DANGEROUS, DIRTY AND DIFFICULT – THE REAL-WORLD NECCESITY OF URBAN FREIGHT TRANSPORT BY HEAVY VEHICLE, AND THE MEASURES THAT MUST BE TAKEN TO IMPROVE IT

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ABSTRACT

The transport of freight is integral to the successful operation of society, and various forces continually increase the size of the freight transport task. Transport regulators must maximise the efficiency of current freight transport modes in order to deliver effective short and medium term benefits, while simultaneously planning to address the future needs of the freight transport task. Under several key criteria, road freight transport by heavy vehicle is a clear candidate for short-term improvements. Despite contributing to a large portion of the freight transport task in many countries, heavy vehicles are relatively much more dangerous, have a far greater impact on the environment and are problematic in other areas such as infrastructure wear and congestion.

This paper presents the case for the introduction of longer and heavier freight vehicles to address these concerns. Opponents of this approach cite negative characteristics of such vehicles as reasons against their introduction. These arguments are discussed in the context of recent research, new technologies, field trials, and innovative policy measures, demonstrating that longer and heavier vehicles are not only a necessary requirement, but can also be the catalyst for much-needed improvements in the areas of safety and environmental performance.

INTRODUCTION

The transport of freight is integral to the successful operation of society, and various economic and social forces are continually increasing the size and complexity of the freight transport task. This places increased pressure on infrastructure and creates challenges, particularly in areas where there is little opportunity to increase freight transport capacity via the construction of new infrastructure. Therefore, transport regulators and policy makers must maximise the efficiency of current freight transport modes in order to deliver effective short and medium term benefits, while simultaneously planning to address the future needs of the freight transport task. Issues separate to the predominantly economic concerns of efficiency and productivity such as the safety and environmental performance of freight transport modes should be addressed as key priorities.

The question remains as to which sectors of the freight transport network should be targeted for improvement, and how should these improvements be effected? From a holistic perspective, the safety, efficiency and productivity of all freight transport tasks should be continually improved. How this can be achieved in the current economic climate and in the context of the environmental debate, lies in the degree to which the freight transport mode meets several key criteria. Primarily, the mode should presently complete a large portion of the freight transport task, as this will ensure that improvements yield results which generate noticeable impacts. Additionally, the mode's share of the transport task should be projected to increase, as this will guarantee continued benefits in the future. Finally, the mode should presently demonstrate clear performance deficiencies, and also have the potential for these deficiencies to be addressed.

Using these criteria, road freight transport by heavy vehicle emerges as a clear candidate for the short-term focus of improvement efforts. Despite contributing to a large portion of the freight transport task in many countries, heavy vehicles are relatively much more dangerous, have a far greater impact on the environment and are problematic in other areas such as infrastructure wear and congestion. Despite this, they perform a key role in the modern freight transport task, and one which other transport modes often cannot complete. Therefore, the continual improvement of this transport mode must be addressed as a key priority in the short term.

This paper presents evidence collected to support this recommendation; looking to the current and projected role of heavy vehicles in the freight transport task, the performance of heavy vehicles in terms of road safety and carbon emissions, and builds the case for the introduction of longer and heavier vehicles (LHVs) as a priority. Opponents of this approach often cite negative characteristics of LHVs as reasons against their introduction. Such arguments will be discussed in the context of recent research, new technologies, field trials, and innovative policy measures, demonstrating that LHVs are not only a necessary requirement in the continual development of the freight transport network, but can also be the catalyst for much-needed improvements in the areas of safety and environmental performance.

1. THE MODERN FREIGHT TRANSPORT TASK

The inland surface freight transport task is considerable, and forms a pivotal role in the economies of many countries. The size of this task (in billions of tonne-km), and the modal split between the four most prominent transport modes is shown in Figure 1. Evidently, road freight transport forms a large share for a number of countries, most notably the 27 member states of the European Union (EU-27), where it performs approximately three-quarters of the total inland surface freight transport task. While the overall size of the freight transport tasks for countries such as Australia and Mexico are much smaller in comparison, the contribution of heavy vehicles to the movement of freight in these countries is proportionally much larger.

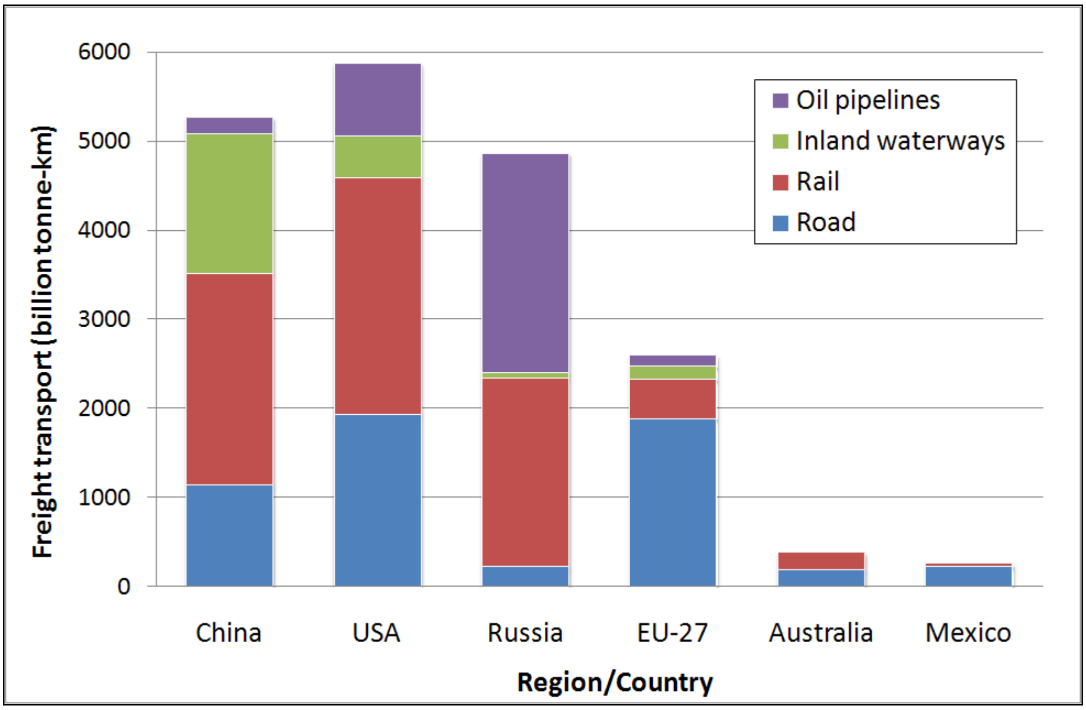

Figure 1: The inland surface freight transport task [1, 2 and 3]

While these statistics demonstrate that road freight transport by heavy vehicle is not the most prevalent mode of surface transport across countries in terms of freight volume (and indeed, volumes of sea freight typically eclipse inland surface transport volumes by a large margin), the contribution of heavy vehicles to the economies of many countries is undeniable. Similarly, the contribution of rail to the inland surface freight transport task in most countries is also considerable, particularly for countries such as China, the USA, and Russia, where it surpasses the transport of freight by road.

However, key differences between the two modes are the recently observed and projected growth (in terms of the volume of freight transported by tonne-km) of each. While the freight transport task has grown rapidly in most populated regions throughout the world, a trend that is projected to continue, it is typically road freight that has experienced the greatest increase. Figure 2 shows the percentage growth figures for the total freight transport task contrasted with the growth of the road freight transport task reported by various countries and regions for the ten years prior to 2005.

Even though this general trend does not apply to every country or region, it is indicative of a gradual shift of the modal split of inland surface freight transportation on a global scale. There are various reasons for this, mainly related to the key advantage of heavy vehicles and road transport compared to other modes – flexibility. While railway, pipeline and inland waterways can provide cost effective transport solutions on defined freight routes, in most instances they are not capable of reaching all of the required freight destinations, and will not be able to without the development of specific infrastructure.

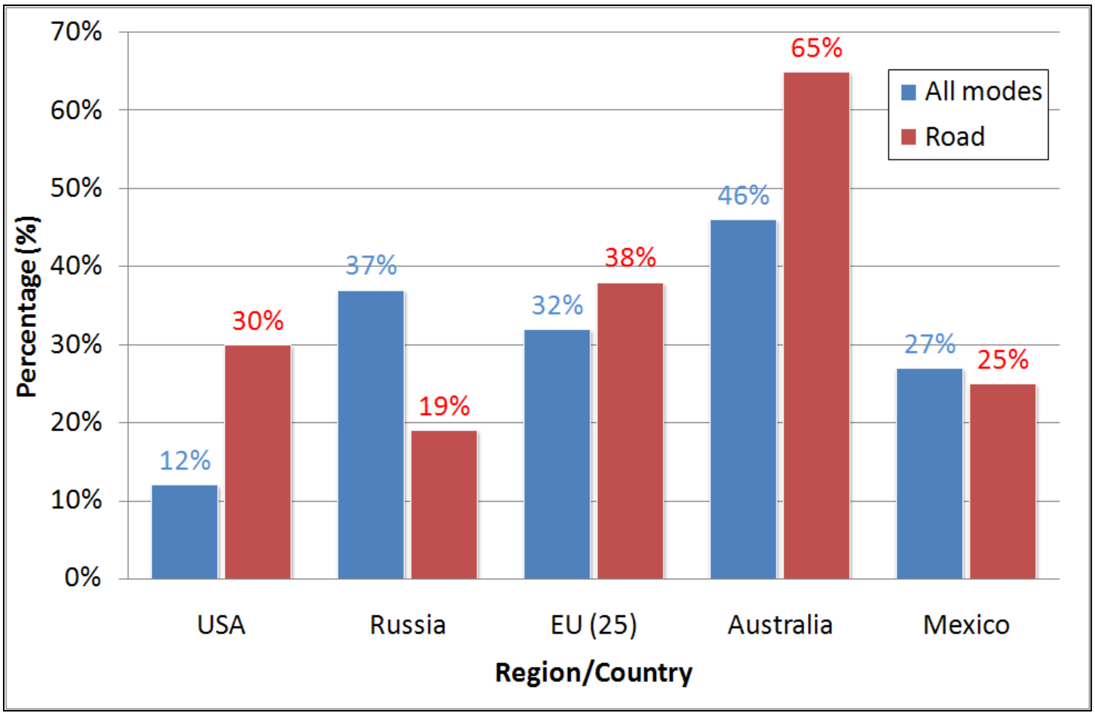

Figure 2: Growth in road transport systems [4]
(Source: adapted from Woodrooffe et al., 2010)

In the case of road freight transport, the majority of the infrastructure required already exists, as it has been developed to accommodate population increases and the increased volume of private vehicle traffic that this has generated. Paved roads account for approximately 80% of the physical transportation systems in the USA, with similar figures for Mexico, and in most cases between 90 and 95% for European Union member countries [5].

This factor, along with various others which include the tendency for consolidation of large-scale manufacturing and production facilities, and the increased demand for diverse ranges of products at the consumer level, will fuel further demand for heavy vehicle transport in the future. Various sources have estimated this increase to be quite high. As an example, it is estimated that the size of the Australian domestic freight transport task will double between the period of 2000 to 2020, and in response, kilometres travelled by articulated vehicles in urban areas will treble from 0.69 to 2.29 billion kilometres [6], with many other countries in the developed world reporting similar figures.

These statistics and projections indicate that heavy vehicles perform a vital role in the modern freight transport network, and future demand will significantly increase. In the context of the criteria denoting areas of the freight transport sector that should be focused on for improvement, heavy vehicles already complete large portions of the transport task and show signs of continued growth, therefore representing a key area for future development. As discussed in the following section, LHVs also satisfy the last criterion as they are often regarded as having safety and environmental performance deficiencies.

2. DANGEROUS, DIRTY AND DIFFICULT

Heavy vehicles, while having clear advantages for certain types of transport operations, are the worst performing mode in critical measures. These include their contribution to traffic safety statistics, their environmental impact (both in terms of carbon and noise emissions), and the increased levels of congestion that they contribute to when compared to other freight transport modes.

The safety performance of heavy vehicles is of primary concern. While total crash volumes are generally decreasing despite increases in vehicle-kilometres [4], the heavy vehicle crash rate remains relatively high compared to other modes. Lawson [7] reported the crash and casualty rates per billion tonne-km of various freight modes, based on data collected in the USA. A summary of these figures is shown in Table 1. Evidently, fatality, injury and crash rates are much higher for heavy vehicles than any other mode. Although such figures are not directly transferrable to other countries and regions, it is expected that they are indicative of the general trend amongst developed nations.

Table 1: Crash and casualty rates for various freight modes [7]

Freight mode	**Fatalities per billion tonne-km**	**Injuries per billion tonne-km**	**Crashes per billion tonne-km**
Shipping*	0.05	0.23	5
Rail (excluding crossing accidents)**	0.21	3.12	1
Rail (including crossings accidents)**	0.34	3.52	2
Heavy vehicle	0.36	13.22	214

***Ocean-going ships on inland waterways**
**** Separated due to the difficulty in determining causal factors in truck/rail crashes**

It should also be noted that the 'vision zero' policy direction with reference to road fatality statistics which is currently in various stages of implementation and discussion throughout the world, is presently a reality for the rail industries of many European nations. According to figures released by Europe's pro-rail alliance [8] Belgium, Denmark, Estonia, Finland, The Netherlands, Sweden, Slovenia and the UK did not experience a single traveller fatality as part of their rail network operations in 2008. While it is not clear how these figures relate to freight transport, it is reasonable to assume that they are indicative of the generally high level of operational safety within the rail industry – an assumption which is supported by the low accident rate reported by Lawson for the American rail industry. This further highlights the relatively poor performance of heavy vehicles as a freight transport mode in this regard.

Given the current attention on human-induced climate change, the emission of carbon dioxide and other greenhouse gases by heavy freight vehicles are another major concern. The International Maritime Organisation [9] reported on the carbon dioxide emission efficiencies (in grams of CO_2 emitted per tonne-km) for various freight transport operations, including shipping, rail, and road. Shipping operations were reported as having the best CO_2 efficiency (between 10 and 60 g of CO_2 per tonne-km); rail having between 15 and 120 g of CO_2 per tonne-km, while road transport was the worst-performing, occupying a range between 80 and approximately 180 g of CO_2 per tonne-km.

Similar figures are reported by the European Environmental Agency [10], with rail, inland waterway transport, and road transport contributing 21.4, 31.4 and 108.1 grams of CO_2 per tonne-km, respectively. General figures and trends in the carbon dioxide efficiency values for these transport modes for several years since 1995 are depicted in Figure 3. While the figures show a decreasing trend (improving performance) for the carbon dioxide emission efficiency of road transport, the figures are still much higher than for other modes. Improvements in the performance of heavy vehicles to date can be largely attributed to more stringent greenhouse gas emissions regulations however, further significant reductions are unlikely within the realm of currently available technologies. In the future, diesel-electric hybrids may deliver reductions in fuel consumption in the order of 20 – 30%, however even with such decreases the environmental impact of freight transport by heavy vehicle will remain high.

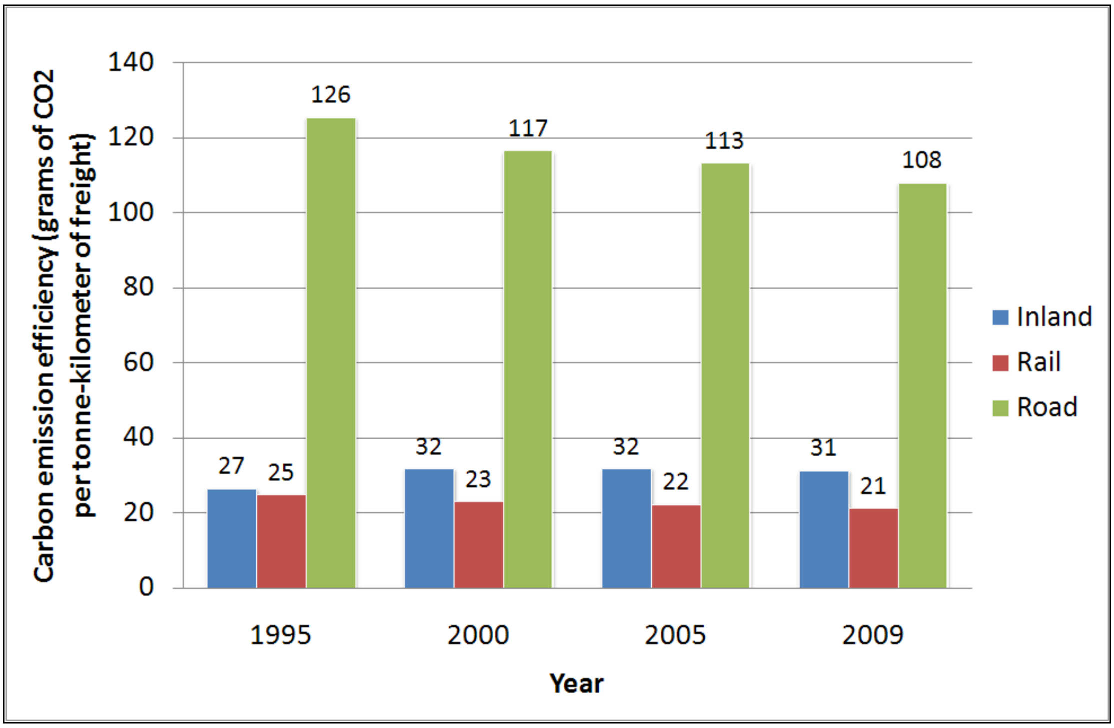

Figure 3: Carbon emission efficiency [10]

Lastly, freight transport by heavy vehicle creates further difficulties for society, particularly in key areas such as air quality in populated areas, noise emissions, and impacts on infrastructure. With regards to noise emissions, studies typically rate road noise as the primary source of annoyance from the noise of all transport operations. In a recent EU study, survey results indicated that 67% of respondents reported to be 'not at all' annoyed by rail noise, compared with only 16.7% of respondents who answered positively to the same question regarding road noise [11]. While these figures are undoubtedly influenced by an exposure-related bias, the most important aspect is the end result; that more people are negatively affected by the noise of road transport than by other modes. Additionally, increased heavy vehicle volumes further compound existing traffic congestion problems, particularly in inter-urban areas, and on major highways.

Clearly, heavy vehicles demonstrate the lowest level of performance in key safety and environmental measures, adding further impetus that urgent improvement actions are required to mitigate these effects. As a direct response to the issues of environmental performance, the introduction of longer and heavier vehicles will be discussed as a necessary requirement in the continual development of the freight transport network.

3. THE CASE FOR LONGER AND HEAVIER VEHICLES

The basic case for LHVs is conceptually simple. Longer vehicles can transport more volume, and heavier vehicles can transport more mass, thus addressing two key constraints of the road freight transport industry. There are currently many examples of how this concept can be translated into practice, each having common and specific advantages and disadvantages. The simplest method of implementing LHVs involves combining existing vehicle units to form longer combinations. This is the basis of the European Modular System (EMS) concept, whereby the hauling units from semi-trailers and truck-trailer combinations (maximum overall lengths of 16.5 and 18.75 meters, respectively) are combined to create several combinations of 25.25 meters overall length, and gross mass of up to 60 tonnes, as depicted in Figure 4.

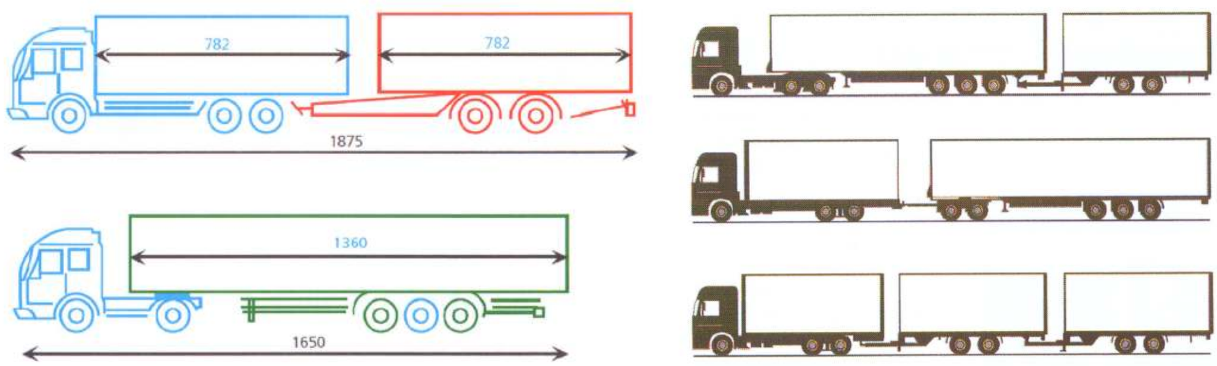

Figure 4: The European Modular System (EMS) concept [12]
(Source: adapted from Rijkswaterstaat, 2010)

The magnitude of the productivity benefits of LHVs is relatively high. As an example, EMS vehicles have the potential can increase current payload volumes and masses by an approximate factor of 1.5, or effectively meaning that two EMS vehicles can perform the same transport task as three previous vehicles. This approach also has the distinct benefit that little additional cost is required, as the EMS concept is based on existing vehicle units. However this also causes the main disadvantage; that there is no flexibility to change the design according to specific operational requirements or constraints.

The other popular method of increasing vehicle productivity is to modify existing vehicle unit or configuration designs, such as slightly increasing the length of a semi-trailer combination, adding another axle to increase the vehicle's carrying capacity, or creating a new type of trailer configuration such the 'B-double' vehicle introduced in Australia the late 1980s. Conversely to the EMS concept, this approach allows for maximum flexibility in design, however the extra capital expense required to cover the purchase price of new equipment can slow their adoption into the marketplace.

The increased productivity of LHVs has an impact on the emissions efficiency, as shown in Figure 5 below, which presents the emissions efficiency results for several vehicle combinations and highlights the difference between 'standard' sized vehicles and LHVs. The figures were calculated using an idealised scenario for vehicle operation (on a flat road when travelling at constant speed), and as a result the carbon dioxide emission efficiency figures are lower than the typical heavy vehicle figures listed previously. The two 'standard' vehicles represent the typical designs permitted under European regulations for cross-border freight transport, and demonstrate the lowest results for carbon dioxide emissions efficiency of all the vehicle combinations. The third lowest vehicle is the standard European semi-trailer vehicle, with an extra 4 tonnes of GCM permitted, which translates roughly to an extra 3 tonnes of payload. While this vehicle achieves a 10% increase in productivity, there is no net benefit in terms of carbon dioxide emissions efficiency when compared the standard vehicle on which it is based.

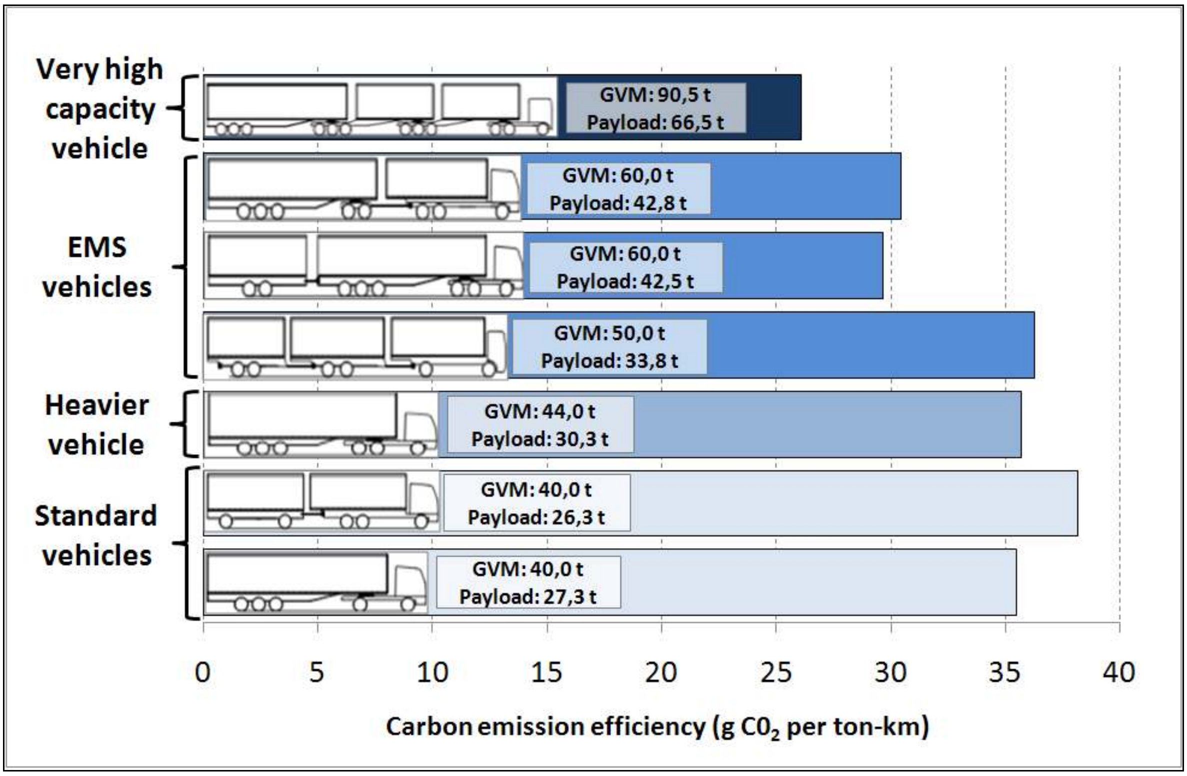

Figure 5: Carbon dioxide efficiency metrics for various heavy vehicle combinations

Of the three EMS combinations, it is clear that increasing gross mass to 60 tonnes provides the largest benefit in productivity and emissions efficiency. The triple-trailer EMS, while demonstrating an emissions efficiency roughly in-between the two standard vehicles, and worse than the other two EMS combinations, is designed specifically for improved low-speed turning performance. Further increases in productivity and energy efficiency are available via the introduction of the very-high capacity vehicle, a B-triple, with a payload of 90.5 tonnes, however it is not intended that such a vehicle is proposed as a widespread alternative to standard or EMS vehicles, due to its specific operating requirements.

While moves to allow LHVs access to the road network have recently become popular, these vehicles are in conflict with existing prescriptive regulations, which nations rely on to define limits on weights and dimensions, and subsequently deliver an acceptable level of safety and infrastructure performance. For these reasons, proposals to introduce LHVs are often heavily criticised, with arguments typically focussing on the predicted impact of the vehicles in areas such as road safety, infrastructure and also modal shift, particularly in the Europe Union.

Numerous studies have quantified these impacts in recent times, and various research results are presented here in the context of the most critical arguments against LHVs. It will be demonstrated that not only can LHVs provide productivity and carbon dioxide emissions efficiency benefits, their introduction can also be the catalyst for much-needed safety and environmental performance improvements, when combined with new technologies and innovative policy measures.

4. THE CASE AGAINST LONGER AND HEAVIER VEHICLES

The most prominent arguments against LHVs are based on the claim that LHVs have lower dynamic stability, and therefore a higher crash rate. The dynamic stability of such vehicles has been studied extensively using computer simulation and field tests, and as a result this claim has been disproven. The most comprehensive study investigating this issue was conducted by the Joint OECD/ITF Transport Research Centre (JTRC) working group, which assessed the safety performance of 39 heavy vehicle combinations from OECD member countries. The study found that in most cases, higher capacity vehicles have equivalent, and sometimes better intrinsic safety characteristics than standard vehicles [4]. Of course, there were examples of LHVs which performed unfavourably, but the results of the studies show that LHV designs are available which out-perform present vehicles.

Another key safety criticism against LHVs is that they have much higher kinetic energy when travelling, which will lead to more serious crash outcomes, and may also exceed the performance limits of key safety infrastructure such as crash barriers. While this is a logical argument and is supported by defined physical laws, key factors are neglected. Active safety systems, (some available now and others in the near future) such as lane-departure warning systems, forward and side collision warning systems, adaptive cruise control, and electronic stability control can be introduced to mitigate the crash risk as much as possible. Additionally, the occurrence of situations where heavy vehicles have broken through protective barriers suggests a need to review current designs, and if upgrades are required, the overall effects on overall road safety would be beneficial.

Additionally, the JTRC study also referred to the results of Canadian studies of the crash involvement of LHVs in Canada, and commented that reported crash rates for LHVs were less than those for typical vehicles. Similar findings have been reported on the basis of large-scale field trials in the Netherlands [12], and in Australia it is generally reported that trucks towing two trailers demonstrate one of the lowest crash rates of all types of heavy vehicle. Findings such as these led the JRTC to the conclusion that the introduction of LHVs would have positive outcomes on road safety. Similarly, De Ceuster et al. [13] in a study for the European Commission, commented that their investigation did not reveal an inherent increase of the safety risks as a result of the introduction of LHVs.

One particular characteristic of longer vehicles which is often presented as a safety and infrastructure risk concerns their increased road space requirements, particularly during low speed turns, where they require a far greater clear area for safe manoeuvring. This issue was investigated by the JTRC, and it was found that there was a definite relationship between vehicle length and increasing road space requirements when completing low speed turns [4]. Even so, when considering this issue it is of critical importance to recognise that such a characteristic does not mean that longer vehicles are inherently unsafe in this regard, only that their introduction should be limited to areas of the road network which have been investigated and determined as being capable of safely accommodating them.

An example of an innovative network access system that allows this to be achieved is currently in operation as the Performance Based Standards (PBS) scheme in Australia. The idea of a performance-based (as opposed to prescriptive) system of regulation was proposed under the Canadian Heavy Vehicle Weights and Dimensions Study [14]. Australia's National Transport Commission (NTC) has further refined this concept, which investigates vehicle performance under key areas of safety and infrastructure (such as low-speed turning performance), and grants road network access arrangements based on the level of performance achieved by the vehicle. Four levels of access are provided, each representing a more stringent set of requirements. Via a process of classification of the road network, this has led to a comprehensive series of maps detailing permitted access for vehicles under the four performance classes. An overview of the national PBS route network is shown in Figure 6.

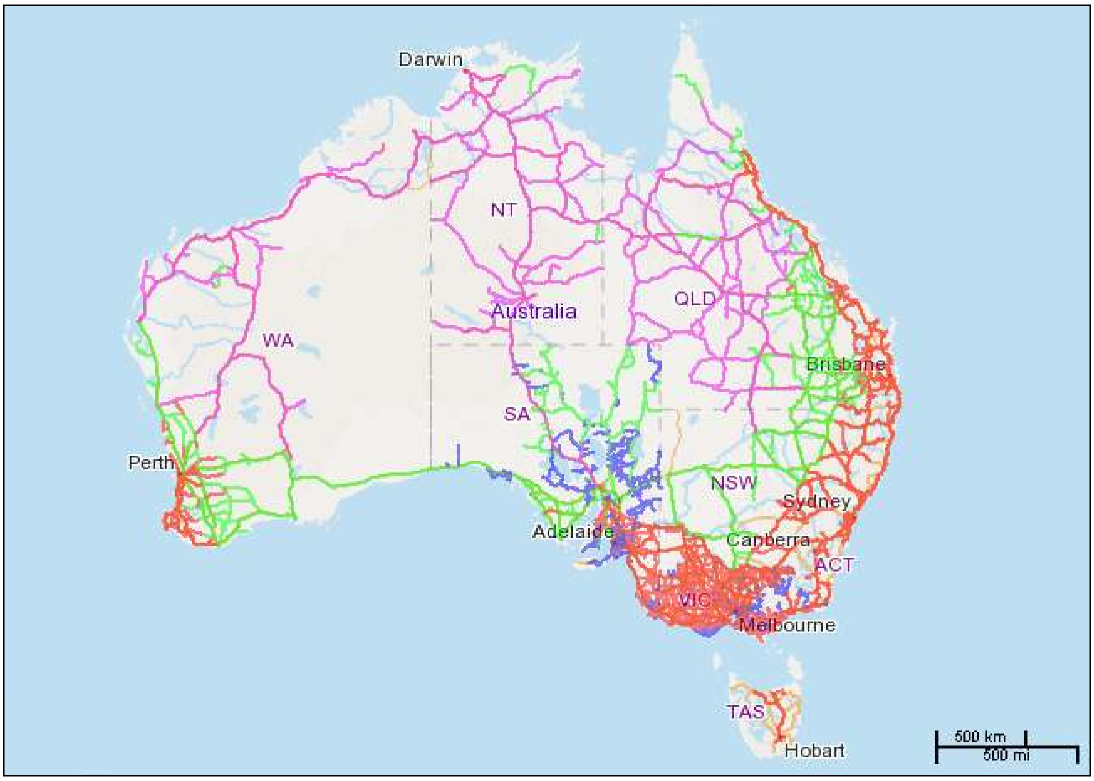

Figure 6: Australia's innovative heavy vehicle network access system [15]

This regulatory policy also addresses other perceived risks to operational safety and impacts on infrastructure, such as the extra time required for other road users to overtake LHVs, and the issues associated with clearance times when crossing intersections and railway lines. Such considerations are taken into account during the network classification exercise, and the resulting network map ensures that vehicles can be operated safely on the pre-defined routes.

Another often quoted negative aspect of the performance of heavier vehicles is the predicted reduction in acceleration and gradeability performance (ability to maintain speed when travelling on grades), due to the higher load placed on the vehicle's engine and driveline. This would have two effects; leading to an increased speed differential between heavy vehicles and other traffic on some highway sections (leading to increased overtaking) and also causing problems regarding intersection clearance times. While the operational aspects of both of these issues can be addressed using the performance-based network classification scheme (as described above), there are other simple measures that can be implemented to mitigate this risk, such as a minimum engine performance requirement for longer and heavier vehicle operation.

Furthermore, some research indicates that the majority of vehicle combinations would not experience a dangerous decrease in performance if operated at increased mass. As per Annex 1 of the European Council Directive 97/27/EC, vehicles must have a minimum power-to-weight ratio of 5 kW/t, translating to a minimum power requirement of 200 kW for 40-tonne vehicles While the suitability of this requirement in ensuring a required level of performance for vehicles with up to 60 t GCM should be thoroughly investigated, Keuchel et al. [16] indicated that for the majority of the European fleet, this requirement was already exceeded, with 26.7% of vehicles having between 251 and 300 kW, and over 50% between 301 and 350 kW, according to Federal Motor Transport Authority statistics.

The impact of heavy vehicles on infrastructure is another particular concern, and is often cited as a reason against the introduction of LHVs. If pavement surfaces are not suited to increased mass, increased wear will result, and eventually lead to damage in the form of rutting, cracking and other forms of failure. Bridge lifetimes can also be reduced. Previous efforts to quantify the effects on pavements and bridges have utilised various methods. Simple approximations can be conducted based on the equivalent standard axle load (ESAL) method, and more complex analysis methods involving modelling software are also available. The ESAL method defines a vehicle's effects on pavements as the sum of the impacts of its individual axles relative to a reference axle at a standard load.

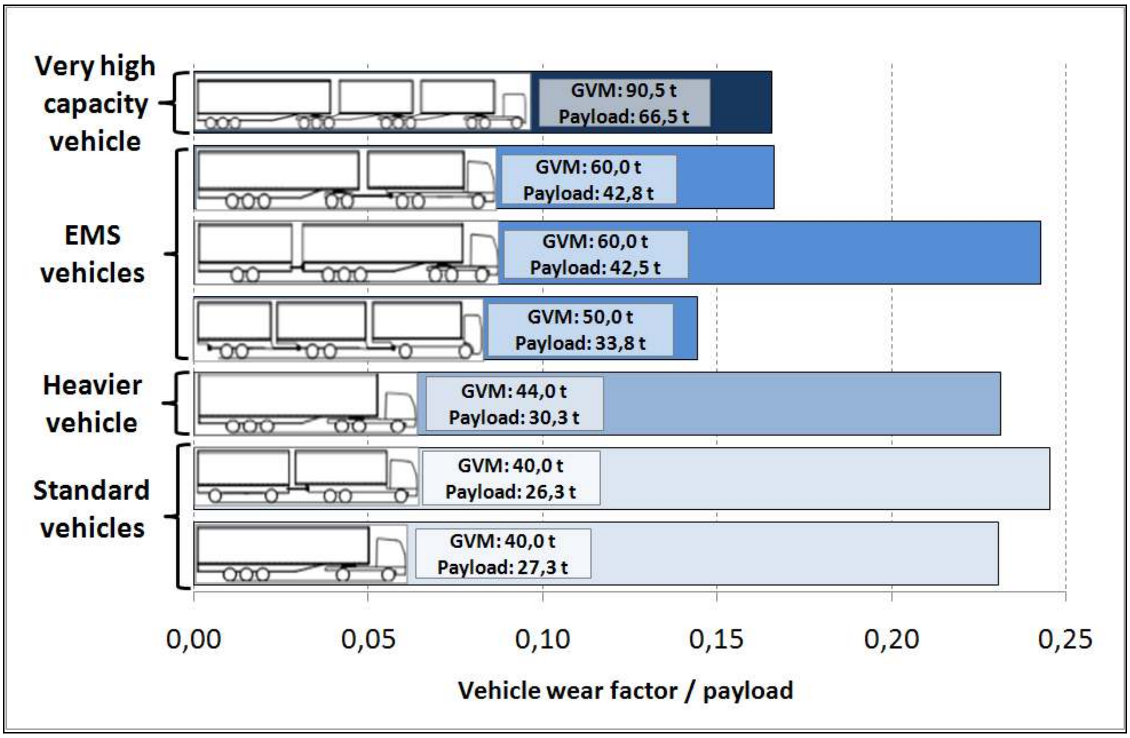

Figure 7: Vehicle road wear performance relative to payload

While this method demonstrates some LHVs are more aggressive than existing designs with regards to their impact on pavement surfaces [4, 12, 17 and 18], they generally perform better when considering the vehicles' increased payload efficiency. This effect is shown in Figure 7, which compares different pavement wear factors calculated using the ESAL method relative to the payload of the vehicle. While it is evident that two of the EMS designs demonstrate the best performance under this measure, axle load limits must be carefully specified in order to avoid the semi-trailer and rigid EMS combination, which does not represent an infrastructure benefit compared with the standard vehicles.

However, despite which method is used, there is widespread agreement on the fact that the most critical aspect of the impact of heavy vehicles on pavements are the individual load of each axle, as opposed to the total mass of the vehicle. Hence, a vehicle that is balanced in terms of the distribution of load across each of its axles is the most favourable in terms of its impact on the pavement. Technologies such as on-board weighing systems are presently available to achieve an even load distribution, and if their use was introduced as a requirement for LHV operation, the issue of heavy vehicle overloading could also be addressed.

In a similar manner, the effects on bridges can also be assessed using both simple formulae, and complex simulation software. While bridge analyses also account for axle load, unlike pavement analysis, axle spacing and total vehicle mass become important. Previous studies (using varying analysis methodology) have come to differing (and often opposing) results. As an example, Germany's federal highway research institute (BASt) estimated that bridge upgrade works required to facilitate the national introduction of longer and heavier vehicles would be in the order of €4-8 billion [19]. In contrast, the TRL study of 2006 found that only 3.3% of bridges in the UK would be at risk if 60 tonne LHV's were introduced [18].

Comparisons such as this highlight the fact that the impact of LHVs on both bridges and pavements are highly influenced by local design standards, and as a result the effects should be assessed on a case-by case basis. If necessary, route restrictions can be applied, and bridges should be upgraded where required. Studies have indicated that the required investment cost will be lower than the resultant financial benefit for the transport sector, and as a result, a taxation system could be introduced to re-coup the expenditure, as has been implemented in Sweden [13].

The potential for modal shift to occur is one of the most prominent arguments against the introduction of LHVs in Europe, as it is claimed to be contrary to existing freight transport policy, which is to increase the sustainability of freight transport operations. It is claimed that by improving the productivity of road freight transport, costs will drop, encouraging freight to move onto the roads, and away from the more sustainable modes such as rail. Such an argument, while perhaps not often considered, is applicable to any nation where there is the possibility for competition between road freight transport and other modes.

Many previous studies have attempted to quantify the magnitude of the modal shift that could occur following the introduction of LHVs, however the results are widely varied and highly dependent upon the assumptions and scale of the analysis, and the specific vehicle designs used. For these reasons, the results of such studies will not be summarized or discussed here. Regardless, the results of such studies should be considered important, as a shift from rail to road of goods transport would indeed be counter-productive in the context of the much lower emissions and safety performance of heavy vehicles.

However, the potential for modal shift must not be used an argument against the introduction of LHVs, for one simple reason. The continual improvement of the efficiency of all freight transport modes should be the overarching goal, as this is the only way of ensuring that freight transport operations are as sustainable as possible, and that society can continue to meet the challenges of the growing freight transport task. Thus, any potential modal shift that improvement actions cause should be addressed using broader policy measures.

5. CONCLUSIONS AND RECCOMMENDATIONS

The freight transport task is growing, and will continue to grow in the future. Within this, the role played by heavy vehicles is crucial, as these vehicles make an important contribution to the economies of many countries, complete transport tasks that other modes often cannot, and is expected to experience significant growth in the future. Heavy vehicles also have key performance deficiencies, particularly in relation to road safety and their impact on the environment. In this regard, heavy vehicles satisfy all of the established criteria to be selected as an area of the transport sector that warrants immediate attention for improvement in the short term.

As has been demonstrated, the implementation of longer and heavier vehicles is a key step towards achieving this goal. Whilst opponents to the use of LHVs argue that they are an unfeasible solution, research indicates that despite their reputation as being dangerous, difficult and dirty, they have many advantages over the use of standard freight transport; including better inherent safety and less damage to infrastructure. Furthermore, via the application of advanced technologies, careful planning and appropriate policy implementation, there are very few issues that cannot be adequately addressed. In this regard, longer and heavier vehicles offer not only the chance to make basic improvements to the road freight transport industry, but can actually be the catalyst for much-needed improvements in all areas of operation.

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