

## PERFORMANCE BASED STANDARDS ENABLING TRANSPORT DECARBONISATION

J.H. Woodrooffe  
Research Scientist  
Emeritus, University  
of Michigan



### **Abstract**

This paper contemplates next generation performance based standards (PBS) designed to measure and quantify the impact of road freight transport vehicles on society and the environment. Presently there is a lack of standard objective measures that inform the public and policy makers on the impact of high capacity vehicles (HCV) with respect to societal benefits including fuel consumption, CO<sub>2</sub> emissions, safety, public health, traffic congestion, mobility etc. The paper discusses the concept of next generation PBS, including, parameters requiring consideration, how the metrics could be defined and puts forward the concept of a sustainability index for freight transport. The paper concludes with some examples of next generation PBS metrics that can be used to measure transport sustainability and societal impact of both the vehicle and transport system.

**Keywords:** Trucks, heavy vehicle, freight transport efficiency, high capacity vehicles, performance based standards, safety, sustainability, sustainability index, societal impact, decarbonisation, CO<sub>2</sub>, greenhouse gas.

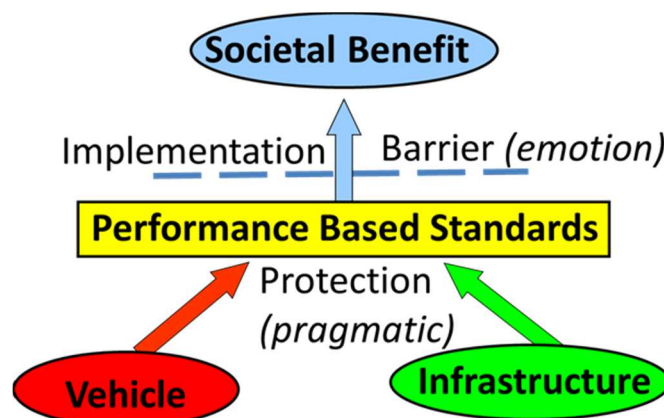
## 1. Introduction

The earliest record of formal heavy vehicle size and weight regulation dates back to 450 BC. The Roman legal code specified lane width equivalent of 2.45m where roads are relatively straight and 4.90 m in curves. In AD 438, the Theodosian code set weight limits to the equivalent of 750 kg on ox-drawn wagons, 500g on horse drawn wagon and 100 kg on a cart. Compliance was achieved by restricting vehicle power by limiting the number of animals that could be used to haul a vehicle (Lay 1992). This early prescriptive approach to size and weight policy lasted for over 2,500 years evolving over time to the truck size and weight policy instruments in common use today.

In the early 1980s, Canada conducted a comprehensive truck size and weight study that created the first performance based standards (PBS) for heavy vehicles, which was a marked departure from the approach used since Roman times. These new metrics were used to develop policy that transformed truck transportation efficiency in Canada (Ervin 1986). More recently Australia advanced the use of PBS largely replacing their prescriptive system in a comprehensive realignment of their policy (NTC 2010). In both these cases PBS focused on engineering issues such as vehicle stability and compatibility with road network geometry and strength.

## 2. Next Generation PBS

While current generation PBS focus on the essential requirements of vehicle performance and infrastructure compatibility, they do not address broader issues related to societal impact such as energy use, carbon emissions, safety impacts and transport efficiency. Policy makers are not equipped with metrics that define the societal benefit of high capacity road freight vehicles. Attempts to integrate high capacity vehicles into the national fleet are often defeated through emotional reaction rather than evidence-based argument due to a lack of objective metrics and data to provide substantive support particularly with respect to societal benefit assessment as depicted in Figure 1.



**Figure 1: Pictorial model showing the absence of metrics addressing societal benefit.**

Societal benefit can be measured in many ways with parameters that cover a very broad range as found in the list below. The challenge will be to select ones that can be reliably measured so the analysis remains relevant but not overly complicated. • Traffic casualties

- Broader public health effects – e.g. Respiratory disease
- Carbon and emissions
- Mobility – Congestion, lost time and emissions
- Infrastructure consumption – roads and bridges
- Economic impact – business, commerce and international competitiveness (Regional, national and international)
- Sustainability

From a study of potential societal benefit metrics will likely come a set of “next generation” PBS to measure the impact of particular freight vehicle or transport options on society. Combining the “current” with “next generation” PBS metrics, would provide a set of tools useful to road authorities, the public and higher level policy makers.

Vehicle compatibility standards (road authority toolbox)

- Vehicle stability
- Trailer dynamics
- Powertrain
- Maneuverability
- Infrastructure

Societal value standards (Policy maker toolbox)

- Safety (Road crash casualties)
- Public health
- Mobility (congestion)
- Decarbonisation
- Infrastructure consumption (per unit cargo)
- Economic impact
- Sustainability

## **2.1 Sustainable Transport**

Sustainability is an overarching principal that will likely guide future public policy in order to ensure policy instruments provide accountability, opportunity and stewardship for future generations. The traditional approach of simply focusing on the road and vehicle will likely give way to a broader transportation system approach where task of transporting goods transcends from single mode optimization to broader transport system optimization. This will require a more pragmatic, thoughtful and inclusive decision-making process based on data that balances local, regional and global priorities. Some form of sustainability index integrated with all modes of transport would be helpful. With such an index in place, one possible approach to

encourage low carbon transport would be to assign a minimum threshold requirement in order to qualify as “sustainable transport”. To address the shortage of objective metrics and data for assessing societal impact, the following example parameters are presented for consideration.

Examples of sustainable parameters may include:

- Intermodal compatibility
- Electrification, hybridization and fuel use (% carbon/unit transported)
- System carbon use
- Load migration and modal shift
- Safety and societal service
- Vehicle load factor (cargo mass and volume utilization)

Intermodal compatibility suggests containerized freight. This would not only apply to shipments in ISO standardized containers, it could also include a new generation of high capacity containers and promote innovation in handling and logistics of containerized freight to minimize carbon. For example, container life cycle considerations could be included to encourage container reuse as well as back haul freight credits. Intermodal compatibility metrics could also encourage innovation in container loading such as the development of small-enclosed units similar to palletized freight that would make loading building easier by allowing stacking within the primary container and providing an efficient way of unloading containers and distributing loads in secure packets at the destination port.

Electrification, hybridization and fuel use are normally assessed at the vehicle level for a given transport task i.e. how much energy is required to move a unit of freight over distance (liters of fuel/freight-tonne-km). Alternative propulsion options such as electrification or hydrogen fuel cells can have significant carbon content depending on how the electricity or hydrogen is generated. Hybridization and electrification have the advantage of capturing kinetic energy during braking which provides energy recycling benefits. Alternative energy such as natural gas and biofuels are important options but the carbon required to extract, process and transport fuels as well as leakage of natural gas to the atmosphere needs to be considered.

System carbon use reflects the all-in carbon footprint at both the vehicle and system level. The vehicle level this can include such things as tires, and lubricants which are consumed over time and distance. It takes approximately 80 liters of oil to manufacture one new truck tire (Bandag, 2007). A six-axle tractor semitrailer on dual wheels has 22 tires which amounts to 1,760 liters of oil invested in tires. As the tires wear this equivalent oil is consumed and can be accounted for but as long as the tire is not burned, the carbon remains sequestered. Truck tires can be retreaded which consumes about 27 liters of oil or about 66 percent less oil than a new replacement tire. The carbon saving associated with retread tires is compelling and while the pure economic incentives to retread are strong, the consideration of carbon content is not well appreciated. Tire casings have a working life limit of about 10 years due to embrittlement of the rubber compound. In addition, tires can only be retreaded so many times depending on use, in most cases about four times. The challenge is at end of life where many are processed for

fuel creating CO<sub>2</sub> rather than locking the rubber away in products such as pavement additives or land fill.

Carbon use at the system level is well illustrated by vehicle electrification. An electric vehicle may have zero carbon output from the tailpipe but if the electrical energy used by the vehicle was produced by burning coal then the thermal efficiency of the coal plant must be considered as well and electrical delivery losses. Coal fired power plants tend to have significantly lower thermal efficiency than vehicle engines (ranging from about 27 to 37 percent (DOE 2010)).

Therefore, based on thermal efficiency alone, an electric vehicle powered by electricity generated from coal can produce considerably more greenhouse gas than the same vehicle powered by an internal combustion engine. The difference becomes more acute when electrical transmission and distribution losses are included amounting to about 6 percent of total US power generated (World Bank 2014).

Finally, the effectiveness with which a given region utilizes carbon for transportation requires careful consideration. The question is how much carbon does a given population use and of this how much is consumed by transportation. This is different from transportation efficiency at the vehicle level (carbon/cargo-tonne-km). The metric for system level transport analysis would more likely be “transport carbon”/person.

Load migration and modal shift can occur when high capacity vehicles are introduced. Whether or not this actually occurs is highly dependent on regional transport markets and the presence of viable alternative mode options. The objective should always be to encourage use of modes and intermodal transport options that help to improve the efficiency of the overall transport system rather than improving the efficiency of one particular mode.

Load migration is the shift freight within a particular mode. For example, more efficient trucks tend to cause load migration from smaller trucks to larger trucks which ultimately improves truck transport efficiency. The US size and weight study (FHWA 2015) found that for the future truck scenarios examined, load migration was substantially larger than modal shift meaning that in the USA, larger vehicles are expected to consolidate freight from smaller vehicles and have minimal effect on railway operations.

Safety and societal service addresses the net safety opportunity costs associated with a particular transport option as well as some means of crediting societal service. For example, a vehicle transporting emergency supplies to a disaster area would be performing a vital societal service. Under this assignment, vehicles might be permitted to have higher infrastructure consumption from increased weight in exchange for important societal service.

Vehicle load factor measures how well the potential transport capacity of a particular vehicle or fleet of vehicles is being utilized. Often when the mass limits of a vehicle are reached there remains some cubic capacity within the cargo area. The remaining cubic capacity represents a transport opportunity for very low density freight. Under the right conditions, it may be possible to slightly reduce the amount of high density freight in a particular vehicle so that low density

freight can be included to occupy the available cubic capacity thereby achieving truck volume optimization at maximum GVW. In addition, effective use of backhaul potential has always been a priority of truck fleets but there remains significant potential for improvement.

At present these approaches present challenges for logistics operations and shippers but in the future, better cargo shipping data and freight aggregating systems and backhaul opportunity identification can be expected, improving truck load factors to bring significant benefits in overall transport efficiency. Having a metric to measure and audit road transport load factor will be an important tool for enabling better utilization of available road transport capacity.

**3. Societal Benefits**

Societal benefits in the context of this paper consist of a collection parameters that impact society at large. Represented as opportunity costs, societal benefit examples would include safety, CO<sub>2</sub> emissions, carbon use, public health and infrastructure consumption. To assess opportunity costs several factors will need to be considered. As an example, Table 1 provides a partial list of variables with percent measured benefits derived from a study of a HCV program in Alberta Canada (Woodrooffe 2001).

**Table 1: A partial list of measured societal benefits attributed to an HCV system used in Alberta Canada (program level analysis)**

System category	Benefit Estimate
Improved productivity	44%
Improved safety	2.5 to 5 times*
Reduced fuel consumption	32%
Reduced emissions	32%
Reduced infrastructure consumption	40%
Reduced VMT	44%
Reduced shipper cost	29%

Source: Assessments of Alberta HCV Program- Montufar et.al 2007, Woodrooffe et.al. (2001)

Table 2 provides an example of some system level benefits where a policy initiative would reduce truck travel by 10 percent in the USA (Woodrooffe 2016). In this case highway casualties, vehicle fuel use and carbon emissions are accounted for in both quantity and monetary value. It is anticipated that next generation PBS would include many more metrics along the lines of those listed previously in this document.

**Table 2: Sample opportunity costs for a 10 percent reduction in truck travel (system level analysis)**

Benefit study variable	Injury severity	Reductions assuming 10% reduction in exposure	Estimated annual benefits (\$US Billion)
Estimated safety benefits attributed to a 10% reduction in truck travel distance	no apparent injury	21562	0.20
	possible injury	2,929	0.44
	evident injury	2,724	0.68
	disabling injury	1,453	0.87
	Killed	330	2.54
	Total safety cost saving attributed to 10% reduction in exposure		
Estimated fuel and emissions benefits attributed to a 10% reduction in truck travel distance	Category	Quantity saved	Annual cost saving (\$US Billion)
	Diesel fuel reduction	10.6 billion liters	10.60
	CO2 reduction	28.3 Million metric tons CO2	0.680
Combined benefits	<b>Total estimated annual savings</b>		<b>16.01</b>

#### 4. Conclusion

Current generation road transport performance based standards focus on the essential requirements of vehicle performance and infrastructure compatibility. They do not address broader issues related to societal impact such as energy use, carbon emissions, safety impacts and transport efficiency. Policy makers interested in improved transport efficiency and decarbonisation do not have at their disposal a generally accepted performance based system to support higher level transport policy and to counter emotional arguments that prevent policy implementation related to transport optimization.

This study concludes that standard metrics and evaluation methods are needed to support the development of regional transport policy that is both efficient and minimizes CO<sub>2</sub> generated through combustion as well as vehicle related carbon content management associated with tires and lubricants. It is anticipated that these standardized metrics and evaluation methods could be adopted worldwide allowing for international benchmarking of transport carbon emissions. The evaluation criteria that are tied to these new metrics can be flexible and vary from country to country, region to region given the priorities and conditions that apply. In this way there is a standardized method of assessment with a flexible set of criteria to account for unique regional priorities and conditions.

## 5. References

Bandag. (2007). Efficiencies - Retread Facts. Retrieved April 13, 2007. Available at: [www.bandag.com/TireProducts/RetreadFacts.aspx](http://www.bandag.com/TireProducts/RetreadFacts.aspx).

DOE (2010) "Improving the thermal efficiency of coal-fired plants in the United States." US Department of Energy.

Ervin Robert D., Guy Yoram (1986) "The influence of weights and dimensions on the stability and control of heavy trucks in Canada." Roads and Transportation Association of Canada in affiliation with UMTRI.

FHWA (2015) "Modal Shift Comparative Analysis Technical Report, Comprehensive truck Size and Weight Limits Study." Federal Highway Administration USA.

Lay Max G., (1992) Ways of the World: A History of the World's Roads and of the Vehicles that Used Them ISBN-13: 978-0813526911

NTC (2010) Performance Based Standards, Regulatory Impact Statement. National Transport Commission Australia.

Woodrooffe J.H.F, (2016) Opportunity cost for society related to us size and weight regulation - freight efficiency. US Transportation Research Board Record.

Woodrooffe, J. (2001) Long Combination Vehicle Safety Performance in Alberta 1995 to 1998. Alberta, CA, Alberta infrastructure and Transportation Policy and Corporate Services Division.

World Bank (2014) "Electric power transmission and distribution losses (% of output)." Based on OECD/IEA statistics. Available at: <http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS>