN - UNLADEN	2.15 0.03	4.53 .07	7.50 0.241	6.70 .48	8.07 0.71
TOTAL ESA'S - LADEN - UNLADEN	23 891 334	17 422 269	19 238 618	15 953 1 143	16 140 1 420
OVERALL TOTAL ESA'S	24 225	17 691	19 856	17 096	17 560
FUEL CONSOMPTION LTS PER 100 KM	29.0	52.0	56.0	58.0	63.0
KILOMETREAGE	3 578 064	1 238 412	825 930	766 682	671 048
FUEL CONSUMPTION LTS	1 027 638	643 974	462 521	444 675	422 760
TOTAL TONNAGE	208 906	222 298	200 070	195 242	213 600
PAYLOAD TONNE/ESA	4.18	5.70	5.20	6.27	6.20

TABLE 5 : RELATIONSHIP BETWEEN AXLE MASS AND ROAD DAMAGE

Axle Group	Loading in tonnes at which equiv. to 1 Std Axle	Regulation Mass Limit (tonnes)	Standard Axle Equivalencies (ESAs)	Road Damage Factor in ESA/tonne
Single steer -2 tyres	5.4	6.0	1.524	0.254
Tandem steer 2 tyres/axle	9.1	11.0	2.135	0.194
Single axle 4 tyres	8.2	9.0	1.451	0.161
Tandem axle 4 tyres/axle	13.6	16.5	2.167	0.131
Triaxle 4 tyres/axle	18.5	20.0	1.366	0.068

Looking at the two extremes from Table 4, if the task is undertaken utilising a 2-axle truck with an allowable gross mass of 13.9 tonnes and payload of 9.0 tonnes, the total trips necessary, laden and unladen, would be 22 224, consuming 1 037 638 litres of fuel and subjecting the road to the equivalent of 24 225 standard axle loadings.

In comparison, an 8-wheel rigid truck with a 4-axle dog trailer, with a gross combination mass of 58.5 tonnes and payload capacity of 39 tonnes, would accomplish the task in 5 130 trips, consume 462 521 litres of fuel and subject the road to the equivalent of 19 856 standard axle loadings.

Comparing these two examples and taking the cost of fuel to be about 55¢ per litre savings in fuel cost alone would be about $316 000 for this particular task. There would also be a reduction of 37% in road wear.

From the foregoing, it is readily apparent that the potential benefits of using vehicle combinations with increased payloads, but with the increased payloads being distributed over a greater number of axles, with each axle complying with the regulation limits, are :-

. A considerable saving in fuel

. A reduction in the number of vehicle movements, and

. A reduction in pavement deterioration.

In order to gain such public acceptance, all of those connected with the road transport industry - designers, builders, operators and administrators - have a real responsibility to achieve in a sensible and acceptable manner innovations in commercial vehicle design and operation which will not only be of benefit to the community as the end recipients of transport costs, but be acceptable to the community as road users.

SUMMARY & CONCLUSIONS

Road transport is usually characterised by its dual ownership in Western Australia. The road network is financed and administered by the Main Roads Department and Local Government Authorities, whereas the vehicles using it are largely in private ownership. In the absence of unified ownership and control, regulation of the mass and dimension limits for commercial vehicles is necessary to achieve a balance between the potential of vehicles to carry large and heavy loads and the capability of the road network to accommodate such vehicles.

Restrictions on the mass of vehicles and axles are applied to ensure the safety of other road users and to ensure an appropriate balance between transport economies and the cost of road construction and maintenance. There are, however, occasions when it is necessary and acceptable to exceed regulation vehicle mass limits. Large combination vehicles, carrying increased pay loads over a greater number of axles, but with all axles complying with regulation mass limits, can be shown to reduce pavement damage, fuel consumption and the number of vehicle movements. In recognition of such benefits, permits are issued within prescribed limits where road and traffic conditions permit.

Consequently a diverse vehicle fleet has developed in Western Australia, enabling the transport industry to respond to the transport needs of the community in a flexible and economic manner. However, such permits are subject to a number of strict conditions to ensure their safe operation with minimum impact on the road network.

Control of axle load limits is of fundamental importance in the protection of road and bridge assets, as well as for the safety of other road users. In Western Australia, control of axle load limits is based upon identification of a network of heavy haulage routes, field enforcement of vehicle and axle mass limits, and a system of financial penalties to discourage overloading. A statewide network of heavy haulage routes, designed to accommodate large, heavy loads, provides a basis for the safe and efficient movement of such vehicles between major industrial and resource centres. Field enforcement of vehicle and axle mass limits in Western Australia is undertaken by mobile police crews equipped with thin plate portable weighing scales. For vehicles found to have exceeded the mass limits, (after allowing weighing and administrative tolerances), a sliding scale of financial penalties is applied. Vehicles operating under permit are also liable to have permits cancelled for serious violations of their permit conditions.

Development of the abovementioned monitoring and control systems in Western Australia has enabled a diverse range of transport vehicles to operate throughout the State in a safe and efficient manner, whilst at the same time safeguarding the substantial public investment in the State's road network.