International Transport Forum

Moving Freight with Better Trucks

Research Report

Summary Document

OECD

International Transport Forum

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INTERNATIONAL TRANSPORT FORUM

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MOVING FREIGHT WITH BETTER TRUCKS

IMPROVING SAFETY, PRODUCTIVITY AND SUSTAINABILITY

SUMMARY DOCUMENT

This is a summary of the report *Moving Freight with Better Trucks*. The report was developed by a group of international experts representing 15 countries under the aegis of the Joint Transport Research Centre of the Organisation for Economic Co-operation and Development (OECD) and the International Transport Forum.

The purpose of this report is to identify potential improvements in terms of more effective safety and environmental regulation for trucks, backed by better systems of enforcement, and to identify opportunities for greater efficiency and higher productivity.

This summary document comprises the key messages and conclusions, as well as the table of contents of the full report together with details of the experts that contributed to the work.

This report presents state of the art research findings, literature survey and benchmarking studies. Key messages are not designed to represent a political consensus on the issues examined and do not necessarily reflect the policy of any individual Government in the Membership of the ITF or OECD.

TABLE OF CONTENTS

KEY MESSAGES AND CONCLUSIONS

Context

Freight transport demand has grown rapidly and will grow further as our economies recover from the current downturn. This puts pressure on the capacity of transport networks and community acceptance of the environmental and safety impacts of freight transport, especially by truck. Regulatory and pricing frameworks can be improved to deliver more optimal outcomes as the freight task grows. The purpose of this report is to identify potential improvements in terms of more effective safety and environmental regulation for trucks, backed by better systems of enforcement, and to identify opportunities for greater efficiency and higher productivity.

In particular, the report aims to inform deliberations on authorisations for more extensive use of higher capacity vehicles[1]. This is currently under consideration in many countries because of the potential of such vehicles to yield major productivity gains:

- Several northern European nations are testing European Modular Vehicles, a family of vehicles composed of combinations of standard trailers with length limits of 25.25 m and load limits of 60 tonnes.
- The State of Victoria, Australia, started testing of a family of trucks with length limits of 30 m and load limits of 77.5 tonnes in 2009.
- The Province of Ontario, Canada, issued a limited number of permits in 2009 for testing long combination vehicles capable of hauling two full size trailers up to a mass of 63.5 tonnes and to a length of 40 metres.
- There is some discussion in the United States in relation to the surface transportation authorisation bill about possibly increasing length and mass limits for trucks in interstate traffic where the current mass limit is 80 000 lbs (36.3 tonnes) and the maximum length of combination vehicles is established by Federal law and State permit programmes.

The net effects of such vehicles depend on a range of factors that vary widely between regions. The report reviews the information available on the economic, safety and environmental characteristics of heavy trucks and supplements it by modelling the performance of 39 workhorse[2] and higher capacity vehicles in use around the world.

The report offers proposals on how regulatory frameworks can be modified to promote innovation that can improve safety and environmental outcomes, protect infrastructure assets and drive efficiency. This includes the use of higher capacity vehicles in appropriate circumstances but involves better regulation for all vehicles. The report does not propose specific interventions but offers a series of options for governments to respond to the challenge of rapidly increasing demand for road freight.

Key Messages

1. **The freight transport task is growing rapidly in most regions and requires effective utilisation of all modes of transport**. Road haulage is most suited to serving much of the

growing demand for transport. Other modal options provide competitive services on key freight corridors but cannot serve all of the locations required.

2. **The safety and environmental impacts of road haulage require regulatory intervention for optimal outcomes**. This includes controlling access to the road network and safety and emissions standards. Regulatory systems can be improved through more effective compliance regimes and through performance based standards that provide flexibility to enable technological innovations to deliver better levels of safety and environmental protection.

3. **Compliance can be improved greatly through legislation that assigns responsibility** for respecting the regulations to actors across the supply chain and grants powers to compliance agencies to use alternatives to roadside checks. This includes inspecting the financial and loading records of shippers, receivers and transport companies to control overloading.

4. **Compliance regimes can be enhanced by exploiting technological innovations** such as GPS tracking for route access compliance, advanced weigh-in-motion systems to monitor truck loading without the need to stop vehicles at the roadside and the use of remote checking of on-board diagnostic systems. Enforcement can be automated with vehicle recognition systems. Information technologies can be used to target high risk drivers and transport operators. Accreditation schemes can be used to stimulate the adoption of best practice safety management systems.

5. **A performance based approach to regulation offers the potential to meet community objectives for road freight transport more fully**. Such an approach — adopted in a number of countries, including Australia and Canada — defines the environmental and safety objectives to be attained whilst leaving the means for achieving them unspecified. This allows industry to innovate to increase productivity whilst meeting sustainability and safety goals. In Australia performance based standards have been used to authorise access to suitable parts of the road network for vehicles that do not conform to prescriptive limits on mass or dimensions.

6. **Many higher capacity vehicles have equivalent or even better intrinsic safety characteristics in some respects than most common workhorse trucks**. This is suggested by the literature and by computer modelling undertaken for this report of 39 heavy truck types and confirmed by a number of case studies of higher capacity vehicles on the road (*e.g.* in Canada, Sweden and Australia). Their dynamic stability tends to be superior. Their axle load distribution, on a greater number of axles, often enhances brake capacity, with shorter stopping distances[3] and reduced brake fade. For HCVs on the road today, driver selection, operational controls and higher levels of safety equipment contribute to significantly better safety records for these vehicles[4].

7. **Truck crash energies mean safety regulation must pay particular attention to managing truck speeds and driver alertness and impairment.** Safety barriers and bridge piers are vulnerable to the energy of impacts from all categories of heavy trucks and most are fitted with guard rails designed to redirect large vehicles away from critical structures. Bridge piers might need to be protected with additional barriers. Lane departure warning systems promise to reduce risks of collision for all types of trucks. Modifying regulatory frameworks to deploy such electronic safety systems and incentivise uptake ahead of prescription is a clear priority.

8. **Further research is needed into other safety aspects of trucks**, including the potential aggravation of the consequences of accidents when higher capacity vehicles are involved and possible countermeasures. Vehicle length also presents risks for overtaking and blocks visibility

for other road users. The impact of vehicle length on safety and congestion are yet to be fully quantified.

9. **Higher capacity vehicles have potential to improve fuel efficiency and reduce emissions**. Basic aspects of truck design such as the length, wheelbase, width, height, axle loads, axle spacing and gross vehicle weight are limited by size and weight regulations. These factors directly influence fuel consumption. Computational analysis show that in many instances higher capacity vehicles can perform equally if not better than workhorse vehicles in terms of fuel efficiency and emissions.

10. **Higher capacity vehicles can result in fewer vehicle-kilometres travelled** for a given amount of freight transported. This is particularly true in relation to the volume of goods that can be carried per truck. Load volume rather than weight now often determines the number of trucks required. The reduction of truck numbers is contingent on avoiding a major decline in vehicle load factors[5]. Modular systems that couple standard trailers provide valuable flexibility for matching loads and for facilitating intermodal transfers. Case study results (Alberta and Saskatchewan in Canada, Sweden and Australia) suggest that the use of higher capacity vehicles has reduced the amount of truck traffic on the road, with benefits for safety and the environment, including reducing the growth of fuel consumption and CO2 emissions.

11. **The lower unit costs offered by higher productivity trucks could result in increased overall demand for road freight transport and a transfer of freight from other modes,** Even if this has not been the case to date where higher capacity trucks have been introduced, it could be the case in other regions or countries depending on the local conditions. Induced demand effects are likely to be small but the potential for modal transfer varies greatly between commodities and markets. This can introduce an inter-modal component to truck regulation. Policies to shift freight from roads to rail and inland waterways may lead some governments to prohibit higher capacity vehicles from the road network or from specific corridors, foregoing possible efficiency gains.

12. **Road pricing systems can be developed to manage use of the transport network more efficiently,** including with respect to the choice of mode for freight transport where alternative options are available. Fixed road network access charges, tolls and electronic kilometre charges can be differentiated to link them to truck road-wear, safety and environmental characteristics, truck productivity, and provide incentives for the use of low impact vehicles. Electronic kilometre charges provide incentives for improving truck load factors and can be varied to manage congestion if they are applied to passenger cars as well as heavy vehicles. Efficient pricing for the use of all transport infrastructure, including in relation to environmental and safety costs, is critical if the modes are to compete on an equal footing.

13. **The capacity of the road network is not uniform**. Optimising the use of higher productivity trucks will involve limiting their access to the network to links where their use is compatible with strength and geometry of the infrastructure. Technology is available to monitor and control access. Higher capacity vehicle access to the road network needs to be based on a balance of productivity benefits, infrastructure costs and safety and environment costs and benefits. Such investments, however, need to be considered carefully as in some cases the costs of adjusting infrastructure to accommodate HCVs could outweigh the benefits of their introduction

14. **Road infrastructure and trucks need to be developed in concert.** The benefits from the higher productivity of higher capacity vehicles sometimes justify investment in parts of the main road

network to accommodate them. In these cases the productivity benefits might provide resources to finance these investments. National approaches to infrastructure funding differ. Some countries earmark revenues from road charges and fuel taxes to expenditure on roads, or in some cases other transport infrastructure, others prefer to avoid earmarking.. Bridges are often the weak points, but appropriate regulation of vehicle design, targeted bridge protection or strengthening programmes and intelligent truck traffic management can provide the necessary protection for bridge assets.

15. **Further research and data is needed for solid, evidence-based decision making.** While this report is broad in scope it is not exhaustive. In order to properly evaluate the impact of road freight operations, the safety and compliance performance of the whole truck fleet should be consistently measured and monitored. The output of such monitoring would better inform the public of the performance of the trucking industry, support policing and enforcement and facilitate evidence driven policy development.

16. **Significant opportunities for improvement of the regulation of heavy trucks have been identified.** With more flexible regulation and enhanced compliance systems for safety, environmental and asset protection rules, simultaneous improvements in safety, sustainability and productivity of the general heavy vehicle fleet can be achieved. Appropriate use of higher capacity vehicles, assessed against performance standards, subject to route restrictions and enhanced road access and safety compliance regimes will lead to improved productivity and sustainability. Flanking measures are a potential means to guard against a shift from rail to road in markets where this might occur and is counter to national transport policy. Higher capacity vehicles have been operated extensively for a variety of freight tasks in some areas of the world without adverse impacts. The evidence available indicates significant safety, sustainability and productivity improvements. The experience also demonstrates that effective regulation is essential to benefiting from this potential. The benefits achievable depend on national and regional geographic infrastructure and market conditions. These have to be accounted for in assessing the merits of authorising higher capacity vehicles.

Conclusions

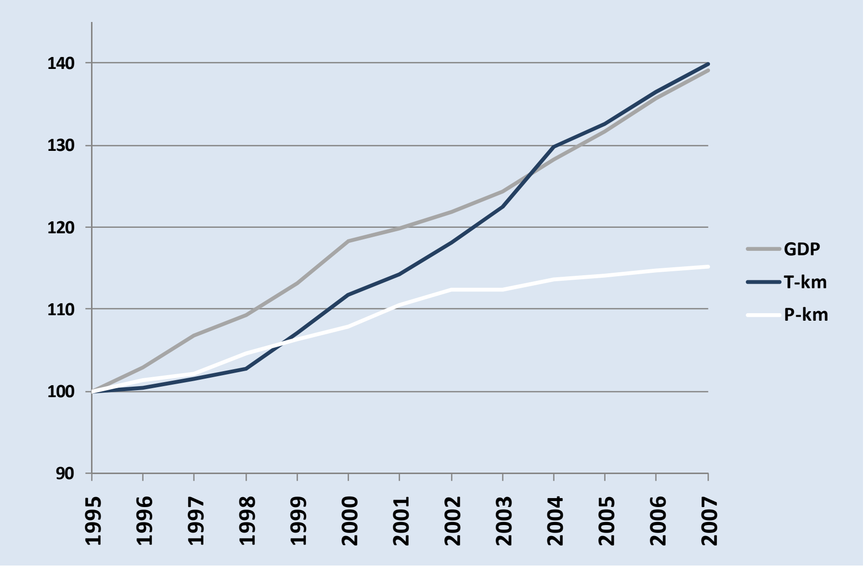
The Freight Task

1. *The amount of freight transport is increasing, with road haulage carrying the major part of the growth.*

The different transport modes develop their capacities and qualities in mutual competition and interdependency, as demonstrated by the increasing importance of intermodal terminals. Key factors in the choice of transport used by shippers are service quality requirements, the value to weight ratio and the density of the goods to be transported.

The freight transport task has grown significantly in recent decades in most countries; growing faster than passenger transport and in line with GDP for ITF countries in aggregate (see Figure 1). Trends differ from country to country and differ markedly between the three largest regions (Figure 2): in the United States the growth rate of 12% over 10 years to 2005 corresponds closely to the overall rate of economic growth in the country. Freight transport increased much more rapidly over the period in Europe (32 %) largely as a result of ongoing integration of the region’s economy. Russia also saw rapid growth, 37%, in the recovery following the collapse in trade with the fall of the Soviet Union. Japan at the other extreme saw only 2% growth, in line with its sluggish economic performance. In the UK freight transport and GDP growth has decoupled, with freight growing more slowly than GDP. For most countries, growth in road freight transport has exceeded overall growth in surface transport, with Russia and Mexico the major exceptions.

Figure 1. **GDP, Freight and Passenger Transport Growth in ITF Member Countries**
(GDP in 2005 Euros−1995=100)

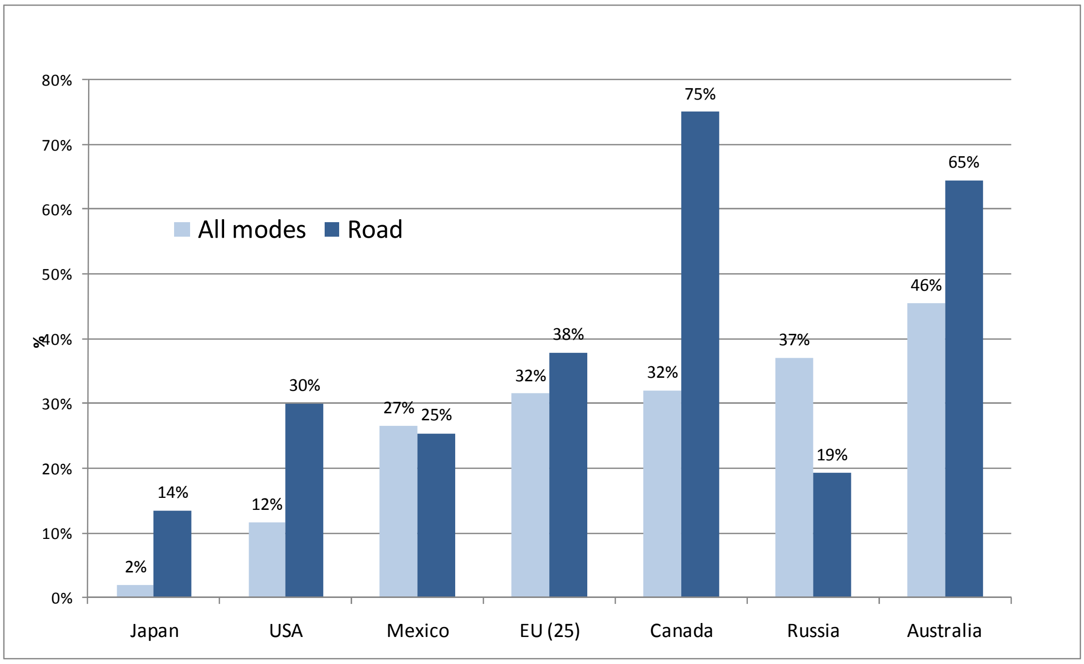


Source: ITF database.

The current recession is likely to shift these projections several years to the right. Recovery may take several years but when it comes freight will probably grow rapidly, as has been the case with previous recoveries. Long term trends may see some attenuation in the rate of trade growth as a result of a rebalancing of flows of capital and goods, but any reduction in international transport might be compensated by increased domestic transport of intermediate and finished products.

Because of its flexibility and timeliness, road transport is expected to account for much of the growth in freight transport for the foreseeable future. Projections, made before the onset of the recession in 2008, forecast very significant growth in road freight transport. The United States expected the volume (in tonnes) to double between 2000 and 2035 (FHWA, 2008). Projections reported by Bureau of Infrastructure, Transport and Regional Economics in Australia foresee an annual increase of 5%. Projections made in 2003 for freight transport growth to 2030 in the European Union are shown in Figure 3. In the USA and Russia (as well as India and China) growth is expected to be more balanced between roads and railways, with rail maintaining a dominant if eroding share of overall freight transport.

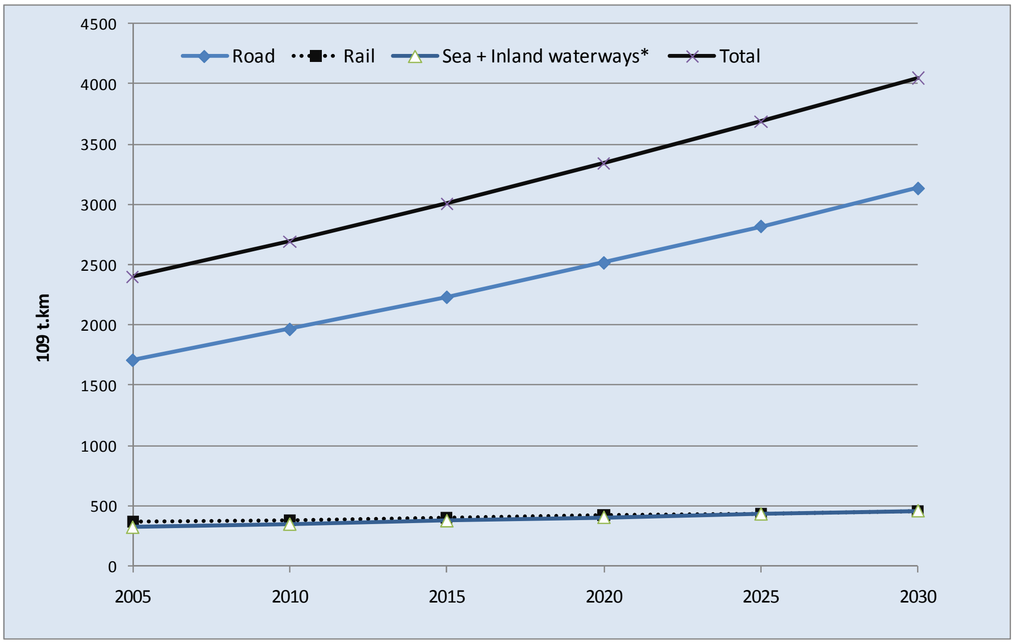
Figure 2. **Volume (ton-miles) growth in % for domestic freight transport by road and for all modes between 1995 and 2005***



Sources: European Commission, Directorate-General Energy and Transport, Japan Statistics Bureau, Transport statistics in North America, Federal State Statistics Service (Russia), ITF, Bureau of Transport and Regional Economics (Australia).

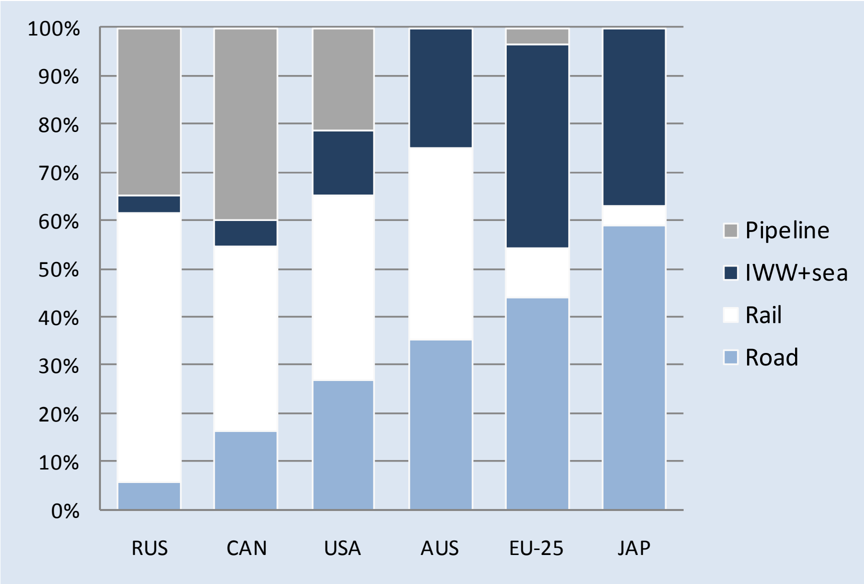
* US data (all modes) do not include container freight that is shipped inland without being opened and repackaged at the port

Figure 3. **Projections for volume of freight transport in the EU-25 by 2030 in billion t-km**



Source: European Commission, Directorate-General Energy and Transport

Figure 4. **Modal distribution of inland surface freight transport 2005 (tkm)**



Sources: European Commission; Japan Statistics Bureau; US Bureau of Transport statistics for North America; Federal State Statistics Service, Russia; ITF database.

2. Trucks are here to stay; managing their impacts is therefore critical to sustainable transport policy.

Although trucks have benefited in recent decades from innovations that have improved their fuel efficiency, reduced emissions and lessened infrastructure impacts and crash rates, there remains further capacity for improvement with respect to their performance on these measures. All avenues to reducing their impacts need to be explored.

The evolution of technical regulations for environmental protection and improved safety generally follows some form of "best available technology at no excessive extra cost" (BATNEEC) approach. Regulations are largely driven by developments in technology but regulations also drive innovation by setting performance standards that can sometimes be met through alternative technological development routes and competing technologies. One of the keys to developing new regulatory standards is to avoid picking winning technologies or locking technological development into specific paths that might discourage investment in developing alternative and more effective technologies in the longer term. This is difficult as regulators will naturally be inclined to assess what is currently possible using knowledge of current technologies to determine standards.

For many proposed regulatory interventions, benefits and costs are quantified in monetary terms. In other cases, assessments are based on the cost-effectiveness of meeting agreed standards for air quality for example. Greenhouse gas targets may begin to drive fuel efficiency regulations for trucks in the future and crash fatality targets are becoming increasingly central to road safety policy.

Regulatory standards are only one of the elements to managing freight transport environmental and safety outcomes. When the marginal benefits of regulations for new vehicles show declining returns it can be more effective to instead target the worst performing vehicles in the current vehicle fleet. For example, in 2002 Japan introduced retrospective NOx and PM emissions standards for old heavy duty vehicles. These require old trucks and buses to be retrofitted to meet 1997/98 emissions limits, or scrapped. Enhanced maintenance and inspection programmes can also be effective.

Contemporary road safety policy, following safe system approaches, emphasises synergies between the full range of potential interventions – regulation of driver behaviour, infrastructure design, vehicle technology, traffic management, fleet maintenance, personnel management and shipper responsibilities. Environmental performance is also conditioned by the combination of vehicle technology, vehicle configuration, traffic management, vehicle maintenance and fleet management, driver behaviour and logistics.

Achieving major improvements in performance requires improvement on all fronts. This includes: using the right vehicles for the right tasks, to optimise the number of vehicles used; charging transport services efficiently, to reflect external costs and price them efficiently in relation to other logistic costs; and improving load factors both by customising vehicles, improving the supply chain and setting transport charges to provide efficient price signals. There is scope for improving the regulatory framework in all of these areas.

Regulatory Challenges

3. *Governments have a responsibility to establish regulatory conditions that improve road transport efficiency, safety and sustainability.*

The challenge for governments is to establish the right framework conditions for minimising the external impacts of freight transport whilst allowing the trucking industry to provide efficient transport services. The overall aim of government policies towards transport is to maximise socio-economic welfare. External costs, such as congestion, air pollution, greenhouse gas emissions and safety, require regulatory or pricing intervention to reduce them to acceptable levels. These costs also need to be accounted for in planning and investment decisions.

Government intervention in trucking and associated activities is extensive. It includes regulation of vehicle weights and dimensions, technical characteristics of vehicles, vehicle access to the road network, driver licensing and behaviour and the practices of transport operators. Regulatory solutions must respond to freight needs whilst meeting community expectations for improved health, safety and quality of life. In some instances, trucking regulation is fragmented (between jurisdictions), excessively prescriptive, and slow to respond to changing technology, industry needs and community expectations. This undermines its effectiveness in meeting objectives.

A more sophisticated approach to heavy vehicle regulation could deliver better outcomes through the adoption of regulatory mechanisms that promote innovation by providing for flexibility in the way outcomes are met. Well designed regulatory intervention will achieve safety and environmental objectives in the most cost effective way, *i.e.* with the lowest impact on productivity.

A way forward for road transport regulation is to implement a package of:

- Measures to enhance compliance, exploiting the full potential for technological and regulatory innovation to improve enforcement.

- Performance based standards that allow higher productivity whilst maintaining or improving safety outcomes.

- Pricing reforms, to allocate costs between heavy vehicle types more closely according to their impact on road infrastructure, provide stronger incentives for mitigating environmental and safety costs.

These points are considered in more detail below.

Compliance

4. Innovative approaches and new technologies are available for achieving more effective compliance with regulations.

Improvement in regulatory compliance is a vital component of the effort to achieve a more sustainable transport system. Regulatory enforcement can benefit from the same advances in technology and management as general transport operations. Achievement of improved safety, productivity, and asset and environment protection requires a comprehensive approach to compliance. More effective enforcement alleviates problems of unfair competition from companies that break regulatory requirements. The main method of achieving compliance has been enforcement based on designated officers observing an offence. However, other tools are being developed to improve safety and compliance outcomes, such as weigh-in-motion systems.

The current trend in trucking enforcement includes:

- electronic detection of non-compliance;

- use of information technology to gather and apply information on patterns of behaviour, to enable the focussing of enforcement resources on high-risk drivers and operators;

- use of accreditation and safety ratings schemes to encourage the application of safety management systems; and

- imposition of legal requirements on off-road parties with control over truck operations.

Regulatory enforcement can benefit from the same advances in technology and management as general transport operations, using vehicle positioning systems, weigh-in-motion systems, on-board monitoring systems and detection and measurement equipment at the roadside and embedded in the roadway, *e.g.* advanced weigh-in-motion systems.

Improved information technology enables more rapid and efficient processing of detected breaches and the development of operator compliance and risk profiles. That enables the targeting of high-risk operators, either through safety ratings, compliance scores or operator licensing schemes. A range of flexible interventions can be used to achieve behaviour change or the removal of recalcitrant parties from the road transport industry. Operator licensing or safety rating schemes are in place in many countries. They require operators to manage company practices in order to achieve satisfactory safety and compliance levels.

Compliance and Chain of Responsibility

5. *Compliance can be improved greatly through legislation that assigns responsibility for respecting the regulations to actors across the supply chain and grants powers to compliance agencies to use alternatives to roadside checks.*

Accreditation may be used as a complement and/or a substitute for operator licensing and will typically have external validation that agreed standards or agreed processes, rules and procedures are being adhered to. In return for demonstrating high levels of compliance through auditable systems, transport operators can be granted concessions of commercial benefit, such as increased road access, higher mass limits and reduced incidence of road-side vehicle inspections.

For many breaches of road transport law, the party directly responsible is the driver. However, in most cases, the driver is not the only party to exercise a degree of control over on-road outcomes. In a fiercely competitive industry, each party in the transport chain is subject to pressure from those exercising higher control. For example, speeding offences, overloading and hours of service may be a response to schedules for which little or no flexibility is allowed. Recognising this, Australian States and Territories are progressively implementing 'chain of responsibility' laws which extend legal liability for compliance to all parties who exercise some degree of control over on-road outcomes. This 'chain of responsibility' principle is: *all who have control, whether direct or indirect, over a transport operation bear responsibility for conduct which affects compliance and should be made accountable for failure to discharge that responsibility*. Individuals held to be at fault under these provisions are required to demonstrate that they have taken 'reasonable steps' to achieve compliance with road transport law.

Operator licensing schemes, mandatory and non-mandatory accreditation and a requirement to undertake 'reasonable steps' under chain of responsibility legislation are all means of encouraging or requiring transport operators to take a systematic approach to management systems in order to achieve high levels of safety. Route compliance, vehicle mass and other vehicle and operator characteristics can be monitored. The challenge is to develop the administrative and institutional arrangements to cost-effectively maintain compliance. Enforcement agencies can be given powers to inspect financial and commercial documentation held by shippers and their clients as a highly cost effective approach to monitoring compliance, including speed, mass, vehicle condition and hours of service. Legal regimes of shared responsibility can be effective in reducing conflicts of interest in the observation of regulatory requirements.

If the community can gain greater confidence that heavy vehicles are complying with operating conditions, it is more likely that it will tolerate flexibility in standards that have traditionally been imposed as absolutes. This has the potential to change the nature of standards from 'one size fits all' to an to a more differentiated approach based on the nature of the specific freight task and requirements that vary in time and by place, supported by systems to ensure that compliance with regulatory requirements is achieved. Rather than preventing variation, modern approaches to compliance can enable variation in standards and result in safety and productivity gains.

Regulatory Approaches

6. *Performance based standards can enable innovation in truck design to more fully respond to industrial and societal demands.*

Current regulatory frameworks can be improved by introducing performance based standards as an alternative to some prescriptive vehicle design regulations. This would enable standards to be more closely linked to the safety, operational, infrastructure and environmental performance outcomes sought and would provide the industry with more freedom to release the maximum potential for innovation in both vehicle design and use.

Heavy trucks, including higher capacity vehicles, are capable of achieving better productivity, infrastructure wear, environmental and safety outcomes that serve the objectives of the broad community but careful regulation is required to ensure that all four outcomes are improved. Regulatory requirements may be formulated in various ways:

- A prescriptive standard specifies the means by which the regulatory objective is to be achieved. Prescriptive standards applied to trucking include vehicle length, width and mass.
- A performance based standard specifies the objective to be achieved, but leaves the means to achieve it flexible.

Most requirements relating to vehicle weights and dimensions are prescriptive. They have evolved over a long period and with significant regional differences, including within federal jurisdictions. With prescriptive measures, industry has little flexibility in determining how the objectives underlying regulations are to be met and innovation in vehicle design is constrained.

Performance based regulation can be used to either replace or supplement prescriptive standards for truck weights and dimensions. This form of regulation has been adopted in other sectors, such as occupational health and safety and food standards, and is now well established as the approach preferred for effective and efficient regulation.

Canada pioneered the use of performance standards for trucks (in the 1980s) and used them to develop a set of heavy vehicles considered most appropriate for use in inter-provincial operations. The initial set of vehicles comprised four types of truck. A later amendment added three more truck types and an intercity bus. The Canadian approach has been to use performance standards as the basis for the development of prescriptive standards to describe specific vehicle types.

The Australian PBS scheme has substituted performance standards for many prescriptive regulations and this higher degree of flexibility has allowed for more innovation in vehicle design. Initial industry concerns over the expense and difficulty of the process led to a review of the system and recommendations to simplify the process. This experience should be of use for other countries seeking to make use of PBS.

In both Canada and Australia it has been demonstrated that if regulatory arrangements can offer flexibility, industry will respond by operating the most efficient vehicle combinations. In these two countries, there appears to have been widespread community acceptance of larger freight vehicles, provided that their operation is managed effectively.

Environment and Efficiency

7. Improved productivity can contribute to reducing the number of trucks on the road.

Higher capacity vehicles provide major productivity benefits to their operators. Where they have been introduced they also appear to have substituted for a larger number of conventional trucks. Evaluations of the operation of HCVs are available from Sweden, Canada and Australia. The experience in these three countries supports the proposition that considerable productivity improvements and emissions reductions can be achieved by the use of HCVs, although this result can not be simply transferred to areas with very different conditions, *e.g.* in terms of geography or infrastructure, without specific evaluation

A study of the freight market in Sweden (Vierth *et al*., 2008) – where HCVs have been allowed for many years – considered the impact of restricting vehicle types to those universally authorised under EU directives for use in international trade. The study found that the cost per truck trip would decrease by five to twelve per cent, depending on commodity group, but the number of trucks needed for transporting the same quantity of freight would increase by 35-50 per cent. On average, 1.37 trucks of maximum EU size would be required to replace one truck of maximum Swedish size. It was estimated that the overall cost of transportation by truck would increase by 24 per cent.

In a Canadian study, Woodrooffe (2001) found that using single semitrailer configurations in Alberta in place of HCVs would lead to an 80% increase in truck movements and result in a 40% cost increase for shippers currently using HCVs. The increased use of HCVs has enabled Alberta's growing freight task to be serviced by a smaller number of heavy vehicles. From an economic efficiency and societal benefit point of view this amounts to a significant gain in transportation cost efficiency with a major reduction in fuel use and greenhouse gas emissions and a large reduction in pavement wear.

In Australia, B-doubles (vehicles comprising a tractor towing two B-coupled semi trailers – length 26 metres and gross combination mass 68.5 tonnes) were introduced in 1984, based on a Canadian design. By 2006, Australia had a total of 69 600 articulated trucks, of which 11 400 were B-doubles. Under conservative assumptions, it is estimated that if Australia had not introduced B-doubles, an additional 6 700 articulated vehicles would have been required to undertake the same road freight task. A more recent estimate places the reductions in articulated vehicles use at between 15 000 and 20 000. Use of B-doubles is estimated to have reduced the fuel consumed by the articulated vehicle fleet by 11% (Victoria Department of Transport, 2008).

8. Improvements in road freight productivity will have an impact on road freight demand and on other modes of transport.

Reducing the unit cost of road freight will tend to stimulate demand for road haulage. This will erode some of the reduction in truck numbers that might result from the introduction of HCVs. The impact of road freight productivity improvements on other modes of freight transport varies greatly between freight market sectors and between regions. It will depend to a large extent on the efficiency and regulatory arrangements for competing modes of transport but in some regions the adverse effect on other modes could potentially be sufficient to outweigh positive effects within the road sector.

Reducing road freight costs per unit of goods moved through the introduction of HCVs will have a number of effects on the transport market and will stimulate overall demand for road haulage. The initial effect of productivity gains will be to yield higher profits for the operators using these vehicles but in a market as competitive as road haulage the benefits will rapidly be passed on to shippers and to final consumers resulting in lower costs for transport and lower prices for the goods transported. Some of the gains may be offset by logistic changes that result in additional km travelled but save on overall logistic costs. There may be a tendency for trucks to be used less efficiently, at lower load factors, although this appears less likely than with other factors that reduce transport costs (such as falling fuel prices) because the rationale for using HCVs is to achieve higher productivity. The economic literature on the price sensitivity of road freight demand is thin and records a wide range of responses for vehicle km travelled, ranging from near zero to around 80%[6] depending on the market examined, the commodity carried the size and the source of the price change, and the methodology used (Graham and Glaister, 2004).

Increases in the productivity of road haulage will also influence overall modal split in freight transport. The impact is limited by the fact that many freight transport markets are not contestable between modes. It will be proportionately largest where rail carries only small quantities of freight in comparison with road as in these circumstances a relatively small addition to the quantity of freight carried on the roads can equate to a large part of the volume of rail traffic.

Facilitating an increase in the use of intermodal load units (containers, swap bodies etc.) will help to develop the markets for these non-road modes. Multimodal operations also benefit when truck regulations allow road freight vehicles to move more than one standard container or swap body per haul. The introduction of HCVs can therefore have positive impacts on rail markets as well as negative impacts, depending on whether road and rail are complements or substitutes.

Investment in infrastructure and improvement in the regulatory environments for rail, coastal and inland shipping are essential to their future competitiveness, and more important than changes in road haulage productivity in determining modal split. Using regulations to impose a modal split on the freight task, rather than limit external costs per unit of freight moved regardless of mode, risks using resources very inefficiently and is difficult to sustain in dynamic economies.

Some of the potential for reducing truck numbers as a result of the use of HCVs is eroded by the stimulus to demand from cutting costs. The size of the impact overall is difficult to predict. One recent study used a value for average price sensitivity on the trans-European road network to model the impact of reducing road freight costs 33% through the introduction of heavier (60 t) and longer (25.25 m) trucks (EC 2008). It found an initial reduction in the number of vehicles kilometres driven of 13% as a result of authorising these HCVs. This impact was slightly offset by induced demand and through modal shift, which together added 1% to truck vkm. Thus the net overall effect was a 12% reduction in vehicle kms driven.

A cross-European average hides substantial variation between regions. Some other studies have suggested much larger impacts on modal shift. A study in the United Kingdom by TRL (Knight *et al.*, 2008) illustrates the limitations of applying average values across diverse markets. It estimated that introducing 60 t heavy goods vehicles in Great Britain would carry a substantial risk of increased CO_2 emissions and other environmental drawbacks due to a potential modal shift from rail to road, affecting in particular the deep sea container market. The study estimated that this risk would be substantially reduced if maximum mass were limited to 50 tonnes.

The impact of the costs of transport on demand for freight transport services varies greatly between market segments. Variations in the cross elasticity between road and rail freight are particularly large, highly sensitive to the relative size of road and rail freight shares in the market segment of interest and poorly researched. This is reflected in the difference between the EC and TRL results as the UK rail market is not typical of Europe. Differences between European, Japanese, North American and Australian markets are pronounced and the results of these kinds of study are not easily transferable. Detailed modelling of the changes in the costs that result from using HCVs in specific markets is needed to better estimate the impact on demand and on modal shift for countries without experience of operating HCVs.

9. *Improvements to systems of road charges can contribute to the efficient development of surface freight transport.*

Road charge can be used to allocate costs between vehicle classes according to their impact on infrastructure and differentiate between vehicles according to environmental performance and relevant safety impacts. Differences in the way road and rail infrastructure use is charged can be a critical factor in intermodal competition.

An effective road pricing regime for trucks is seen by many as a key requirement in the development of efficient freight transport. The primary objective of a more refined road pricing system for trucks would be to more directly link charges for road use to road wear and to the external costs of using roads including safety and environmental impacts. Electronic truck km charges can also be used to manage congestion but are more effective when they also apply to light duty vehicles. Ensuring these variable costs are paid for pro-rata is the primary task.

Recovering the fixed costs of building capacity, for territorial development or to relieve congestion, can also be an objective for road pricing. The prices that result from this approach do not always coincide with charging to cover the variable costs of using roads. On lightly used roads, charging variable costs will result in lower prices than charging to cover fixed costs. On heavily congested routes, where expansion is not a realistic possibility, charges for managing congestion can increase prices higher than required to recover fixed construction costs. Charges for using rail infrastructure can similarly be based on covering a variety of fixed and variable cost elements. Divergence in the approaches applied to charging for roads and rail use can have major consequences for intermodal competition. Any tendency to cross-subsidise passenger rail services from freight revenues will also undermine the competitiveness of rail freight transport.

In most countries road user charges are not closely related to road use or the associated infrastructure or social costs. The main charging instruments are some form of fixed periodic charge (*e.g.* vignette or registration charge) and a fuel tax. Revenues from these charges typically accrue to general government funds, although in some countries they are paid into dedicated road or transport funds. Charging for the variable costs of road use by trucks, taking into account axle mass, road type and road condition, could enable shippers and transport operators to factor key costs into their choice of mode, route, vehicle, axle mass and vehicle configuration. Pricing reforms could be incremental, beginning with supplementary charges for HCVs to the extent that they impose additional costs, for example in relation to bridge strengthening. If road owners received such incremental infrastructure-related road revenues, they would have an incentive to respond to demands for the operation of higher capacity trucks.

Safety

10. *Many technologies are available for improving truck safety but some may need incentives for large-scale implementation.*

Safety improvements can be gained from recent advances in active safety equipment and driver support systems that alert the driver or intervene when risks are detected and not responded to promptly. Where the social benefits of these systems are greater than their private benefits to transport operators there is a case for regulatory intervention. The productivity gains available through changes in the regulation of truck weights and dimensions could provide an opportunity for accelerated introduction of some of the more expensive safety technologies.

Recent years have seen the development of systems that detect crash risks and either alert truck drivers to the need for action and/or intervene directly to avoid the crash or mitigate its consequences. Table 1 lists a selection of systems which are relatively new to the market, and thus not widely deployed, or still in the stage of final development but expected to be available within the next few years. Common to all of them is the need for concerted efforts by many actors in order to achieve successful implementation.

Table 1. **Key truck safety systems**

Imminent risk detection, alert and avoidance systems	7. Curve Speed Warning
1. Roll Stability Control	8. Intelligent Speed Adaptation
2. Lane Departure Warning	**Vehicle component condition warning system**
3. Forward Collision Warning	9. Onboard Brake Stroke Monitoring
4. Electronic Stability Control	10. Tyre Pressure Monitoring
5. Side Collision Warning	**Driver condition warning system**
Anticipating risk detection and prevention systems	11. Driver Fatigue Detection and Warning
6. Adaptive Cruise Control	12. Onboard Monitoring and Reporting Systems

Motor carriers are slow to voluntarily adopt new safety technologies unless tangible safety and economic benefits are evident. In the case of crash avoidance technologies such as ESC, small fleets and owner operators are less likely to see direct benefits because of limited travel exposure therefore acceptance of the technology among this industry sector is low. On the other hand large fleets can measure the benefits directly through reduced crash rates and are more likely to invest in the technology. Test evaluations and analyses are critical to demonstrating benefits. When the major beneficiaries of a safety feature are not the operator or occupant of the vehicle to which it is fitted there are several approaches to promoting uptake. These include provision of tax offsets or rebates, direct subsidy of purchase and fitment costs, reduced charges for vehicles with the safety feature, relaxation of an existing regulatory restriction (*e.g.* access to parts of the road network where the new technology resolves safety issues), and regulation mandating the fitment of the safety feature.

An opportunity for mandating new safety systems arises where regulations are modified to permit higher capacity trucks. In a *quid pro quo* approach the industry could be given the benefit of higher productivity whilst being required to improve safety. The costs of new safety technologies often delay their consideration for mandatory fitment and the regulatory process itself can add significant further delay. One opportunity to accelerate the process is to incentivise operators to fit the system voluntarily by making it a condition of productivity concessions, such as wider access to the road network or increased payload capacity.

11. The use of higher capacity vehicles can improve overall safety outcomes.

Analyses and practical experience with higher capacity vehicles, on the roads where they have been permitted, have concluded that their safety performance is no worse than that of traditional workhorse trucks. If higher capacity trucks substitute for a larger number of smaller vehicles their use may improve road safety overall.

In most studies of the potential impact of HCVs, it has been assumed that the crash risk of HCVs per vehicle km travelled (VKT) is the same as other heavy trucks, so that reduced aggregate VKT will lead to proportionate safety benefits. This assumption is generally supported by the findings of the computer-based analysis discussed below, although the exact effect would depend on which HCV was compared to which workhorse vehicle. On the key manoeuvrability and stability measures that most influence crash risks, higher capacity vehicles often perform better than the workhorse vehicles used to transport the majority of road freight around the world today.

Lack of detailed data makes it difficult to assess crash risk on an individual truck basis. A study by TRL in the U.K. (Knight *et al.*, 2008) assessed the various consequences of allowing different types of longer and heavier vehicles (LHVs) on the roads in Great Britain. It concluded that vehicles significantly larger than the current limits would be likely to increase safety risks per vehicle km, but decrease safety risks per unit of goods moved. Mandating new safety technologies, specific to vehicle configurations, and existing manoeuvrability standards would mitigate many of the risks, increase the reduction in casualties per unit of goods moved, and encourage wider use of new technologies in the standard goods vehicle fleet.

Studies of experiences in Canada (Barton *et al*., 2003, Woodrooffe *et al.*, 2004, Montufar *et al.*, 2007, Regehr, 2009) found that accident involvement of higher productivity vehicles per kilometre are significantly less than those of single trailer trucks in general operations. A study on the use of long combination vehicles (LCVs) in Alberta showed that for a given quantity and density of freight transported by articulated trucks, each LCV replaces one and one-half to two standard five-axle semitrailers, which, over the same period and on the same roads, had higher collision rates than LCVs. Thus, with appropriate regulatory controls, LCVs provided increased freight productivity and had significantly fewer collisions than would have occurred if standard configurations had been used to haul the freight. Driver selection, operational controls and higher levels of safety equipment may contribute to significantly better safety records for these vehicles on the road.

The various studies and experiences from recent years agree that a transfer of goods to trucks with higher cargo capacity should result in a reduction in casualties per unit of goods moved. The potential for further safety benefits depends on operational controls and the extent to which new, available, safety technology is successfully introduced with these types of trucks, *e.g.* as part of a legislation package through which they become permitted. Some of these technological safety measures can equally be applied to the current workhorse trucks, while others are inherent in the configuration of the higher capacity trucks.

Benchmarking

12. *Computer simulations show major variations in truck performance, with some Higher Capacity Vehicles (HCVs) performing better than today's workhorse trucks.*

A comparative analysis of the dynamic stability, geometric performance, payload efficiency and infrastructure impact of 39 workhorse and higher capacity vehicles, using computer simulation, revealed major differences between these vehicles. The study demonstrated the potential value of this tool for optimising truck design and vehicle standards. The analysis indicates that, on key performance measures, higher capacity vehicles perform often better than the workhorse vehicles used to transport the majority of road freight around the world today.

Computer simulations were undertaken to benchmark safety and productivity performance of representative trucks from participating member countries. Each vehicle was classified in one the following three general categories:

- Workhorse vehicles – the trucks most commonly used for long haul transport, with a gross combination mass (GCM) of less than 50 tonnes and a length of less than 22 metres.
- Higher capacity vehicles – with a GCM of up to 70 tonnes and a length of up to 30 metres, typically operated under restricted access conditions dependant on the road network.
- Very high capacity vehicles – with a GCM of at least 52 tonnes and a length of at least 30 metres and typically operated under permit conditions and often in rural or remote areas.

Each truck was assessed against key vehicle safety performance measures. The measures were based largely on a subset of the Australian National Transport Commission's (NTC) Performance Based Standards (PBS) scheme and are consistent with the measures used in Canada since the 1980s. The study provides an understanding of general vehicle performance in the broader international context. Table 2 shows the selection of standards used in this study to benchmark the performance of the 39 trucks.

Table 2. **Performance Standards – used in computer-based benchmarking of trucks in this study**

	Standard	Description
Vehicle stability	Static rollover threshold	Ensures that geometry and suspension provide a set level of vehicle stability
	Yaw damping coefficient	Ensures that vehicles do not suffer excessive roll oscillation after manoeuvres
Trailer dynamic performance	High-speed transient off-tracking	Ensures that trailers follow the path of the prime mover during unbraked avoidance manoeuvres
	Rearward amplification	Ensures that trailers of multi-articulated vehicles do not swing excessively after avoidance manoeuvres
	Load transfer ratio	Ensures that the vehicle does not approach wheel lift-off and possible roll-over during avoidance manoeuvres.
Vehicle manoeuvrability	Low-speed swept path	Ensures that a vehicle may safely manoeuvre around corners typical of those found on its compatible network without cutting the corner

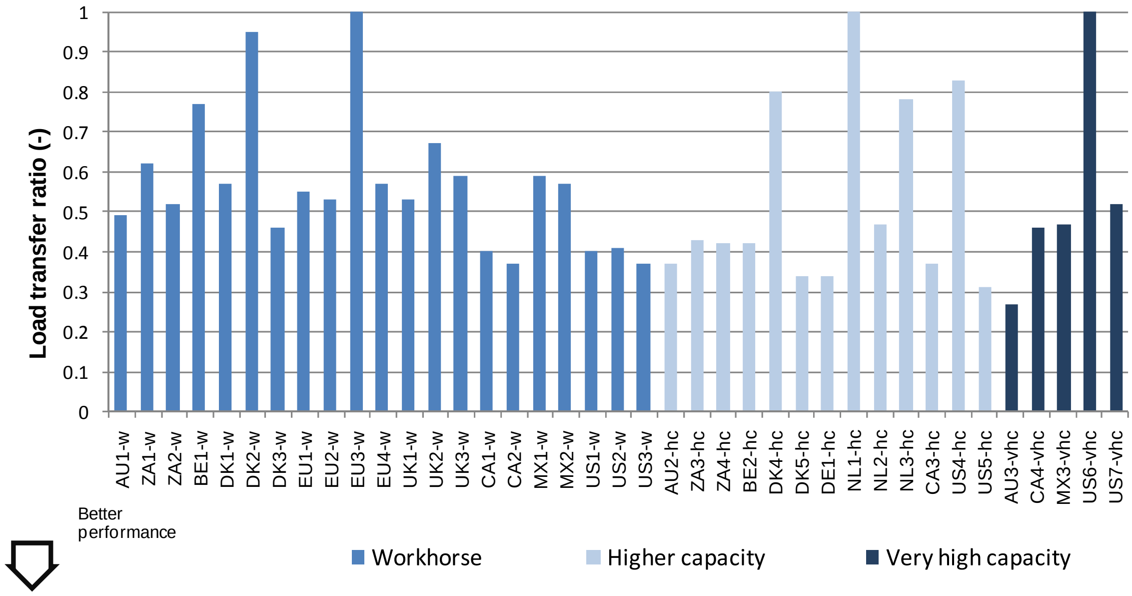
High-speed transient off-tracking, *rearward amplification* and *load transfer ratio* all relate to stability in lane change manoeuvres. The results were similar within each vehicle category and Figure 5 shows that very high capacity vehicles can offer comparable, and in some cases better, dynamic performance than some common workhorse vehicles. One truck from each category reached critical instability (wheel lift off or rollover at LTR values of 1.0) during this manoeuvre.

The *yaw damping* measure quantifies the rate at which yaw oscillations decay after a short duration steer input and pertain to heavy vehicles with one or more articulation points. The best performing vehicles are workhorse semi-trailers. Higher capacity and very high capacity vehicles perform well if the trailers are roll-coupled throughout.

Static rollover threshold is determined by increasing the lateral acceleration of the vehicle until rollover occurs. Of the vehicles examined, 64% of the work horse vehicles, 76% of the higher capacity vehicles and 100% of the very high capacity vehicles exceeded minimum requirements, indicating that, static rollover threshold tends to improve with vehicle length.

Low speed swept path is a measure of amount of road width required to negotiate a specific turn at low speed. The data clearly indicate that the workhorse vehicles have the best performance and the very high capacity vehicles have the poorest performance. In general, shorter vehicles have better low speed swept path performance.

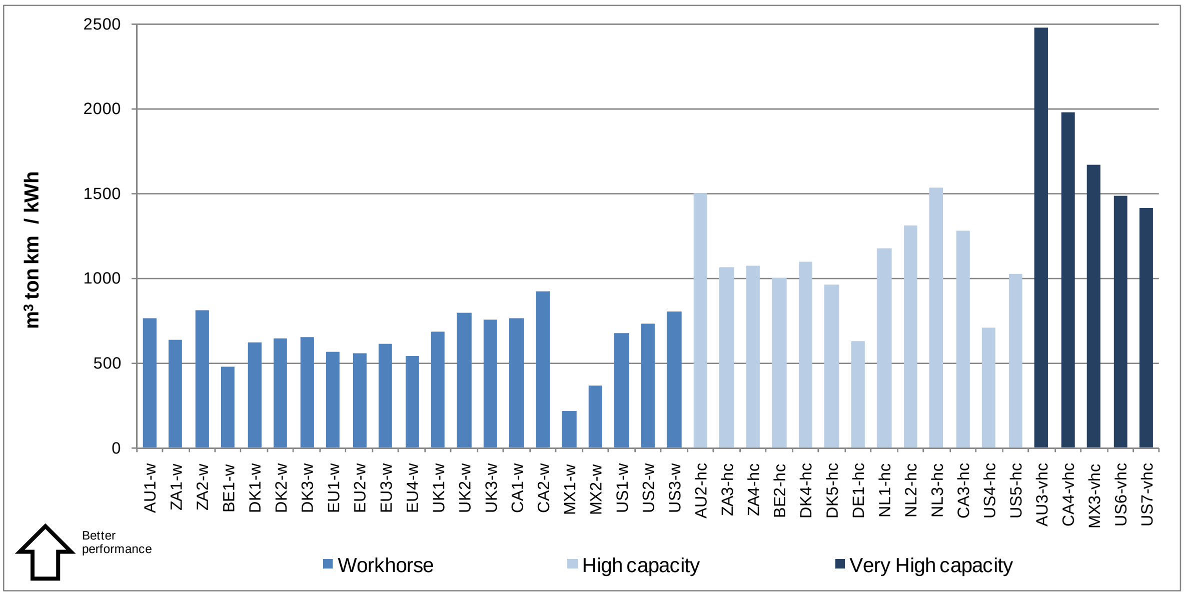
Figure 5. **Load transfer ratio**



A major part of the benchmarking investigation was directed at comparing productivity and fuel efficiency measures, which are influenced by vehicle mass, aerodynamic drag and tyre rolling resistance and therefore affected by size and weight regulation. Other important variables such as engine and driveline efficiencies also have significant influence but they are limited by technological development applying more or less equally to all vehicles and not influenced by size and weight regulation. Therefore this study focussed on the energy consumed to overcome rolling resistance and aerodynamics by the trucks at a steady state speed of 90 km/hr on level ground with no wind effects.

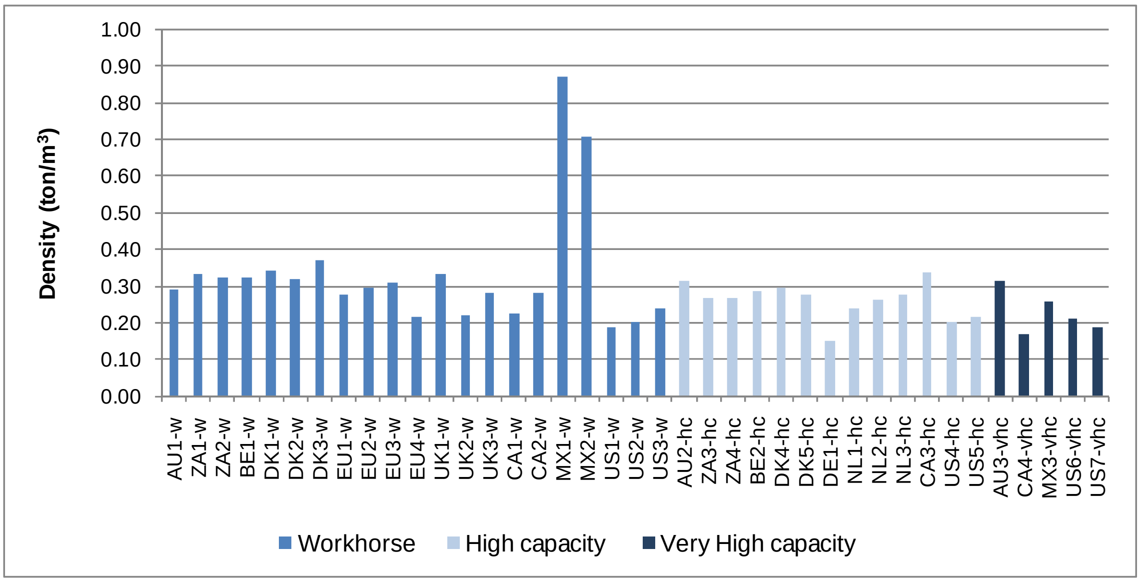
There is no simple measure with which the productivity of different vehicles across different commodities can be compared, but combining mass and volume capacity – while remaining imperfect– considerably improves the differentiation of different vehicles. The resulting cargo size (mass x volume) per unit of energy consumption values shown in Figure 6 very effectively differentiate the productivity performance of the three vehicle classes. Within each vehicle class the variations are significant and the performance measures improve with increasing vehicle capacity category. Since CO_2 emissions are directly proportional to diesel fuel use, the relative emission characteristics of the trucks will match those shown in Figure 6.

Figure 6. **Cargo size (mass x volume) per unit of energy consumption**



Optimum cargo density is defined as the density of freight that would occupy the total available cubic capacity of a truck while simultaneously reaching its cargo mass limits. The optimised vehicle densities, illustrated in Figure 7, show the specificity of the tanker vehicles (MX1 and MX2), specivially designed to carry high density liquid product and that the very high capacity vehicles are better suited to lower density freight. On balance, the workhorse vehicles appear to be better suited to carry higher density freight. This finding is of particular interest to assessment of potential shifts from rail to HCVs, given that rail is best suited to dense bulk freight while increased truck size is best suited for freight of decreasing density. That may obviously induce a higher shift from rail to road for low density freight.

Figure 7. **Optimum cargo density**



The benchmarking exercise included a comparison of the impacts of the trucks on pavements. The road wear comparison was based on the relative vehicle wear factor (VWF) for each truck which is the ratio of the VWF of the truck and that of a reference vehicle (a 40 t/16.50 m long 5-axle truck with a 2-axle tractor and a 3-axle semitrailer). The higher capacity vehicles and the very high capacity vehicles generally cause less wear and tear to the road. Most of the workhorse vehicles have quite a high wear factor. Similar comparisons were made for different pavement types, including rigid pavements, with similar results.

The benchmarking process showed that simulation based analysis of trucks can be useful for improving vehicle performance, safety and efficiency. The data obtained from the vehicle simulations and the comparison of vehicle performance against the selected measures highlighted areas for improvement as well as good practice and showed that HCVs can on a number of parameters perform better than workhorse vehicles.

Infrastructure

13. Trucks and road networks need to be developed in harmony

In the short term, truck traffic and truck configurations must be adapted to road design, geometries and above all to the strength of pavements and bridge assets. Truck combinations that are less aggressive to pavements should, as far as possible, be preferred. The infrastructure assets should, in the longer term, be developed to facilitate optimal use of road capacity by trucks. This development might be funded by financial mechanisms that recover any additional cost from the introduction of higher capacity vehicles, such as differentiated charges for road network access based on vehicle road wear characteristics.

Existing main roads were constructed according to guidelines based on weight and geometry characteristics of the vehicle fleet envisaged when the guidelines were made. Making such roads available for longer and heavier trucks requires careful evaluation and may call for infrastructure strengthening and modification of geometry. The benchmarking study undertaken for this report confirms a need to monitor the impacts of current truck traffic on road infrastructure. It also underlines the need for road owners and the trucking industry to actively engage in coordinated and optimised development of trucks and infrastructure to allow improvements in truck productivity with minimised increases in network costs.

Pavement wear varies greatly with truck configuration and pavement type. Axle numbers, axle group spacing, wheel types (dual or single) and tyre properties all contribute to this variation within groups of trucks of comparable gross mass. Gross mass is of less importance for pavements than the load distribution between axles and axle groups. Carriers should be encouraged to optimise the distribution of axle loads. The modern instrumentation of trucks, in particular on-board weighing systems allowing the driver to know the loads on each axle, is expected to permit implementation of such policies.

The challenge for the road owners is to preserve the road asset at minimum cost whilst accommodating higher capacity vehicles to the extent that maximises overall benefits. It means that the gain of productivity shall be shared between all parties, including the road owner. The experiences of Australia and Canada in this regard are instructive.

Many of Australia's safety-related performance-based standards specify four different performance levels. The purpose is to match the on-road performance of the truck to the risk environment that it will be operating in whilst making optimal use of available capacity in the network. Guidelines assist road owners in classifying routes into one of the four levels: Level 1 - General Access; Level 2 - B-double routes; Level 3 - Double Road Train routes; Level 4 - Triple Road Train routes. With vehicles assessed as meeting one of the four performance levels, access may be granted to the corresponding network level. A similar system has been adopted in the Netherlands.

In 1994, the province of Saskatchewan in Canada implemented a policy of partnerships with private companies to reduce truck transportation costs and ensure a “safe, reliable, efficient, environmentally sound highway system”, financed by a combination of public and private sector funds. New truck configurations that will reduce trucking costs by optimising the vehicle with the highway system as well as cargo handling facilities are evaluated on the basis of safety, road and bridge impacts, and haul savings. The cost savings generated for trucking companies by these partnerships provide new revenue for making improvements to the specific highways used by their vehicles.

Investment to adapt infrastructure is a component of many changes in vehicle mass limit regulations. For example, the Swedish parliament adopted a 10-year programme in 1987 to modify national regulations for conformity with EU law, authorising higher axle loads on all arterial roads throughout the country and also on some county roads. At the same time it increased the maximum permitted gross load to 60 tonnes. Associated infrastructure investment costs amounted to a total of SEK 13 billion (EUR 1.5 billion), primarily for bridges, which was recovered from the transport companies by general truck taxation.

Such investments, however, need to be considered carefully, as in some cases the costs of adjusting infrastructure to accommodate higher capacity vehicles could outweigh the benefits of their introduction.

14. Optimised truck configurations are required to minimise damage to bridges.

To protect bridges, if truck mass is increased truck length and the number of axles should at least be increased accordingly. One factor determining the vehicle mass limit should be the assessment of bridge capacity using evaluation tools such as a bridge formula. For trucks that exceed bridge-dependent gross mass limits, and for medium and long span bridges, the increased risk of bridge damage can be limited by managing traffic on the bridge. Signposting and automatic weighing stations can be used to ensure that minimum distances between heavy trucks crossing bridges, thus avoiding overloading the structure.

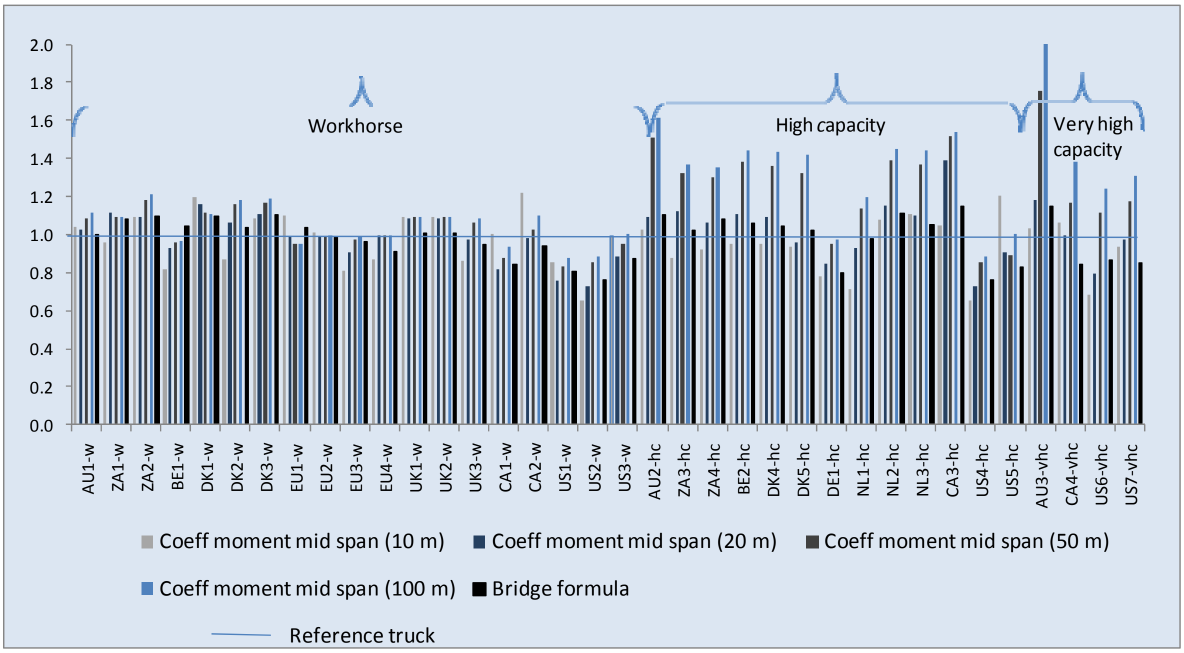
Bridges are routinely designed for loads considerably larger than those imposed by vehicles currently in use. The use of higher capacity vehicles could, however, mean significant differences in applied loading.

The key issue to be addressed in a bridge evaluation is to check that none of the structural elements will be damaged under the maximum load effect encountered during the bridge lifetime. Most of the design codes distinguish ultimate limit states, which correspond to failure or permanent damage, and serviceability limit states. The latter correspond to strains that affect bridge operation (*e.g.* traffic safety) but not the stability nor the durability of the structure, and are reversible.

The impact due to the running of a single truck on a bridge increases proportionally with the gross vehicle mass (or axle and group of axle loads for local effects), and with the 3^{rd} to 5^{th} power of the gross vehicle mass (or of axle and group of axle loads for local effects) in fatigue. This increase is less if the length of the vehicle increases. If gross mass limits are increased, vehicle length and the number of axles should be increased at least proportionally. A bridge formula is recommended to provide a useful guide to regulating vehicles to protect bridges from the accumulation of weight on too few axles.

The measure for structural impacts on bridges used in the benchmarking of the trucks was a relative coefficient of aggressiveness with respect to a standard European articulated truck (5-axle 40 t, 16.5 m), based on the true load effects induced in several simple bridges. Results are shown in Figure 8 and depend on the span length. There are significant differences between the different vehicle types. The worst performing vehicles are, on short and medium spans, those with the highest ratio between the gross vehicle mass and the vehicle length, and on long spans, the longest and heaviest vehicles, *i.e.* the higher and very high capacity vehicles.

Figure 8. **Comparison of impacts of trucks on bridges as shown by the relative coefficients of aggressiveness with respect to a reference truck**



For medium and long span bridges (above 50 m), a minimum spacing between trucks that exceed a particular gross mass limit would be useful in order to reduce the risk of bridge damage. For short and medium span bridges, it would be useful to avoid the meeting or overtaking of two very heavy trucks at the worst location along the bridge. Recent research has proposed strategies to manage the access of heavy vehicles to sensitive bridges.

Decisions to grant access for higher capacity vehicles to a road network must be based on a careful consideration including all the factors discussed above. It may be necessary to limit access to parts of the network depending on infrastructure characteristics and any investment required, for instance to strengthen certain bridges. It may also be desirable to limit access to parts of the network where the benefits are largest. Technology is available to ensure compliance with access restrictions.

Opportunities

15. Society expects road transport to be safe, sustainable, efficient and compliant with regulations.

The key to effective utilisation of trucks is to demonstrate to the community and their political leaders that these vehicles comply with regulatory restrictions, deliver high safety and environmental outcomes and recover the costs associated with their use of the network. The tools to deliver these requirements are available. The challenge for regulatory agencies is to implement an integrated and effective approach to the regulation of trucking.

Truck performance in terms of productivity, safety and mitigation of environmental impacts can be improved through innovation in vehicle technology and design and improvements in logistic and operational management. The economic and technological environment in which freight transport operates is dynamic and a variety of initiatives are necessary to release this potential in full. These include voluntary or semi-mandatory accreditation and certification schemes, compliance support, shared responsibility for on-road outcomes and more responsive regulation. In particular, a flexible and performance-based approach to dimension and mass limits and related regulations is needed with periodic renewal to maintain relevant standards. A number of countries have innovated in this direction with demonstrated benefits.

NOTES

[1]. Higher capacity vehicle (HCV) is the term used in this report to describe vehicles with weights and/or dimensions outside that permitted in conventional regulation. This term embraces European 'Longer and/or Heavier Vehicles', North American 'Long Combination Vehicles' and Australian 'Higher Productivity Vehicles'. The term higher productivity trucks is also used synonymously in this report.

[2]. Workhorse vehicle is employed to mean the most commonly used truck configurations for long distance transport.

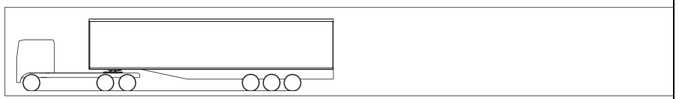
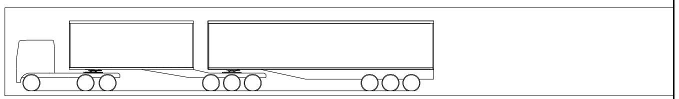
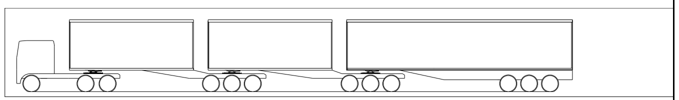
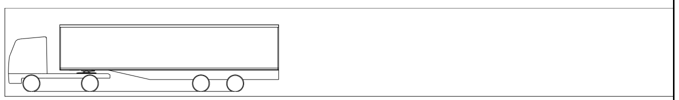
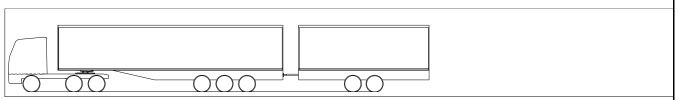
[3]. Excess braking capacity can be a problem for unloaded vehicles but this is avoided by the use of ABS and load-proportionate braking systems, which are mandatory or will shortly be mandatory in most OECD countries

[4]. These factors were accounted for in the Canadian studies.

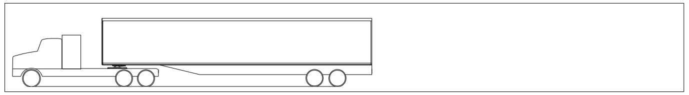
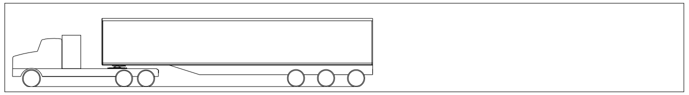
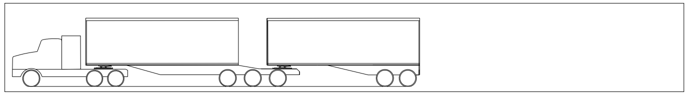
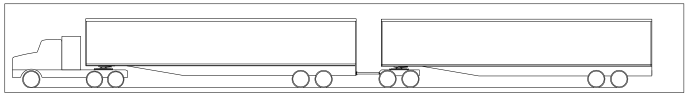
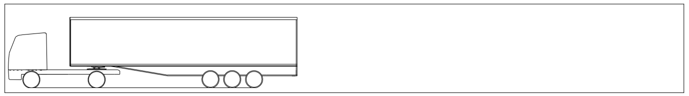
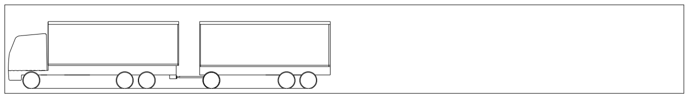
[5]. Electronic kilometre charges have been effective in providing incentives for consolidating loads and achieving higher load factors.

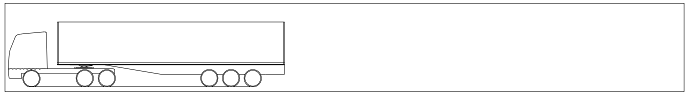
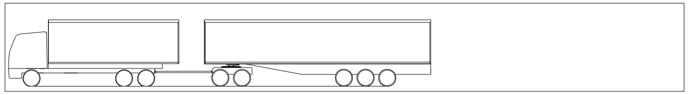
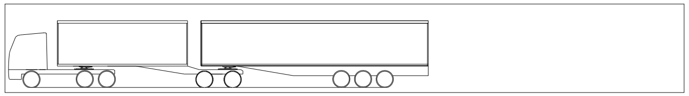
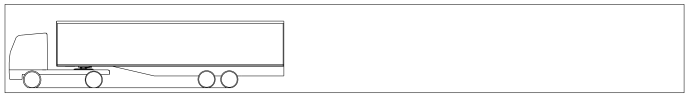
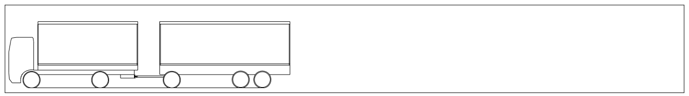
[6]. *i.e.* a 10% decrease in cost per vehicle km would result in an 8% increase in vehicle km travelled.

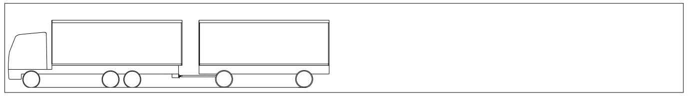
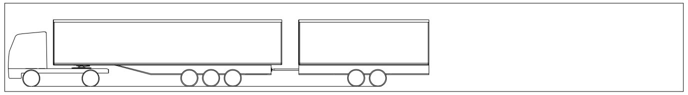
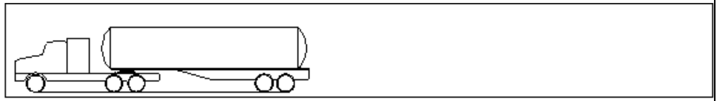
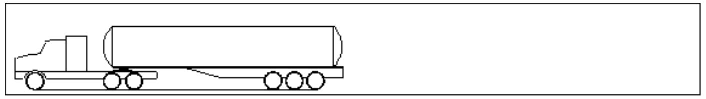
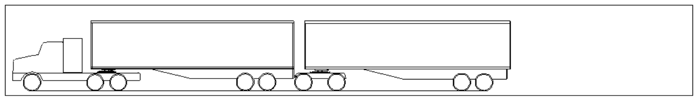
ANNEX VEHICLES AS MODELLED DURING BENCHMARKING STUDY[1]

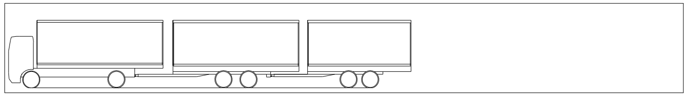
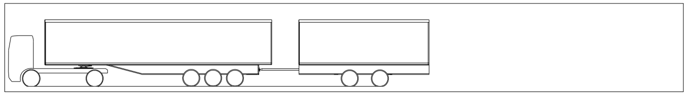
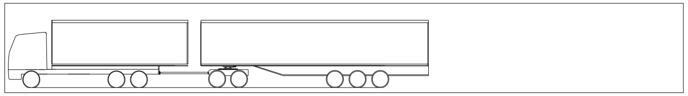
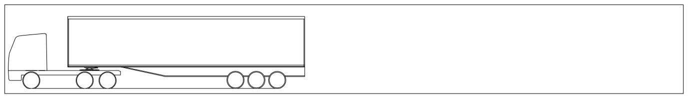
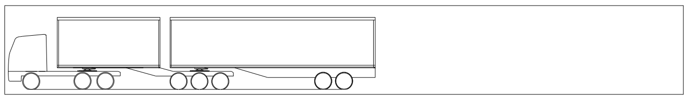
Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
Australia 1 AU1-w	45.500 29.000	19.000	Workhorse		Tractor semi-trailer T12b3
Australia 2 AU2-h	68.000 44.500	25.010	Higher capacity		B-double T12b3b3
Australia 3 AU3-v	90.500 60.000	33.310	Very high capacity		B-triple T12b3b3b3
Belgium 1 BE1-w	39.000 25.000	16.200	Workhorse		Tractor semi-trailer T11b2
Belgium 2 BE2-h	60.000 39.300	25.25	Higher capacity European modular vehicle		Tractor semi-trailer with rigid drawbar trailer T12b3a2

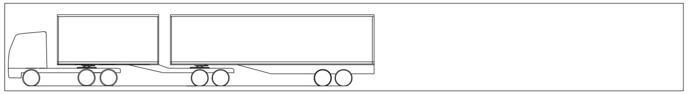
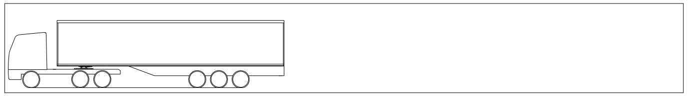
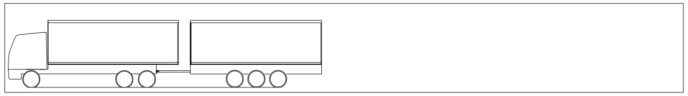
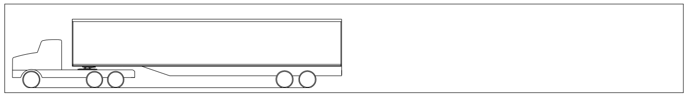
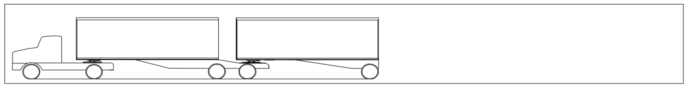
[1] These vehicles represent real vehicles. Their lengths do not necessarily correspond exactly to the maximum authorised length.

Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
Canada 1 CA1-w	39.500 25.300	21.550	Workhorse		Tractor semi-trailer T12b2
Canada 2 CA2-w	46.500 31.300	21.550	Workhorse		Tractor semi-trailer T12b3
Canada 3 CA3-h	62.500 42.300	20.430	Higher capacity		B-double T12b3b2
Canada 4 CA4-v	62.500 37.300	38.330	Very high capacity		A' train double T12b2a2b2
Denmark 1 DK1-w	44.000 30.000	16.480	Workhorse		Tractor semi-trailer T11b3
Denmark 2 DK2-w	48.000 32.000	18.750	Workhorse		Rigid truck trailer R12a1b2

Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
Denmark 3 DK3-w	48.000 32.300	16.500	Workhorse		Tractor semi-trailer T12b3
Denmark 4 DK4-h	60.000 40.700	25.250	Higher capacity European modular vehicle		Truck trailer R12a2b3
Denmark 5 DK5-h	60.000 38.000	25.100	Higher capacity		B-double T12b2b3
Europe 1 EU1-w	38.000 24.000	16.500	Workhorse		Tractor semi-trailer T11b2
Europe 2 EU2-w	40.000 26.000	16.480	Workhorse		Tractor semi-trailer T11b3
Europe 3 EU3-w	40.000 27.000	16.895	Workhorse		Truck trailer R11a1b2

Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
Europe 4 EU4-w	40.000 21.900	18.750	Workhorse		Rigid truck with rigid drawbar trailer R12a2
Germany 1 DE1-h	40.000 20.800	25.235	Higher capacity European modular vehicle		Tractor semi-trailer with rigid drawbar trailer T11b3a2
Mexico 1 MX1-w	41.500 26.650	16.950	Workhorse		Tractor semi-trailer T12b2
Mexico 2 MX2-w	48.500 31.850	19.250	Workhorse		Tractor semi-trailer T12b3
Mexico 3 MX3-v	66.500 42.849	30.730	Very high capacity		‘A’ train double T12b2a2b2

Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
Netherlands 1 NL1-h	50.000 33.410	24.200	Higher capacity		Rigid truck with two rigid drawbar trailers R11a2a2
Netherlands 2 NL2-h	60.000 37.702	25.200	Higher capacity European modular vehicle		Tractor semi-trailer with rigid drawbar trailer T11b3a2
Netherlands 3 NL3-h	60.000 39.720	25.240	Higher capacity		Rigid truck trailer R12a2b3
South Africa 1 ZA1-w	43.500 28.140	15.313	Workhorse		Tractor semi-trailer T12b2
South Africa 2 ZA2-w	49.300 31.900	17.745	Workhorse		Tractor semi-trailer T12b3
South Africa 3 ZA3-h	56.000 33.800	21.972	Higher capacity		B-double T12b3b2

Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
South Africa 4 ZA4-h	56.000 34.240	21.983	Higher capacity		B-double T12b2b2
United Kingdom 1 UK1-w	44.000 29.109	16.500 height = 4.0 m	Workhorse		Tractor semi-trailer T12b3
United Kingdom 2 UK2-w	44.000 26.130	16.500 height = 4.90 m	Workhorse		Tractor semi-trailer T12b3
United Kingdom 3 UK3-w	44.000 28.000	18.750	Workhorse		Rigid truck with rigid drawbar trailer R12a3
United States 1 US1-w	36.350 (80,138 lbs) 21.150 (46,628 lbs)	19.770	Workhorse		Tractor semi-trailer T12b2
United States 2 US2-w	36.360 (80,160 lbs) 23.460 (51,720 lbs)	21.980	Workhorse		B-double T11b2b1

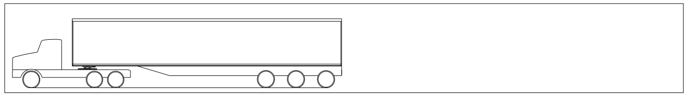
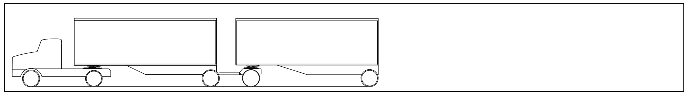
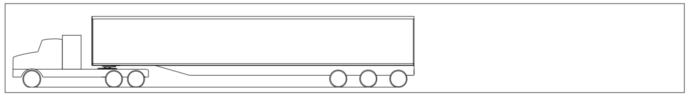
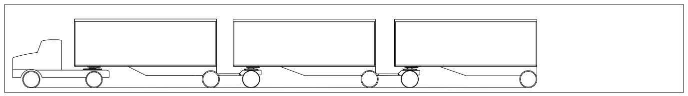
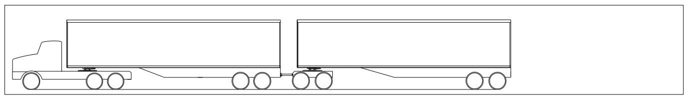
Vehicle origin & identification number	GCM (t) / Payload (t)	Length (m)	Vehicle Classification	Schematic	Vehicle description & vehicle code
United States 3 US3-w	41.900 (92,374 lbs) 26.700 (58,863 lbs)	19.770	Workhorse		Tractor semi-trailer T12b3
United States 4 US4-h	36.360 (80,138 lbs) 23.586 (51,998 lbs)	22.060	Higher capacity		'A' train double T11b1a1b1
United States 5 US5-h	44.100 (97,224 lbs) 28.900 (63,714 lbs)	25.120	Higher capacity		Tractor semi-trailer T12b3
United States 6 US6-v	53.752 (118,503 lbs) 37.287 (82,203 lbs)	31.570	Very high capacity		'A' train triple T11b1a1b1a1b1
United States 7 US7-v	57.040 (125,751 lbs) 32.840 (72,400 lbs)	30.960	Very high capacity		'A' train double T12b2a2b2

TABLE OF CONTENTS OF THE FULL REPORT

ACKNOWLEDGEMENTS AND LIST OF PARTICIPANTS

This report is the result of a three-year co-operative effort by an international group of experts representing 15 countries as well as the European Commission. The working group benefitted also from various consultation events to hear and learn from a wider group of experts, including the Seminar on *Regulating Heavy Vehicles for Safety and Efficiency, Australia as a case study*, (Paris, September 2007); consultations with industry stakeholders (Paris, May 2008, and Jönköping, August 2008), the International Conference on *Efficient, Safe and Sustainable Truck Transportation Systems for the Future* (Ann Arbor, June 2009), and a Workshop at the TRB Annual Meeting in January 2010.

The Working Group was chaired by Mr Jorgen Christensen and the work was co-ordinated by the Secretariat of the Joint Transport Research Centre. The report was subject to expert review before completion by independent experts, and the Group is grateful for their advice in improving the work.

The report was formally approved by the Joint Transport Research Committee at its March 2010 session.

The Secretariat is very appreciative of all the time and effort the contributors dedicated to this report.

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