Performance-based Standards for the Road Sector

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FOREWORD

The OECD brings together 30 member countries and helps governments meet the challenges of a globalised economy. The OECD's Programme of Research on Road Transport and Intermodal linkages (RTR), which ended in 2003, took a co-operative international approach to addressing transport issues among OECD member countries.

The mission of the RTR Programme was to promote economic development in OECD member countries by enhancing transport safety, efficiency and sustainability through a co-operative research programme on road and intermodal transport. The Programme recommended options for the development and implementation of effective transport policies for members and encouraged outreach activities for non-member countries.

From 1 January 2004, following a decision by OECD Council and ECMT Ministers, a Joint OECD/ECMT Transport Research Centre was established which brought together the previously separate activities of the OECD's RTR Programme and the ECMT's economic research activities.

This study on Performance-Based Standards for the Roads Sector was carried out by an OECD Working Group under the RTR Programme 2001-2003. The report explores the case for regulatory reform of the heavy vehicle sector, examining regulatory principles and current practice. Examples of performance-based standards are examined, implementation issues are discussed and potential outcomes are presented based on experience and research from participating countries.

Abstract

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Traditionally, heavy vehicles have been regulated by tightly defined prescriptive limits (such as mass and size limits), which provide little scope for innovation. This traditional approach provides a 'one size fits all' outcome, despite significant variations in road and traffic characteristics across road networks, and between urban and inter-city or inter-region routes. An improved regulatory system would encourage innovation and provide a better match between vehicles and roads. Under a performance-based approach to regulation, standards would specify the performance required from vehicle operations rather than mandating how this level of performance is to be achieved.

This report demonstrates how performance standards can more directly regulate safety outcomes and infrastructure protection than current prescriptive regulations. Examples of such performance-based standards are provided from a number of countries. The introduction of performance-based regulations will bring many challenges, such as public perception, political acceptance, institutional changes and changes to enforcement practices. These implementation issues are examined in the report. The introduction of performance-based standards could advance safety and freight transport efficiency. The extent of these improvements is dependent on the standards set. A chapter on potential outcomes reviews a number of scenarios and their effects on safety, productivity and infrastructure protection.

Fields: Traffic and transport planning (72); Economics and administration (10); Vehicle design and safety (91)

Keywords: Economic efficiency; enforcement (law); road freight; freight transport; harmonization; lorry; safety policy; road network; road safety; compliance; road transport regulation; specification (standard).

* The OECD International Transport Documentation (ITRD) database contains more than 300 000 bibliographical references on transport research literature. About 10 000 references are added each year from the world's published literature on transport. ITRD is a powerful tool to identify global research on transport, each record containing an informative abstract.

TABLE OF CONTENTS

Executive Summary and Recommendations 7

Chapter 1 Introduction 15

Chapter 2 Regulatory Principles 17

Chapter 3 Current Approaches 29

Chapter 4 Best Practice Directions 35

Chapter 5 Performance Based Measures and Standards 63

Chapter 6 Implementation Issues 75

Chapter 7 Potential Outcomes 81

Bibliography 89

Appendix A Performance-Based Standards for the Road Sector: Terms of Reference 93

Appendix B Performance Measure and Standards Proposed in Australia 99

Appendix C List of Working Group Members 103

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The use of heavy vehicles is regulated predominantly by prescriptive rules that evolved over a long period and which differ internationally, including within federal jurisdictions. Despite efforts towards international harmonisation, considerable variations in regulations between jurisdictions remain, particularly in relation to innovative approaches to solving transport needs.

Under a performance-based approach to regulation, standards would specify the performance required from vehicle operations rather than mandating how this level of performance is to be achieved. This approach to regulation has been adopted internationally 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.

Road safety

With the growth in both the freight task and the proportion of heavier vehicles in mixed traffic conditions, and the drive for productivity gains, basic road safety and traffic performance criteria for the regulation of heavy vehicles may be insufficient (*e.g.* the control of vehicle stability during emergency manoeuvres).

The issues include the possibility that:

- Basic road safety performance thresholds are being approached or exceeded, and are not regulated effectively. For example, vehicles may be approaching or exceeding the threshold at which they can safely operate without rolling over, under the conditions that apply across the road network on which they operate. This has been found with parts of the New Zealand heavy vehicle fleet.

- The regulatory system, particularly enforcement and penalties, is not results-based, limiting its credibility and effectiveness.

- The performance of vehicles complying with prescriptive rules can vary significantly as these rules only provide indirect controls over safety and infrastructure protection outcomes. This variation may lead to some vehicles that comply with prescriptive rules posing an undue risk to safety or infrastructure on parts of the road network.

Development of infrastructure

An efficient and effective regulatory system increasingly needs to be able to deal with the following challenges:

- Specialisation of the freight task and the associated emergence of different needs in different locations, innovative vehicle designs and new approaches to shifting freight.

- Disparities between the performance of the heavy vehicle fleet and the adequacy and design of infrastructure (*e.g.* low and high speed off tracking, pavement and bridge condition).

- Differences in infrastructure standards between regions, jurisdictions and for different road functions (*e.g.* primary arterial roads, local access roads).

Traditional prescriptive 'command and control' style rules do not adapt well to these challenges as they are inflexible and must be modified to reflect changes in technology and societal needs. Increasingly, the regulatory system needs to link priorities for investment in infrastructure, pricing systems and the different functions (including the planning and amenity aspects) of roads with each other and with decisions regarding network access for different vehicle types.

Regulatory frameworks

There are a range of options for how performance-based standards (PBS) can be applied in a regulatory framework. They include:

1. Using assessments of vehicle performance in comparison to the performance standards to develop and refine prescriptive regulations (*underlying basis for prescriptive regulations*).

2. Using assessments of vehicle performance in comparison to the performance standards as the criteria for considering applications for vehicles to operate under exemptions outside the normal regulatory requirements (*exemptions approach*).

3. As the underpinning of a results-based system of performance regulation, replacing existing prescriptive rules (*holistic approach*).

4. A combination of the first two approaches (*hybrid approach*).

5. As the basis for determining access requirements and network standards for different parts of the road network (*road network approach*).

The degree of flexibility inherent in performance based regulation can vary considerably. At the same time, the implications to the community of non-compliance may be greater where the degree of flexibility is greater. Where there is more flexibility, a greater number of factors are under the control of the operator. This may mean that governments require vehicle operators (and other elements of the logistics chain) to take greater responsibility for ensuring compliance with this greater range of factors under their control. In other cases, it might be determined that the risks of non-compliance are too great and that a performance-based prescriptive standard is necessary.

Improved compliance and enforcement

Regulatory systems need to incorporate modern methods of compliance and enforcement (including available technologies) to ensure that the outcomes achieved match the objectives of the regulatory system. The OECD has previously identified the following innovations in the implementation and enforcement phase to ensure that policy outcomes are achieved in practice:

- Rewards and incentives for high/voluntary compliance.

- Nurturing the compliance capacity of business.
- Targeting for low compliance.
- Restorative justice when voluntary compliance fails.
- Responsive enforcement when restorative justice fails.

In the road transport sector, relevant factors to consider include:

- An increasing focus on actual performance (*e.g.* route compliance, pavement loading) rather than weak proxies (*e.g.* axle group mass tolerances).
- Compliance accreditation systems and audit procedures, supported by technology (*e.g.* location identification, on-board weighing devices), that enable continuous office-based monitoring and provide the means for operators to develop greater awareness and responsibility for compliance outcomes.
- A shift to 'risk-based' approaches to compliance and enforcement, providing a more credible regulatory system.

Improvements to the regulatory approach and compliance/enforcement arrangements need to be considered together, rather than in isolation. Both considerations should inform the appraisal of regulatory approaches for applying performance standards.

Performance measures

Examples of performance measures are provided in order to illustrate the potential range and different ways in which they might be applied. In doing so, examples are drawn from countries that have developed very similar performance measures, but applied them in different ways. In all examples, the definition of what is acceptable and what is not acceptable performance depends closely on the capacity of the road infrastructure available.

Implementation issues

Public perception: Public information campaigns can help raise awareness of the factors affecting truck safety and may help the public better understand that regulators are minimising their risks and not simply yielding to the wishes of industry.

Political: Political acceptance will also depend upon public perception. Elected officials tend to dislike highly technical answers to seemingly simple questions. Broad political acceptance of performance-based regulations will require some generalisations, such as tables illustrating typical scenarios, to provide simple guides for responding to the seemingly simple questions.

Institutional: While it may be difficult to dispute the logic of performance-based regulations, on closer examination, the implications for implementation can become quite daunting. Highway design standards, road and traffic conditions and geographic factors can vary widely within public road networks. In addition, many countries have little scope to introduce performance based standards without the agreement of neighbouring jurisdictions as it would impede international traffic.

Harmonisation (flexibility vs. interoperability): Performance-based regulations provide flexibility for industry to operate innovative vehicles that optimise benefits associated with specific haul requirements. However, the benefits generated by harmonised performance criteria may have adverse effects on harmonisation at the vehicle level. Vehicle configurations will have to be approved as specific units. Towing units will have to be "married" to specific trailing units if they are to provide consistent performance. Also, the loading characteristics must be consistent. In some instances, industry will lose flexibility as a cost of increased efficiency.

Enforcement: Regulations and policies must be easily understood if they are to be enforceable. Enforceable regulations must address vehicle parameters that are once removed from the primary inputs affecting vehicle stability characteristics. From an enforcement perspective, performance based regulations may be cumbersome to implement. Effective enforcement in the field will require a combination of technical skills that are not generally evident with field enforcement staff operating under prescriptive regulations.

Legislative systems: Performance-based regulations have been recognised in many areas, but the performance criteria and thresholds are not necessarily consistent in all applications around the world. Although much research has been done to identify key criteria and appropriate threshold values, the criteria are not universally recognised. Consistent legislation is essential for manufacturers to be able to efficiently supply individual markets around the world.

Information exchange: Harmonisation and consistent application will rely upon strong communications. As with any regulatory regime, failure to consider the implications of local change on neighbouring jurisdictions will reduce the integrity of the system. Jurisdictions must work toward common standards, then maintain open communication links to ensure that the common basis for regulations is not compromised by unilateral action by one jurisdiction.

Potential outcomes

Potential outcomes very much depend on the levels of performance that are set. Many of the measures discussed in the report can target safety and infrastructure wear better than the existing prescriptive standards.

The simplest and most widely used application of PBS to date is as part of the approval process for special permit vehicles. With this special permit vehicles are required to undertake a PBS assessment to show that they have adequate safety. Examples for permit vehicles show a reduction in crash risk of 40 percent or more. However, the permit regime is only used for a small number of vehicles in the system and so the safety gains for the whole road transport system are relatively small.

PBS as a basis for prescriptive limits has the advantage that compliance and enforcement are straightforward and relatively low-cost. Although the safety gains per vehicle may well be relatively small, the prescriptive limits regime applies to the whole fleet and all vehicles must comply. Thus the safety gain for the road transport system as a whole may be greater than with the permit approach. Even though this approach has been used in Canada and in New Zealand, it is difficult to quantify the safety gains that have been achieved.

PBS in conjunction with prescriptive limits includes performance requirements alongside and in addition to the prescriptive dimensions and mass regulations. Many countries already use this type of approach for their braking requirements where, in addition to requirements for the braking systems physical characteristics, there is performance requirement which specifies a deceleration or stopping distance that must be able to be achieved. New Zealand has recently introduced a minimum Static Roll

Threshold (SRT) requirement for most large heavy vehicles in addition to the prescriptive limits. It has been estimated that the introduction of a minimum SRT could reduce the number of heavy vehicle rollover crashes by up to 25%.

The key area where PBS potentially contributes to improved sustainability is improved fuel efficiency and hence reduced emissions. Although the analysis is very approximate, a study indicates that an increase in payload capacity could result in a reduction in fuel consumption per unit of payload of at least half that magnitude. In addition, a better match between infrastructure and vehicles could potentially lead to some gains from reduced infrastructure wear and possibly reduced congestion.

Recommendations for further work

This study found that a number of countries are reviewing and updating their regulations concerning the development and operation of road freight vehicles. It also raised a number of areas that need to be further researched to continue to improve current regulations and regulatory outcomes.

International co-operation

Heavy vehicles are produced in a global international market, and no single country is able to shift the principles of design used in vehicle production independently. Pressures for harmonisation are consequently high, and international collaboration and agreement on performance criteria, in particular how performance is measured and tested, would provide much greater opportunities than can be achieved by individual countries.

It should be noted that European Union member states have little scope to introduce performance based standards. Vehicle dimensions for certain vehicles are governed by Directive 96/53/EC, which all Member states have to embody in their own territory, with no national alternative. The accession of Sweden and Finland in the mid 1990's required some flexibility in the directive to allow the continued use of their longer and heavier combinations. However, it appears that in practice the alternative 24/25m long combinations are too large to be acceptable in other Member states. Any changes to the Directive would have to be initiated by the European Commission (the only body allowed to make proposals for directives by the Treaty of Rome) and get the agreement of the member states.

The new European Union countries are in the process of harmonising their truck size and weight regulations with European Union standards. However, the infrastructure needs to be considerably strengthened and upgraded to cope with current EU trucks. The review of regulations and updates that have taken place in other jurisdictions should be of interest in Europe, particularly given the implications for vehicle safety and productivity and infrastructure protection. In addition, pressures to move towards sustainable transport systems means that new environmental regulations will likely have to be introduced in the coming years.

Vehicles/safety

Further research is needed to identify the relationships between different aspects of vehicle performance and safety outcomes. This requires access to data on both performance and crash history. Better understanding of these relationships is essential to improving safety outcomes, improving the outcomes of prescriptive regulations and in establishing performance–based regulations.

In order to provide a scientific basis for differentiating acceptable levels of performance on the basis of risks associated with variations in road and traffic conditions, further research is also required to investigate the links between vehicle performance, safety outcomes and road/traffic conditions.

Development of an overall safety rating should be based on analysis of the contribution of differing aspects of performance to crash outcomes, in combination with estimates of the associated severity of these outcomes. A delphi approach accessing the knowledge and opinions of crash experts is likely to be needed in the absence of comprehensive crash data. A safety rating of this sort can be used as a community acceptance tool but, in combination with minimum acceptable levels of performance for each of the component performance measures, might be used as a regulatory tool. There is potential to use the truck crash study (currently being undertaken in the United States) to add to the information database necessary for this approach.

In association with the development of common performance tests, computer modelling approaches should be reviewed for consistency. This should build on work undertaken in Australia and New Zealand and access the broadest possible range of computer models and expertise internationally. An international standard for vehicle performance tests and computer modelling could then be established.

Asset management

Vehicle/infrastructure interaction is a key consideration in designing performance standards for infrastructure design, but is also central to regulation of heavy vehicles that is intended to ensure asset management outcomes. These regulations are intended to protect road and bridge infrastructure from adverse impacts of heavy vehicle loading. Some aspects of vehicle/infrastructure performance have been subject to considerable research. Other aspects of vehicle infrastructure interaction are little understood, such as the relationships between various pavement, surface and bridge failure mechanisms with vertical and horizontal loading. Differences in these relationships for different assets (for example, for different pavement types and climatic conditions) also need to be better understood.

Research is needed to review existing knowledge of these relationships (possibly based on a delphi survey of experts from around the world and would draw on related research such as long term pavement performance studies) and develop performance measures for the rate at which vehicle use affects asset consumption. These could be used to develop a measure relating the rate of asset consumption by different vehicles to the freight task, that is, an asset–management outcome rating for heavy vehicles.

Environment

Regulations controlling the environmental performance of vehicles are generally already performance-based in many countries, particularly in relation to noise and gaseous emission controls. Approximate analysis has shown that better performing vehicles could improve half fuel consumption per unit payload. Further research is needed to establish any further internationally consistent performance measures and test procedures. This could include a review of the use of environmental ratings for heavy vehicles and heavy vehicle fleets and whether such a rating would have any regulatory benefits and lead to more environmentally friendly system performance.

Compliance

Traditional command and control styles of regulating heavy vehicles generally rely on on-road enforcement, that is, interception and inspection of vehicles, to achieve the desired outcomes. Increasingly, alternative approaches to monitoring compliance and enforcing regulations are being used in some countries. These alternative approaches rely on auditing systems and technology that is able to provide ongoing monitoring of performance at relatively low costs. Technological developments have changed the availability of data, the ways in which it can be used and responsibilities of heavy vehicle operators.

Further research could investigate the relationships between compliance outcomes and various methods of ensuring heavy vehicles comply with regulations. A range of compliance–assurance mechanisms should be investigated including on-road enforcement, audit systems and surveillance methods (including the use of ITS/electronic monitoring systems). In combination with information about the impact of compliance outcomes on performance outcomes, this will allow heavy vehicle regulators to assess the appropriate compliance–assurance mechanisms to achieve desired performance outcomes relating to asset protection, safety and environmental impacts of heavy vehicles.

Chapter 1

INTRODUCTION

Background and focus

Performance standards differ from prescriptive rules by defining performance outcomes rather than specifying how these outcomes should be achieved. This report explores the potential of this approach in regulating heavy vehicles and their access to the road network.

The report examines existing regulatory approaches and then explores how more direct, outcomes–oriented approaches have been applied in some countries. It identifies the circumstances where they might offer benefits over more traditional 'command and control' rules and the range of ways performance standards might be used to improve regulatory outcomes.

Terms of Reference

The Terms of Reference for this project (see Appendix A) defined two expected outcomes of the consideration of performance standards in regulating heavy vehicles:

1. Development of more sustainable transport systems through improved road vehicle regulations controlling vehicle safety and infrastructure impacts, and better environment outcomes.

2. More flexible road transport regulations that provide for increased innovation and more rapid adoption of new technologies.

Existing regulations of heavy vehicle use are generally rigid and only indirectly ensure that vehicles are able to operate in a safe manner and control the amount of road and bridge wear they cause. Increased flexibility in controls on heavy vehicles could help meet the demands of growing freight tasks and limitations to the expansion of infrastructure investment, by allowing better management of the use of existing infrastructure while improving safety and amenity outcomes of heavy vehicle use.

Consideration of this approach is consistent with international moves across many sectors to introduce regulatory reforms. However, information on vehicle performance and its link to safety and infrastructure outcomes needs to be pooled internationally if significant progress is to be made. Additionally, heavy vehicles are produced in a global international market, and no single country is able to shift the principles of design used in vehicle production independently. Pressures for harmonisation are consequently high, and international collaboration and agreement on performance criteria, in particular how performance is measured and tested, would provide much greater opportunities than can be achieved by individual countries.

Chapter 2

REGULATORY PRINCIPLES

Background

The use of heavy vehicles is regulated predominantly by prescriptive rules that evolved over a long period and which differ internationally, including within federal jurisdictions. Despite efforts towards international harmonisation, such as in the European Union and between signatories to the UN agreement, considerable variations in regulations between jurisdictions remain, particularly in relation to innovative approaches to solving transport needs. Recognising the strong international links in modernising regulations, moving to a consistent performance-based approach to regulation of heavy vehicle operations is now being considered as an optional alternative to the existing prescriptive regulations.

Under a performance-based approach to regulation, standards would specify the performance required from vehicle operations rather than mandating how this level of performance is to be achieved. This approach to regulation has been adopted internationally 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.

> *"All governments have a responsibility to review their own regulations and regulatory structures and processes to ensure that they promote efficiently and effectively the economic and social well-being of their people." (OECD 1997, p5)*

> *"Incentives have too often favoured vocal rather than general interests, short term over long term views, pursuit of narrow mission goals at any cost, and use of detailed and traditional controls rather than flexible and innovative approaches." (OECD 1997, p9)*

Performance-based approaches would allow the interactions of vehicles with the roads they use to be taken into account more explicitly. In determining whether a specific vehicle can operate on a particular road, the vehicle's capabilities and the relevant road standards and traffic conditions can be examined jointly, to decide whether the operation will produce the outcomes desired.

Performance-based approaches to regulating heavy vehicles to protect road safety and infrastructure would provide a voluntary alternative to the current prescriptive regulations. They would allow the regulation of vehicles according to how they perform and how they are driven and operated, to match the characteristics of the road network. Traditionally, heavy vehicles have been regulated by tightly defined prescriptive limits (such as mass and size limits), which provide little scope for innovation. This traditional approach provides a 'one size fits all' outcome, despite significant variations in road and traffic characteristics across road networks, and between urban and inter-city or inter-region routes. An improved regulatory system would encourage innovation and provide a better match between vehicles and roads.

Examples from other sectors have been documented:

"The shift from excessively detailed social regulation to market and goal-based approaches also encourages the creation and diffusion of new knowledge. 'Command and control" in the environmental area has often aimed at the adoption of 'best available technology', which favours the use of existing control devices and discourages innovative responses to pollution problems. The current shift towards market incentives and goal-oriented regulations encourages creation of new, less costly means to reduce environmental degradation. In the agro-food sector, introduction of goals-oriented safety regulations encourages innovations, as food processors gain some discretion over how to comply with the standards. In Canada, a new approach in which railways set safety standards under government oversight has speeded up rulemaking and allowed the rail industry to keep pace with technologies that reduce service costs. Goal-oriented regulations for nuclear power plants has [sic] encouraged the nuclear industry to adopt technological innovations and resulted in a significant improvement in plant performance." (OECD 1997, p15).

"Replacement of rigid "command and control" rules with a single "plant safety" standard was estimated to reduce by one-fourth deaths and injuries in those plants in Australia." (OECD 1997, p17).

Best practice approaches to regulation

While most regulations for heavy vehicles remain prescriptive, performance-based approaches to regulation have been the focus of regulation reforms internationally in recent years. This has been to ensure:

- Governments only intervene when there is a need for them to do so.
- The performance that needs to be regulated is transparent.
- Regulations are subject to an ongoing process of evaluation.
- Consistency is achieved across jurisdiction boundaries.
- Innovation and take-up of new technologies and approaches is encouraged by regulations that do not create unnecessary inflexibilities for those who have to comply with them.

Reforms to regulation of food standards and occupational health and safety are the prime examples of major sectors of activity that have moved from fixed prescriptive rules and regulations to performance-based regulation. This regulatory approach started in the occupational health and safety arena in the United Kingdom, and has since spread to a wide range of other areas and other countries.

Regulation can be categorised into a spectrum that ranges from self-regulation through quasi-regulation, to explicit government regulation.

Self-regulation may be appropriate when:

- There are no strong public interest concerns, in particular, no major health and safety concerns.
- The problem is a low risk event, or has a low impact/significance.
- The market can fix the problem itself, or there is an incentive for individuals and groups to develop and comply with self-regulatory arrangements (for example, industry survival, market advantage).

Quasi-regulation (codes, guidelines, rules etc.) should be considered where:

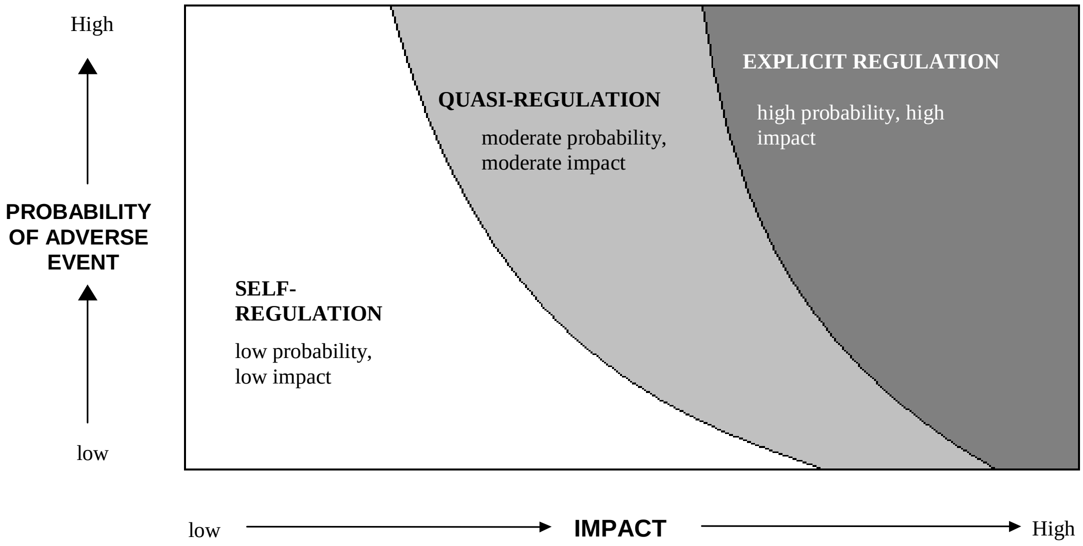
- There is a public interest in some government involvement in regulatory arrangements and the issue is unlikely to be addressed through self-regulation.
- There is an advantage in government engaging in a collaborative approach with industry, with industry having substantial ownership of the scheme.

Explicit regulation should be considered where:

- The problem is high risk, of high impact/significance (for example, a major public health and safety issue).
- The government requires the certainty that is provided by minimum standards backed by legal sanctions.

These choices are illustrated in Figure 2.1.

Figure 2.1. **Relationship between risk and regulatory forms**



Source: Coghlan, 2000

In the processes of Regulatory Review the following examples of applying these principles are used:

> *"For example, a mid-air collision between two aircraft might be a very low probability but, should it eventuate, the consequences are great. Such a matter is likely to justify explicit government regulation. In contrast, the risk of someone being overcharged for a supermarket item may be a moderate probability but the impact is quite low — the diagram suggests such an event should be left to the industry and not be addressed by government regulation." (Coghlan 2000, p7).*

While safety and environmental concerns about heavy vehicles using public roads almost certainly require explicit regulations to ensure the public is protected, issues regarding the protection of infrastructure might be more appropriately addressed through either quasi or explicit regulation, depending on the extent of the concerns. On the other hand, issues such as incentives to improve heavy vehicle productivity can be left to self-regulatory arrangements and normal market forces. Competitive pressures within the road freight and bus passenger sectors can be expected to provide sufficient incentives to operators to minimise their costs and improve productivity. Nevertheless, these same pressures can lead to some operators taking safety risks and cutting corners, to the detriment of the environment and road and bridge infrastructure.

Both Performance Standards and Prescriptive Standards are forms of explicit regulation.

Regulatory principles

The OECD has identified a checklist of regulatory principles to assist countries in ensuring that high quality regulations are prepared. This checklist is set out in a Recommendation of the OECD Council and comprises the questions set out in Box 2.1.

The Recommendation goes on to note:

> *"The drawbacks to this ["command and control"] form of regulation — including its rigidity, tendency to be over-detailed, inability to adapt to changing conditions, high costs, adversarial nature, and ineffectiveness in many situations — have led governments to consider alternative forms of action such as **economic instruments, voluntary agreements, self regulation, information disclosure, persuasion**, and various forms of **performance-based regulation**.*
>
> *"Regulatory officials should be encouraged to carry out, early in the regulatory process, an informed consideration of regulatory and non-regulatory instruments. Such a process will support a process of systematic and open decision making that uses the range of policy instruments more skilfully and more creatively to achieve better policy outcomes." (OECD 1995, p15.)*

In recommending these principles, the OECD Council took into account a range of reasons, including:

> *"Considering that structural adjustment to changing economic and social conditions requires the removal of rigidities and barriers to competition within national economies that are often the result of inflexible, costly or outdated government regulations.*

> *"Considering that the quality and transparency of government regulation is ever more important in an interdependent world where the effects of regulations cross national borders, and where regulatory cooperation is necessary to address urgent issues in areas such as environment, crime, migration, consumer protection, investment and trade." (OECD 1995, p8).*

In line with these principles a number of countries have developed their own checklists describing best practice in regulatory developments. Some of these, such as the Australian list shown below in Box 2.2, explicitly refer to the consideration of performance-based approaches to regulation.

Box 2.1. **OECD Checklist of regulatory principles**

1. Is the problem correctly defined?
2. Is the government action justified?
3. Is regulation the best form of government action?
4. Is there a legal basis for regulation?
5. What is the appropriate level (or levels) of government for this action?
6. Do the benefits of regulation justify the costs?
7. Is the distribution of effects across society transparent?
8. Is the regulation clear, consistent, comprehensible and accessible to users?
9. Have all interested parties had the opportunity to present their views?
10. How will compliance be achieved?

Source: OECD 1995, pp. 9-10.

An essential characteristic of effective and efficient regulation is that any restrictions on competition should be retained only if they provide a net benefit to the community, and only if government objectives cannot be achieved by other means. This principle should be considered, for example, when placing limits on who can undertake a function such as deciding whether a vehicle meets performance standards, to ensure that arrangements are not unnecessarily restrictive. To ensure that this is the case, Regulatory Impact Statements should be prepared to evaluate regulatory proposals against a range of alternatives.

Degree of flexibility

Regulations can vary considerably in terms of how they specify what they are trying to achieve. There is a spectrum in the nature of regulations from prescriptive regulations at one end to solely 'principle-based regulations' at the other.

Principle-based regulations specify requirements very broadly in terms of general objectives and do not incorporate any quantified limits. They provide each organisation with the maximum possible flexibility to determine how best to achieve those objectives.

Box 2.2. **Example of a checklist for the development of regulations**

Set to the minimum necessary
- Kept simple to avoid unnecessary restrictions
- Targeted at the problem to achieve the objectives
- Not imposing an unnecessary burden on those affected

Not unduly prescriptive
- Performance and outcomes focused
- General rather than overly specific
- Flexible enough to allow business some freedom to find the best way to comply

Accessible, transparent and accountable
- Readily available to the public
- Easy to understand
- Fairly and consistently enforced
- Some flexibility for dealing with special circumstances
- Open to appeal and review

Integrated and consistent with other laws
- Addressing a problem not addressed by other regulations
- Recognises existing regulations and international obligations

Communicated effectively
- Written in ‘plain language’
- Clear and concise

Mindful of the compliance burden imposed
- Proportionate to the problem
- Set at a level that minimises costs

Enforceable
- Providing the minimum incentives needed for reasonable compliance
- Able to be monitored and policed effectively, given the available resources.

Source: Productivity Commission 1999, p 57.

For example, a principle-based regulation might specify that heavy vehicle operators need to minimise the impact of their vehicles on road congestion, road safety, road and bridge infrastructure and the environment, in order to improve the efficiency and equity of the road transport system. Heavy vehicle operators would then have to determine the most efficient way of achieving those general objectives. The regulation would not specify what is required to meet the regulation, nor would it provide any quantified limits on the acceptable impacts of vehicles. Guidance on these issues might be provided in supporting codes and guidelines, but options would be left open to vehicle operators to take a different approach if they believed they could prove it met the broadly stated regulation.

At the other end of the spectrum are 'prescriptive regulations', which are defined in very specific terms. Heavy vehicle operators have little flexibility to determine how the objectives underlying these regulations are to be met. For example, the current regulations specify the maximum length, width and height of heavy vehicles. These limits are intended to limit the congestion costs, accident damage, and road wear arising from the use of heavy vehicles, but do not do so explicitly. If an operator can find a safer vehicle design that leads to less congestion or less road wear, the design can only be used if it also meets the fixed prescriptive regulations.

In between these two extremes are 'performance standards' and 'performance–based prescriptive regulations', both of which are examples of results-oriented forms of regulation.

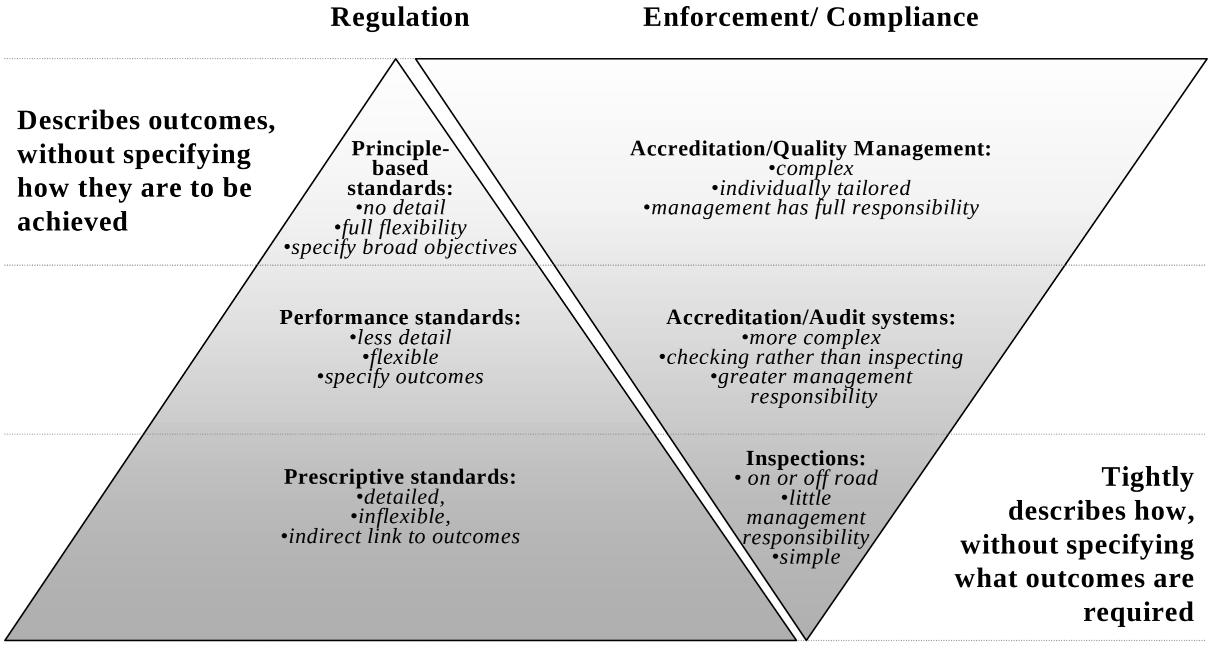
Performance standards are specified in a more precise and measurable manner than principle-based regulations, but provide greater flexibility in how to meet the requirements than prescriptive regulations. For example, a performance standard intended to reduce road congestion might prescribe the maximum road area (swept path) a heavy vehicle is allowed to occupy when undertaking certain road manoeuvres, and then leave it up to heavy vehicle operators as to how best to construct vehicles to achieve that objective. A more flexible performance standard might be one that stated that a vehicle must be able to negotiate curves safely, without detailing specific manoeuvres and measurements that must be made in order to determine whether this is achieved.

Performance-based prescriptive regulations are prescriptive regulations based on performance analyses. Under this approach, specific criteria for performance are developed, as they are for Performance Standards. Prescriptive regulations that deliver the same performance are then established. For example, if a performance standard is developed that specifies the swept path a vehicle can occupy when undertaking specified manoeuvres, prescriptive regulations limiting length, width and wheelbase so that vehicles do not exceed the swept path envelope would form performance-based prescriptive regulations. However, even when prescriptive regulations are based on performance standards, they may be suboptimal because they do not allow for innovative designs and equipment that might allow a vehicle to stay within the same swept path even if the prescriptive limits were exceeded.

Figure 2.2 illustrates the range of approaches that can be taken, and the hierarchy of Performance Standards they make possible.

It is clear that the degree of flexibility inherent in performance based regulation can vary considerably. At the same time, the implications to the community of non-compliance may be greater where the degree of flexibility is greater. Where there is more flexibility, a greater number of factors are under the control of the operator. This may mean that governments require vehicle operators (and other elements of the logistics chain) to take greater responsibility for ensuring compliance with this greater range of factors under their control. In other cases, it might be determined that the risks of non-compliance are too great, and that a performance-based prescriptive standard is necessary.

Figure 2.2. **Hierarchy of possible approaches to regulation**



The system of performance-based regulation is intended to provide greater flexibility than the existing prescriptive standards, but is not expected to shift far up the potential hierarchy of standards at this time. However, moving closer to a principles-based system of regulation presents some potential opportunities, including the maximum degree of flexibility.

Why regulation of road use is needed

Regulation of road use is necessary to ensure that:

- Roads are used safely.
- Road congestion is minimised.
- The amount of road wear is minimised and the costs of repairing roads are recovered from users.
- Road use does not result in excessive noise.
- Air pollution is minimised.

Regulation to meet these objectives will protect community interests to ensure that the total costs of road use are minimised.

This is achieved by minimising the total of:

- Costs faced by road users in operating their vehicles, travel time etc.

- The whole-of-life costs of providing, maintaining and managing the road network, including costs associated with road alignment and geometry, pavement condition and bridge condition.

- Costs imposed on the broader community by road use, such as the costs of accidents and environmental impacts.

The direct costs faced by road users (vehicle operating costs and costs of travel time) are often 10 to 15 times the costs of providing, maintaining and managing road networks. Regulation is necessary to minimise total costs because there are no in-built mechanisms to ensure road users take account of the impact of using their vehicles on the costs of road networks and the broader community.

Consequently, regulations are needed to control:

- Bridge costs.

- Pavement wear.

- Traffic operations.

- Road safety.

Around the world, countries achieve these objectives by regulations for:

- Vehicle configurations.

- Vehicle mass, including gross mass limits, axle spacing mass schedules and axle group mass limits.

- Dimensions, such as length, width, height and rear overhang.

- Road rules.

- Heavy vehicle charges.

In contrast, under a performance-based approach to regulating road use, the relationships between vehicle and road performance must be specified. This means it is necessary to understand the relationship between vehicle use and infrastructure costs, and the relationship between vehicles and road safety for different circumstances applying in different parts of the road network.

In regulating road transport, governments must also take into account administrative, enforcement and compliance costs. This means that a lower cost approach to regulating road use must be found if the administrative costs of a particular approach are higher than necessary – and in the worst case higher than the costs that the regulations are meant to control.

The need for a performance-based approach to regulating heavy vehicles

The main reasons for investigating performance-based approaches to heavy vehicle regulation are that:

- Road transport is a vital component of economic activity in all countries and consequently any improvements to productivity that performance-based regulation can provide are significant.

- There is continuing pressure internationally and at the local community level to improve the safety and amenity of heavy vehicles.

- There is little room in most countries for further wholesale relaxation of prescriptive standards, as has occurred in the past.

- More flexible approaches to regulating the road transport component of multi-modal freight movements might reduce the costs of intermodal interchanges, thereby improving the viability of other modes of transport and reducing total supply chain costs.

The search for regulatory solutions that will support international trends and high growth in road freight is critical to improving the standard of living and economic wellbeing in OECD member countries. In many places, significant increases in the size of the road freight task are forecast, highlighting the importance of continued efforts to improve the overall safety, efficiency and fairness of the road transport system. It is unlikely that these trends can be maintained without the adoption of mechanisms that promote innovation and provide the flexibility for transport operators to improve productivity, at the same time improving road safety and the optimum use of road infrastructure. In the road transport sector this includes a more sophisticated approach to heavy vehicle regulation.

At the same time as providing for innovations in the road transport sector, governments must also meet the community's expectations for improved health, safety and quality of life.

The introduction of better regulation is expected to:

- Encourage innovation.

- Provide a better match between vehicles and roads.

- Increase regulatory transparency by providing a more consistent and more rational regulatory approach.

- Improve performance (by providing better controls on safety and infrastructure wear.

- Improve compliance.

The growth in road freight and inconsistencies between jurisdictions in its regulation are variously interpreted as constraining innovation and net benefits to the community; increasing road safety risk; increasing 'wear and tear' of pavements and bridges; and, reducing amenity.

Gaps in the performance standards and the quality of the performance relationships underpinning the current prescriptive regulations potentially undermine the integrity of a regulatory system, its interpretation and enforcement.

These problems are compounded by the need to provide for an increasingly specialised freight task using the primary freights corridors, and to separate these from the requirements for general access and the amenity needs for local road networks.

Mutually agreed procedures for the consistent assessment of applications for more productive, safer and less damaging vehicles are underdeveloped, particularly for matching the performance of heavy vehicles with differences in road design and traffic operations. The uncertainty extends beyond distinguishing between the freight task and road function and utility to the effectiveness of integrated modal transport, and the role of regulation. It requires the pressure from industry for productivity and investment in infrastructure (for example, bridge strengthening) to be reconciled with the pressures from the community for more effective regulation of heavy vehicle intrusion and local amenity.

Chapter 3

CURRENT APPROACHES

Introduction

Current approaches for regulating vehicle weights and dimensions to promote safety and infrastructure protection vary widely among OECD member countries. A Survey was developed and sent to each member country to obtain specific information about current regulatory practices. The survey obtained information concerning the purpose and basis for regulations on a variety of vehicle characteristics, provisions for issuing permits to allow operations of vehicles with non-standard weights and dimensions, vehicle weights and dimensions enforcement practices, and the specific use of performance-based standards to control weights and dimensions.

Nine nations responded to the survey: Australia, Canada, Czech Republic, Denmark, Japan, Netherlands, New Zealand, Switzerland and the United States.

Current regulatory approach

All responding countries rely primarily on prescriptive standards for regulations of vehicle weight, height, width, length, trailer length, axle spacings, axle loads, and other characteristics related to vehicle safety and infrastructure preservation. The purpose for these regulations is to assure that motor carriers use equipment that is safe and does not cause unacceptable damage to the infrastructure or disruption to traffic operations. European Union countries seek consistency for most weight and dimension standards. (The drivers behind this harmonisation are primarily equal competition and trade, discussed below under the heading *other considerations*).

Table 3.1 summarises the most common vehicle characteristics regulated by OECD member countries to limit pavement and bridge loadings, to assure minimum levels of vehicle handling, stability, and control, and to assure that vehicles dimensions and operating characteristics are compatible with the roads on which they will operate. The table also shows the number of countries that reported in a survey conducted for this project having regulations covering each of the vehicle characteristics. Responses to the survey are discussed below according to the general purposes of the regulations.

Pavement and bridge protection

The vehicle characteristics currently regulated to limit pavement and bridge loadings are gross vehicle mass, axle group mass, suspension performance, axle group mass based on suspension type, axle group mass based on axle spacing, tyre configuration, and tyre pressure. All countries regulate gross mass and axle group mass and many countries regulate most of the other characteristics affecting pavement and bridge loadings. Axle group mass based on suspension type and tyre configuration are regulated by the fewest countries (four). All other characteristics in this group are regulated by at least half the countries responding to the survey.

Limits on gross mass and axle group mass are the primary methods used in all countries to control pavement and bridge loadings. Such measures are prescriptive, although they are based on known relationships between mass and pavement and bridge performance. Considerable research has been conducted in recent years on vehicle-pavement interaction. This research has demonstrated the impacts of dynamic loads on both pavement and bridge performance – static measures of gross mass and axle mass do not capture these dynamic forces. Several countries are moving to reflect the importance of dynamic loads in their regulations. One way they are doing this is to allow additional weight for vehicles equipped with "pavement-friendly" suspensions. While these additional weight allowances are not true performance standards, they have a stronger performance basis than gross mass and axle mass limits that are purely static measures. Research has also demonstrated the impact of tyre pressure on pavement performance. Several countries regulate maximum tyre pressures in addition to gross mass and axle mass. Again, these regulations are not true performance standards, but they do reflect other dimensions of pavement performance that are not captured by gross mass limits and axle mass limits.

Vehicle handling, stability, and control

Another important purpose of regulating vehicle weights and dimensions is to assure that vehicles are stable and that they will handle safely on the highway. Vehicle characteristics included in the survey that are associated with vehicle handling, stability, and control include height, width, load distribution, and the type of trailer connection. All countries regulate vehicle height and length, while two-thirds regulate load distribution. None of these characteristics is a direct measure of vehicle stability and control, however. Several other measures not included in the survey more closely reflect vehicle stability and control properties, but they are not widely used in general weight and dimension regulations. These include lateral acceleration, load transfer ratio, and static rollover threshold. Several countries use these more direct measures of vehicle stability and control in issuing special permits for oversize/overweight operations. One reason such performance standards have not been used for general weight and dimension regulations is likely the fact that they cannot be directly measured in the field. Where these characteristics are used, vehicles must be certified that they meet each applicable characteristic and must carry that certification with them. While such an enforcement regime is quite different from the roadside enforcement regimes widely used in most countries, the benefits of allowing more direct management of vehicle stability and control can be substantial.

Compatibility with highway system

The last group of vehicle characteristics that are regulated by some or all OECD countries are ones intended to assure that vehicles are compatible with the highways on which they will operate. Those characteristics include vehicle length, width, height, trailer length, rear overhang, turning circle, kingpin-to-rear axle distance, number of trailers, and gross mass based on engine horsepower. Most of these characteristics are regulated by a majority of OECD countries.

Most of these dimensional limits are intended to assure that a vehicle is able to safely negotiate curves and turns at interchanges/intersections without encroaching on shoulders or opposing travel lanes. The correlation between the vehicle characteristic being regulated and the desired outcome varies widely across these characteristics. Vehicle length would have the lowest correlation with this measure, but length is regulated for other purposes as well, including allowing acceptable sight distances for passing on two-lane highways. Turning circle is a true performance measure and has the greatest correlation with a vehicle's ability to negotiate curves and intersection turns. Other performance measures that have been used by several countries in evaluating applications for special permits are low and high-speed offtracking. These characteristics are difficult to measure in the field and generally would have to be estimated using computer simulations. That may be one reason why they are not used by more countries in regulating vehicle weights and dimensions.

Table 3.1. **Regulation of various vehicle characteristics by reporting countries**

Vehicle characteristic	Number of countries reporting standard	Number of countries reporting no standard
Height	9	0
Length	9	0
Trailer length	9	0
Width	9	0
Rear overhang	7	2
Axle spacings	6	3
Other internal dimensions	4	5
Turning circle	7	2
King-pin - rear axle distance	7	2
Suspension performance	5	4
Number of trailers \ type of trailer connection	4	5
Gross mass	9	0
Gross mass based on axle spacings (bridge formula)	6	3
Gross mass based on engine horsepower	1	9
Tyre configuration	4	5
Tyre pressure	7	2
Axle group mass	9	0
Axle group mass based on suspension type	4	5
Trailer mass*	0	9
Load distribution	6	3

* Trailer mass limits depend on number of axles and axle load and spacing regulations. None of the countries appear to have specific trailer mass limits that are independent of those other factors.

Weight and dimension limits vary among the different countries, and in some cases those limits vary significantly in different regions of the same country. Key variables affecting weight and dimension limits include traffic volume and highway geometry. Where traffic volumes are low and highways have few sharp curves, transportation officials often allow longer vehicles than in areas with high traffic volumes and poorer highway geometry. If more axles are placed under the vehicle, higher gross weights can also be allowed, subject to the strength of bridges the vehicle must cross.

While vehicle weight and dimension regulations are largely prescriptive in all countries, regulations are strongly influenced by considerations of safety, infrastructure, and traffic performance. In addition to regulations on basic vehicle height, width, and length, many countries also regulate other vehicle characteristics that more directly affect vehicle stability, control, and manoeuvrability. Examples include rear overhang, kingpin-to-rear axle spacing, and other internal dimensions. These are all easily measured and enforced. A related measure used in most countries is the turning radius or circle. This is a more direct performance measure, but is not as easily measured for enforcement purposes. As noted above, several countries grant additional weight if vehicles are equipped with suspensions that lessen the dynamic forces transmitted to the pavement. Canada grants additional weight allowances to b-train configurations that are more stable than conventional multi-trailer combinations. Such regulations may be considered performance-based even though they still rely on prescriptive limits.

As understanding of factors that affect vehicle safety and infrastructure damage has improved, highway officials have recognised that the prescriptive limits they have traditionally used may not be as effective as they would like, particularly when it comes to safety. For instance as vehicle weights have increased, concern about vehicle rollover has grown. Many factors affect a vehicle's propensity to rollover, but most are not easily measured at the roadside using standard vehicle weight and dimension limits. Other factors that can only be assessed using testing facilities or computer simulation play a large part in determining a vehicle's rollover propensity. Similarly, with the increasing use of multi-trailer combinations, there is a concern about stability and control properties of the vehicle that may be affected by the type of coupling between trailers, the suspension system, the type of tyres and other factors. Measures have been developed to assess the performance of different vehicles, but like the measures to assess rollover propensity, those measures can only be evaluated at test facilities or through computer simulation. As noted above, some countries are beginning to use performance-based approaches to regulate vehicle weights and dimensions when evaluating applications for exemptions from general weight and dimension regulations. As public officials and carriers in these countries gain more experience with performance-based regulation, there may be a move to substitute performance-based criteria for the current prescriptive standards in general weight and dimension regulations. Or, as is being considered in Australia, carriers may have an option to operate under prescriptive standards or performance-based criteria. It may be many years before significant moves away from prescriptive regulations and toward performance-based regulations are made in most OECD countries, but performance-based assessments likely will become more common in some countries for purposes of granting special permits and exceptions from general weights and dimensions regulations.

Other Considerations

European Union countries are bound by a Directive on the dimensions of vehicles (Directive 96/53/EC). The drivers behind this harmonisation are primarily equal competition and trade:

- Vehicles are a product that can be sold across the community. If member states have different regulations concerning the technical requirements of vehicles this will introduce distortions in the vehicle market.

- If member states allow different amounts of goods to be carried on vehicles in their territories that gives a distortion in manufacturing and transport costs therefore affecting competition.

There have been attempts to create a common set of masses and dimensions for goods vehicles (and buses) over many years. The first harmonisation was achieved in the mid 1980s with directive 85/3/EEC which set down some masses and dimensions which member states had to accept on their territories, even though they could keep different national standards. This directive was amended over the years until 1996, where a major change was made in that it set dimensions for certain vehicles which all member states had to embody in their own territory – with no national alternative. There is still no agreement on masses, but in practice the 5 axle 40t gross mass vehicle has become the *de facto* standard.

Exemptions

All responding countries grant exemptions from routine weight and dimension regulations, especially for indivisible loads. Practices for granting these exemptions vary from country to country and also depend on the weights and dimensions of the vehicle the carrier proposes to use. Detailed engineering analyses may be required for very heavy loads, and vehicle performance characteristics typically are considered much more than for routine vehicle operations. Depending on the weight and dimensions of the proposed vehicles, restrictions may be placed on the moves including the use of prescribed routes, maximum speed limits, and requirements for escort vehicles. Australia, Canada, and New Zealand, the three countries that have made the most progress in implementing performance-based regulations, rely the most on vehicle performance attributes in making decisions concerning exemptions from general weight and dimension limits. Reviews in other countries also consider vehicle performance characteristics, but generally in a less systematic way than Australia, Canada, and New Zealand.

Standards review

Only Australia, New Zealand, and the United States have reviewed regulations on vehicle mass, dimension, and configuration within the last five years. Each country considered a broad range of potential policy issues, including vehicle stability and control properties, the economics of changes in vehicle weights and dimensions, and potential infrastructure costs associated with changes in weights and dimensions. Work in the United States was completed with no changes proposed to vehicle size and weight limits. Work in New Zealand and Australia is on-going with a specific focus on developing a stronger performance basis for their weights and dimensions regulations. Australian officials, in particular, noted that they expect this project will result in changing many of their prescriptive standards to ones based on performance criteria.

Performance-based standards

Three nations, New Zealand, Australia, and Canada, already have made some progress toward implementing performance standards.

New Zealand has a static roll threshold (SRT) standard explicitly in its regulation and uses several other performance standards in setting prescriptive standards and in evaluating exemptions. Those performance standards include:

- SRT > 0.35g for most heavy trucks (current rule).
- SRT > 0.45 g for fuel tankers and dairy tankers.
- Dynamic load transfer ratio > 0.6 for dairy tankers.
- Hi-speed transient off-tracking < 0.5m for dairy tankers.
- Lo-speed off-tracking < 4.2m.
- Front swing < 350mm.

Use of performance standards has allowed certain over-dimensioned and over-mass vehicles to operate that could not have operated under standard prescriptive regulations. For example, increasing the length of log hauling vehicles from 22 to 24 meters allowed the truck to be loaded in two packets versus one high packet, thereby lowering the centre of gravity. This is expected to decrease rollover accidents by 40%. Similarly, dairy tankers were allowed a 25% increase in payload if they met strict stability requirements. These regulations increased productivity while also resulting in better performing vehicles than had been in use. New Zealand plans to continue the examination of performance standards with the goal of incorporating them, and has identified options ranging from dual performance and prescriptive regulations to 100 percent performance regulations.

Australia also has done extensive research in these areas, much of it in cooperation with New Zealand. Although the use of performance-based standards has been limited to date, Australia expects to rely heavily on such standards in the near future. They expect this to improve safety performance, reduce wear and tear on pavements and bridges, increase vehicle productivity, provide more flexibility in vehicle design to comply with regulations, lead to the introduction of new vehicle designs and technologies that will further improve safety and productivity.

Canada has used performance measures such as high speed, low speed and transient high-speed off-tracking, static roll threshold, load transfer ratio, braking efficiency, friction demand, rearward amplification, and swing-out in assessing exemptions from weights and dimensions limits, but has not formally adopted such measures for general regulation of weights and dimensions. Canada, the United States, and Mexico have considered the feasibility of using vehicle performance criteria in connection with any efforts to harmonise weights and dimension regulations in North America under the North American Free Trade Agreement.

Conclusion

Australia and New Zealand expect to make more extensive use of performance-based standards in the future, and Canada recognises the opportunity to implement true performance based regulations rather than prescriptive regulations based on performance criteria. Other countries are probably further from implementing formal performance-based size and weight regulations. The survey did not focus on impediments to the further adoption of performance-based vehicle weight and dimension regulations, but they certainly exist. Some impediments are discussed in later sections of this report including enforcement of performance-based standards, the development of performance thresholds, and specific opportunities for improving the regulatory framework for heavy vehicle operations. Several survey responses noted potential case study opportunities that might illustrate how specific impediments were resolved in examples to date.

Chapter 4

BEST PRACTICE DIRECTIONS

Regulatory approaches to applying performance standards

Uses of performance standards

Performance measures and standards can be used for a variety of purposes, such as:

- Comparing the performance of different vehicles.
- Helping to ensure that new vehicle designs or concepts will perform appropriately.
- Developing safety or infrastructure wear counter measures.
- As regulatory requirements within a regulatory framework.

The use of performance standards for heavy vehicles in the latter manner forms the emphasis of this report. Within this there are a range of options for how performance standards can be applied in a regulatory framework. They include:

1. Using assessments of vehicle performance in comparison to the performance standards to develop and refine prescriptive regulations (*underlying basis for prescriptive regulations*).
2. Using assessments of vehicle performance in comparison to the performance standards as the criteria for considering applications for vehicles to operate under exemptions outside the normal regulatory requirements (*exemptions approach*).
3. As the underpinning of a results-based system of performance regulation, replacing existing prescriptive rules (*holistic approach*).
4. A combination of the first two approaches (*hybrid approach*).
5. As the basis for determining access requirements and network standards for different parts of the road network (*road network approach*).

These different approaches to the use of performance standards are considered below.

The need for and potential of regulation reform

In determining the appropriate approach to regulation, how different approaches may resolve or ameliorate these problems must be considered, recognising that different circumstances may warrant a different emphasis.

The questions that must be considered are:

- Are current prescriptive limits on heavy vehicle mass and dimensions credible and sufficient for the future?
- Do they constrain innovation and productivity?
- Do current prescriptive rules provide adequate certainty that vehicles operate safely and do not cause undue wear to road infrastructure?
- Are the risks to road safety and to damage to infrastructure incorporated within the provisions for compliance and enforcement?
- Does the regulatory system facilitate the shift to ‘smarter’ compliance and enforcement systems that respond to risks and are more easily communicated?
- Is it practicable to determine a joint research effort?

Whether the solution is to introduce performance-based regulation direct or to use it to improve prescriptive regulation, a more explicit specification of performance criteria, measures and thresholds (or standards) is fundamental to each alternative regulatory system.

Road safety

With the growth in both the freight task and the proportion of heavier vehicles in mixed traffic conditions, and the drive for productivity gains, basic road safety and traffic performance criteria for the regulation of heavy vehicles may be insufficient (*e.g.* the control of vehicle stability during emergency manoeuvres).

The issues include the possibility that:

- Basic road safety performance thresholds are being approached or exceeded, and are not regulated effectively. For example, vehicles may be approaching or exceeding the threshold at which they can safely operate without rolling over, under the conditions that apply across the road network on which they operate. This has been found with parts of the New Zealand heavy vehicle fleet as discussed in Chapter 3.
- The regulatory system, particularly enforcement and penalties, is not results-based, limiting its credibility and effectiveness.
- The performance of vehicles complying with prescriptive rules can vary significantly as these rules only provide indirect controls over safety and infrastructure protection outcomes. This variation may lead to some vehicles that comply with prescriptive rules posing an undue risk to safety or infrastructure on parts of the road network.

Efficient regulation

Freight growth, limits to the potential to expand infrastructure through additional investment and increasing congestion within transport networks have led to moves to consider transport issues from a broader perspective than the narrow confines of a single transport mode. Efficient regulatory systems within this context must address:

- The 'seamless' operation of the freight task, including the design of vehicles for freight transport between jurisdictions and across modes (including an increase in containerisation), *etc*.

- The condition of the infrastructure and the economics of design standards for the major freight corridors (road and rail), modal interchanges, and local access networks.

- Road safety, prevention of excessive infrastructure 'wear and tear', and environmental/ amenity outcomes to be achieved while at the same time providing for innovation and productivity improvements in performance of the transport task.

Development of infrastructure

An efficient and effective regulatory system increasingly needs to be able to deal with the following challenges:

- Specialisation of the freight task and the associated emergence of different needs in different locations, innovative vehicle designs and new approaches to shifting freight.

- Disparities between the performance of the heavy vehicle fleet and the adequacy and design of infrastructure (*e.g*. low and high speed off tracking, pavement and bridge condition).

- Differences in infrastructure standards between regions, jurisdictions and for different road functions (*e.g*. primary arterial roads, local access roads).

Traditional prescriptive 'command and control' style rules do not adapt well to these challenges as they are inflexible and must be modified to reflect changes in technology and societal needs. Increasingly, the regulatory system needs to link priorities for investment in infrastructure, pricing systems, and the different functions (including the planning and amenity aspects) of roads with each other and with decisions regarding network access for different vehicle types.

Improved compliance and enforcement

Regulatory systems need to incorporate modern methods of compliance and enforcement (including available technologies) to ensure that the outcomes achieved match the objectives of the regulatory system. A recent OECD report on regulatory compliance emphasises the importance of compliance results to the efficiency and effectiveness of public policies (OECD 2000). It also emphasises the importance of addressing the compliance outcomes in the design phase of regulations, and developing regulations in conjunction with compliance and enforcement arrangements, instead of in isolation to them.

The report goes on to suggest the following innovations in the implementation and enforcement phase to ensure that policy outcomes are achieved in practice:

- Rewards and incentives for high/voluntary compliance.

- Nurturing the compliance capacity of business.

- Targeting for low compliance.

- Restorative justice when voluntary compliance fails.

- Responsive enforcement when restorative justice fails.

In the road transport sector, relevant factors to consider include:

- An increasing focus on actual performance (*e.g*. route compliance, pavement loading) rather than weak proxies (*e.g*. axle group mass tolerances).

- Available compliance accreditation systems and audit procedures supported by technology (*e.g*. location identification, on-board weighing devices) that enable continuous office-based monitoring and provide the means for operators to develop greater awareness and responsibility for compliance outcomes.

- A shift to 'risk-based' approaches to compliance and enforcement, providing a more credible regulatory system.

Improvements to the regulatory approach and compliance/enforcement arrangements need to be considered together, rather than in isolation. Both considerations should inform the appraisal of regulatory approaches for applying performance standards.

Desirable characteristics of regulatory approaches

The following characteristics are considered to be important in assessing the advantages and disadvantages of each regulatory approach:

Improved outcomes

- Implementing the regulatory approach should result in net benefits to the community – economic, social and environmental. These benefits might include:

  - Productivity benefits to industry in managing the freight task, including growth forecasts.

  - Reductions in road accidents.

  - Improvements in traffic operations and levels of service.

  - Sustainability.

  - Protection of road infrastructure – pavements and bridges.

- Innovation in freight and logistics, including compliance and enforcement systems.

Public policy

- The regulatory approach should provide:
  - Effective regulation reform policies.
  - A basis for attaining consistency in regulatory practices across jurisdictions (federal systems of government; OECD member countries).
  - Effective regulation in the context of broader freight and logistics policies including:
    - Transport/road pricing.
    - Transport infrastructure investment (priorities).
    - Modal integration.
    - Land use planning and the urban distribution task.
  - Seamless transport of freight between jurisdictions, modes of transport and road classification.

Technical feasibility

- Regulations should ‘match’ heavy vehicle performance with road function and road design and traffic performance, relating freight tasks and road design standards.
- Regulations should be practicable, enforceable, provide for interoperability and encourage compliance.

International implications including

- The regulatory approach should recognise the importance of:
  - Consistency and mutual recognition.
  - The impact of globalisation on vehicle design and manufacture, I.T. applications, freight and logistics tasks.
- Opportunities for joint research and development priorities.

Implementation

- Good regulatory design takes account of implementation issues, and focusses on achieving compliance outcomes.

The assessment criteria used by the Working Group are summarised in Box 4.1.

Box 4.1. **Assessment criteria for alternative regulatory approaches**

Performance Standards

1. Performance standards for road safety, protection of infrastructure (pavements and bridges) can be specified and measured, and risks quantified (including computer simulation and field tests).

Mutual Recognition

2. Procedures and guidelines can be applied consistently to enable mutual recognition across multiple jurisdictions (*e.g.* guidelines for vehicle assessment, classification of roads, enforcement practices).

Utility of Roads

3. The freight transport task and vehicle performance can be related to variations in road and traffic conditions and parts of the network, including provisions for general access and regional or route access. Road safety risk and levels of service can be specified for each road classification.

Effective Compliance

4. A cost effective compliance and enforcement system is available, including compliance assurance and audit schemes, linked to the body of transport law, including chain of responsibility provisions and links between risk-based offences and sanctions and penalties.

Accessible

5. The regulation is accessible by the full range of vehicle and parts designers and manufacturers and large and small operators.

International

6. The regulatory regime accommodates international needs and opportunities, relating to the 'seamless' freight task, vehicle design and manufacture and research capacity.

Communications

7. The regulations are easily communicated and supported by education and training.

Implementation

8. Provision is made for existing non-complying vehicles.

Net Community Benefits

9. The regulatory alternative is supported by an evaluation of the net benefits to the community, demonstrating the economic, social and environmental benefits.

Alternative regulatory approaches

Six alternative approaches to the regulations of heavy vehicles have been identified. These are:

- ***Historical development of prescriptive rules*** based on in-field experience and limited analyses – the traditional evolution of prescriptive rules over time, not explicitly linked to defined performance criteria.

- *Use of performance standards as an* ***underlying basis for prescriptive rules*** – the translation of the agreed performance-based measures and thresholds (standards) into the equivalent prescriptive regulations, *i.e.* to use the performance-based measures to modernise the prescriptive regulations.

- *Use of performance standards under an* ***exemption*** *approach* – the application of performance-based regulation for non-standard vehicles outside the range of the prescriptive regulations covering mass and dimensions and general access. This provides for heavy vehicles approved to operate under administrative law arrangements (such as permits, or exemptions). The majority of vehicles would continue to operate under prescriptive regulations. Vehicles operating under administrative law arrangements based on performance standards would attract specific operating conditions that do not apply to other vehicles.

- *Use of a* ***holistic*** *performance standards approach* – the universal application of performance-based regulation, as a replacement for the current prescriptive regulation for heavy vehicles.

- *A* ***hybrid*** *performance standards approach* – a combination of the advantages of the first three regulatory approaches, perhaps as a stage in the eventual adoption of performance-based regulation. Under this approach, the majority of vehicles might continue to operate under prescriptive rules. New vehicle configurations that meet safety, infrastructure and environmental protection criteria could operate under either modified prescriptive regulations that provide standard rules for access to a road network; or exemptions under administrative law that provide greater flexibility but require greater certainty that the performance standards are met on the road through additional operating conditions.

- *A* ***road network*** *approach* – where appropriate performance standards are assigned to different parts of the road network and potentially operating conditions (*e.g.* lower speed limits) applied to ensure lower road and traffic standards are matched by superior vehicle performance. This may allow all current vehicles to have access to the whole network, but with differing operating conditions on different parts of the network to reflect the variations in performance of the vehicles themselves. This approach will provide certainty about safety outcomes being consistently achieved across the network, and could also provide a useful approach to prioritising upgrades across the network. It would require a trade-off to be made between how closely vehicle performance matches the road and traffic conditions on different routes and the number of categories the road network is divided into, bearing in mind that in many cases vehicles will travel on different parts of the network as they travel from origin to destination.

Performance–based standards can be used as alternatives to, or replacements for, a variety of prescriptive regulations. While this paper concentrates on the application of performance standards in place of prescriptive rules on vehicle mass, vehicle dimensions and configurations, they may also be used to control other safety–related outcomes or environmental performance.

Prescriptive regulation

Prescriptive regulations have a limited ability to ensure that vehicles behave in a desirable manner for the road and traffic conditions in which they operate. In addition, the link between most existing prescriptive rules and performance outcomes is tenuous and not well recognised. For example:

- Important road safety measures (*e.g.* stability for high centre of gravity vehicles during emergency manoeuvres in higher traffic volumes) may not be adequately regulated, or may be unnecessarily restrictive (*e.g.* for highly stable vehicles limited to the same prescriptive rules as other, less stable vehicles).

- Axle group mass limits are not the sole determinant of 'wear and tear' on pavements and bridges. While they are significant, the contributions of other factors, such as horizontal tyre forces, are not well understood and generally uncontrolled under present rules in most jurisdictions.

- 'Regulation creep', low levels of enforcement, inconsistent penalties and sanctions and enforcement tolerances allowed on prescriptive regulations undermine the credibility of the regulatory system.

- Limited potential for either innovation or the mutual recognition of vehicles allowed access in particular circumstances within a single jurisdiction.

As the size and mass of heavy vehicles increases, it is increasingly necessary to distinguish between the underlying road safety, infrastructure protection, environmental and amenity and land-use planning criteria for the primary freight (road and rail) network and those for the general access/local road network. Prescriptive regulation is proving to be inefficient in accommodating:

- Differences in swept path envelopes.

- The stability of vehicles in hilly terrain.

- Different bridge protection requirements.

- Stability during emergency manoeuvres in mixed traffic.

For prescriptive regulation there is a heavy reliance on road-side enforcement and little incentive to shift to improved compliance systems (alternative compliance; operator accreditation; audit systems; IT applications for monitoring route/location, speed, on-board weighing etc.). As prescriptive regulations have evolved over a long period, and were not designed with current compliance and enforcement tools and knowledge in mind, compliance outcomes are often poor. Enforcement is ineffective for sub-arterial and local road networks because of the high cost.

Performance-based regulatory systems could significantly improve compliance for the network generally, by improving understanding of the intent of the regulations. Regulatory theory suggests that this is a much under–valued factor in compliance behaviour (Parker 2000, Black 2001). Regulatory theorists also argue that improved enforcement approaches are more likely to be developed and implemented as part of a new regulatory system, than through amending compliance and enforcement systems for existing rules. Nevertheless, many of these benefits are possible under a prescriptive standards regime as well as under a performance standards approach to regulation.

Whilst there may be circumstances where generalised changes in prescriptive limits may be warranted (*i.e.* time has elapsed since the last update of limits on mass and dimensions), this is unlikely to be the situation generally. Some components of the transport system are already performing at or outside the limits of safety and infrastructure capacity, and further relaxation of prescriptive rules is therefore unlikely for these components of the system. As this is traditionally the major driver of broad regulatory reviews, such reviews are unlikely. Other parts of the system perform well within acceptable limits under the same prescriptive rules. Future benefits are more likely to be derived from the innovation and flexibility provided through performance-based systems that recognise these variations in performance, including distinguishing between road classes.

Exemptions approach

The exemption approach could provide an important stage in the development of a performance-based regulatory system and mutual recognition. However, for such an approach to be efficient and effective in achieving wider policy outcomes, it would need to incorporate the development and verification of consistent practices for:

- Performance assessments.
- The specification of operating conditions.
- The classification of the road network.
- Associated compliance and enforcement systems.

However, whilst providing major improvements in the regulation of the largest and heaviest vehicles, the potential of performance-based regulation for the vast majority of heavy vehicles would not be realised. This approach would require a clearly articulated and strong policy framework that will ensure consistent application of the standards. Otherwise, there is a danger of *ad hoc* implementation, and therefore inconsistent outcomes being achieved. By it’s nature, an exemption approach works under administrative decisions of governments, where the potential for inconsistent application is higher than if it were applied under primary legislative requirements.

Further, exemptions are strongly discouraged or simply not provided for in legislative systems in some OECD member countries. This is particularly notable in the European Union, although intra-city/intra-jurisdiction activity is not subject to the same constraints.

Road systems approach

The emphasis of this approach is on addressing the need and potential to more closely match the regulation of heavy vehicles to the different road and traffic circumstances — particularly distinguishing between the transport infrastructure needs of the primary freight task and the greater importance of amenity and environmental factors for local road networks. As such, the emphasis of this approach is on transport planning, rather than on regulation.

The regulatory system would be more credible and manageable if this distinction was emphasised. It deals with the pressures on governments by:

- The freight industry, seeking consistent regulation between jurisdictions and appropriate investment in the primary network.

- Local communities concerned with the intrusion of larger and heavier, and more specialised vehicles on local roads.

This is essentially a technical basis for classifying the freight network that links vehicle performance with the conditions in which a vehicle is operated to ensure that the outcomes meet both community and industry needs. It is likely to be an attractive approach for many jurisdictions having a significant mis-match between heavy vehicle regulations and the classification and condition of the road environment. It also provides a solid basis for identifying future investment priorities for improvements to the freight network, when combined with appropriate data on freight flows.

It is likely to be attractive to industry through the close link between performance standards and infrastructure investment priorities, and for regional and local governments through the potential of the smart compliance technology/IT systems (particularly for route and mass compliance).

As for a number of the other approaches the road systems approach is an essential part of the Hybrid approach and an important stage in the development of a performance based regulatory system.

Holistic approach

The holistic approach could be considered as the ultimate performance-based regulatory approach, similar to that which prevails in occupational health and safety regulatory systems in a number of OECD member countries. Its attainment would require:

- The completion of a joint research programme to provide a strong analytical understanding of the links between vehicle performance and safety and infrastructure outcomes.

- The verification and more widespread application of the ‘smarter’ compliance and enforcement systems.

- A mechanism for prioritising investments in infrastructure and pricing systems to manage access to the road network.

Such an approach provides a useful regulatory framework for:

- Higher level policy analysis, including modal integration.

- Co-ordinating international research effort into the underlying road safety and infrastructure performance relationships.

- Confirming the potential of a regulatory system for facilitating innovation and productivity.

- Focussing research into the development of results–oriented, risk–based compliance and enforcement systems.

- Improving the performance basis for classifying freight routes.

Hybrid approach

The hybrid approach most closely describes the performance-based standards regulatory systems being developed by the Australian National Road Transport Commission, the Land Transport Safety Authority in New Zealand and Austroads (a body whose members encompass the Australian and New Zealand road agencies).

The Australian approach provides an optional system that allows operators to operate under either prescriptive rules or with the additional flexibility afforded by performance standards that achieve the same or better outcomes. It also provides a practical approach to the staged development of a performance-based regulatory system, encompassing key features of each of the other approaches. It incorporates the use of performance standards as an underlying basis for the update of prescriptive regulation (available to the majority of heavy vehicle operators), the consistent assessment of future permits and exemptions using agreed performance criteria and guidelines, appropriate to the route classification system.

The New Zealand approach combines prescriptive regulations with a mandatory performance regulation to control vehicle stability, which has proven to pose a particular safety issue for the New Zealand transport system (more details are given later in this chapter in the section on country examples leading to improved outcomes).

Conclusion

Whilst improvements to the regulatory system must be appropriate for the particular circumstances, in all cases these will require the specification of performance criteria measures and thresholds (standards) and a shift to 'smarter' compliance and enforcement systems as described above.

The important steps from here on include joint OECD member country efforts to:

- Complete whatever evaluations are necessary to improve the specification of the net community benefits, incorporating the experience of member countries.

- Undertake a joint international research effort as necessary to improve the specification of an agreed list of performance standards.

- Design improved compliance and enforcement systems necessary to support a performance-based regulatory system.

Opportunities for improving the regulatory framework for heavy vehicles

Opportunities for improved outcomes

Safety

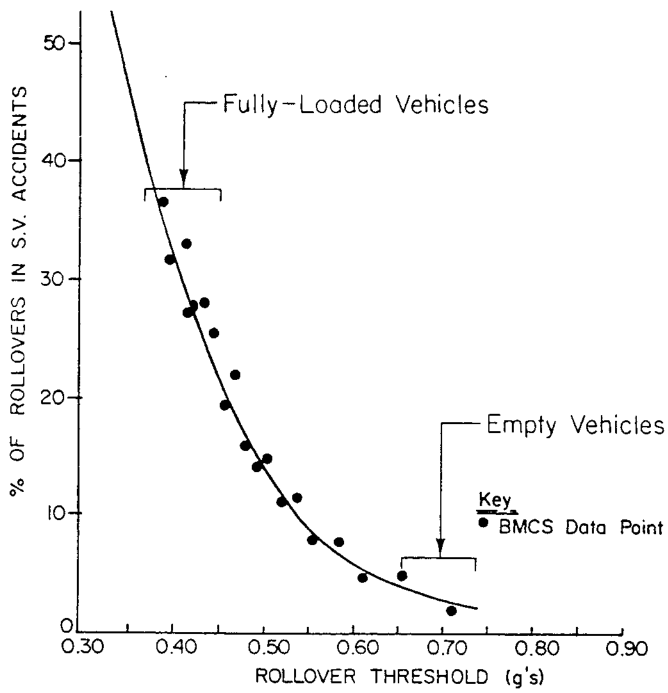
Safety is one of the fundamental drivers for regulating vehicle size and weight. However, the link between the prescriptive size and weight limits and the safety outcomes they are aimed at achieving is rather indirect. For example, by regulating maximum height we are, in part, trying to achieve a level of vehicle stability. But, within this maximum height envelope a wide range of vehicle stabilities is possible, going from very poor to quite good. Performance standards can be more directly aligned to the safety outcome that they are trying to achieve. It should be noted that performance measures generally involve some standardised test manoeuvre or procedure that is representative of actual operating conditions, but do not and cannot cover all possible operating scenarios. Thus, although the performance measure on which a performance standard is based is more directly linked to the safety outcome it is targeting, it is not necessarily a perfect match.

The NRTC and Austroads in Australia are currently undertaking a research programme aimed at developing an alternative compliance regime for heavy vehicles using Performance-Based Standards (PBS) rather than prescriptive requirements. This research (NRTC, 2003b) has identified a set of 20 Performance Standards that would form the basis of this regime (see Appendix B). Sixteen of these measures relate to safety and four of them to infrastructure protection.

While these 16 safety-related performance measures are not the only options that could be used, they have been selected to cover, in the view of the researchers, all the critical safety issues. Thus they provide a useful basis for discussing the potential safety gains from using performance measures as part of the regulatory regime.

Although, for all of these measures, it is obvious what constitutes good and bad performance and that poor performance will lead to worse safety outcomes in most cases, relatively little research and few data are available to quantify the relationship between performance and safety. For some key measures where the negative safety outcome is dramatic (*i.e.* vehicle rollover) some studies have attempted to relate vehicle performance as indicated by Static Roll Threshold (SRT) to rollover crash risk. A well-known early attempt at describing this relationship is shown in Figure 4.1(Ervin, 1983).

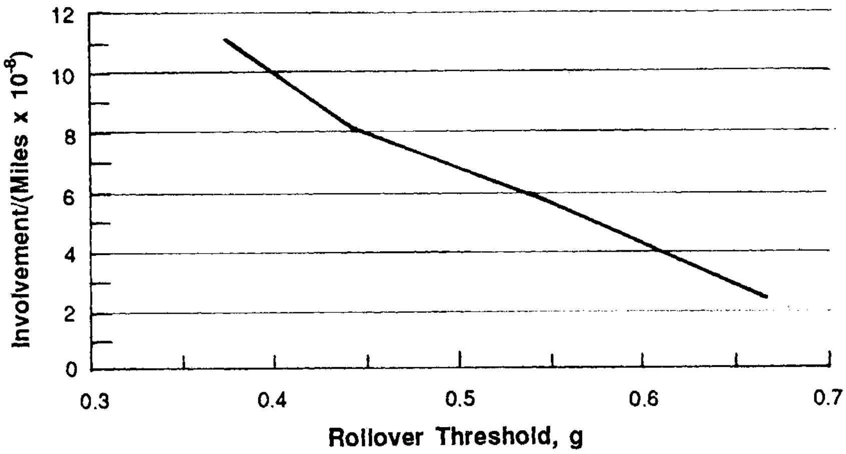
Figure 4.1. **Percentage of single vehicle accidents resulting in rollover**



Source: Ervin, 1983

A study by Fancher reported by Transportation Research Board (1990) found a relationship between fatal crash rate and rollover threshold as shown in Figure 4.2.

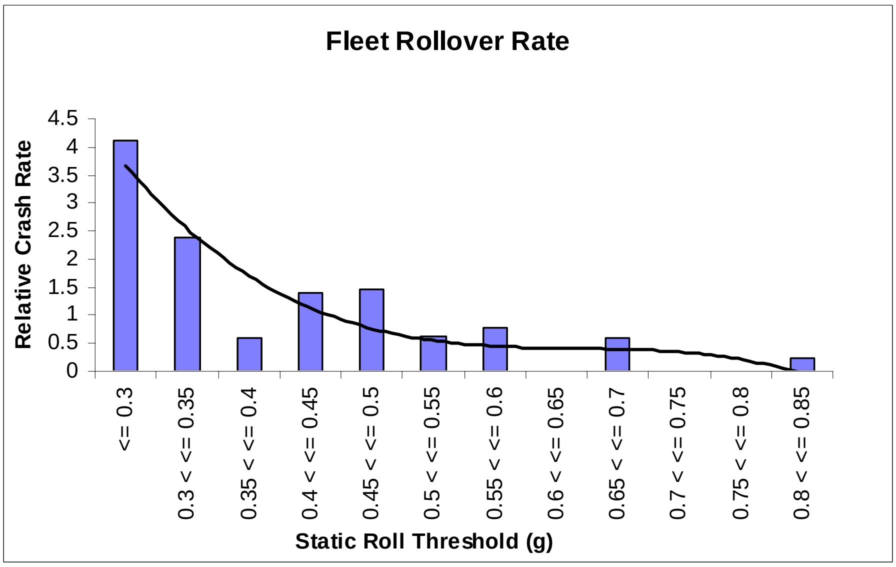
Figure 4.2. **Fatal crash rate versus static roll threshold**



Source: Fancher, 1990

A more recent study in New Zealand estimated the SRT distribution for the heavy vehicle fleet and for heavy vehicles involved in rollover and loss of control crashes. By dividing the crashed vehicle distribution by the fleet distribution the relative crash against SRT distribution as shown in Figure 4.3 was determined.

Figure 4.3. **Rollover crashes compared to static roll threshold in New Zealand**



Source: Mueller *et al*, 1999, de Pont *et al*, 2000.

Although these figures show different measures it is remarkable how similar the trends are, particularly as the underlying vehicle configurations and operating conditions are quite different. Ervin's results are for tractor-semi-trailer combinations in the USA where much of the distance travelled is on divided highways. The New Zealand results are for the entire New Zealand combination vehicle fleet (which is 61% truck-trailers, 29% tractor-semi-trailers, 9% B-doubles and 1% A-doubles) travelling almost entirely on two lane undivided highways. All three studies show a very significant increase in rollover crash rate for vehicles with lower SRTs.

Ervin's study analysed only vehicles involved in crashes and therefore it is not possible to make any further deductions regarding the underlying crash rate without making some additional assumptions about the fleet distribution of SRT and the relative crash involvement rate of vehicles with different SRT levels. The New Zealand study, however, did assess the SRT distribution for the fleet. Their results showed, for example, that in New Zealand approximately 15% of the fleet had an SRT below 0.35g but these vehicles accounted for 40% of the rollover and loss of control crashes. Thus the potential crash reductions achievable through improving the SRT performance of these vehicles can be estimated.

The Fancher study considered the relationship between fatal crash rate and braking efficiency, rearward amplification and steering sensitivity and in each case found an increase in crash rate with poor performance. For the last two measures, there was no safety gain in going from average to good performance. Fancher also considered low speed offtracking but found no link between performance and fatal crash rate. For each of the performance measures used in the Fancher study the vehicles were given one of three values which reflects the difficulty in determining the performance measure values from the limited vehicle data available in a crash database. Thus each of the performance measure sversus fatal crash rate graphs has only three points on it. This is not sufficient to fit a curve for the relationship.

The New Zealand study also considered the relationship between crash rate and Dynamic Load Transfer Ratio (DLTR), High Speed Transient Offtracking (HSTO) and Yaw Damping Ratio (YDR). These are all performance measures that might be expected to affect the rollover and loss of control crash rate. The crash rate versus DLTR curve showed a significant rise in crash rate as the level increased above 0.6 but was reasonably flat at lower DLTR values. HSTO showed a trend of increasing crash rate with increasing HSTO but no steep rise. However, the level of HSTO in the New Zealand fleet is quite low by international standards because the vehicles are not very long. YDR showed indications of a steep rise at levels below 0.15, but there were relatively few vehicles in this category so there is some uncertainty over this finding.

Overall Ervin's results seem to indicate that crash rates keep reducing as the performance measure improves, while the New Zealand study indicates a rapidly increasing crash rate with poor performance but a less clear cut relationship at better performance levels. The Fancher study results are similar to Ervin for SRT but more like the New Zealand study for the other performance measures. It is possible to use the results of these studies to make estimates of the safety gains from improved vehicle performance by setting standards.

A number of the other performance measures listed in the NTRC/Austroads study (see Appendix B) reflect a fit between the vehicle's performance and the infrastructure's capacity to accommodate the vehicle. Thus there is a need for both vehicles and the infrastructure to meet a common standard. For example:

Startability and *Gradability* reflect the vehicle's ability to start from rest on a grade and to maintain speed on a grade. Poor performance can lead to vehicles getting stuck and creating an obstruction or creating congestion so this is clearly undesirable. Provided road designers ensure that the maximum grades are below the minimum vehicle capabilities the system should perform. Quantifying the increased crash risk associated with a mismatch between the road geometry and the vehicle capabilities is very difficult.

Acceleration capability reflects the vehicle's ability to clear intersections and rail crossings, etc. For the infrastructure designer this relates directly to sight distances and speeds. Again the vehicle standard and the infrastructure standards need to match but the increases in crash risk associated with a mismatch are not known and difficult to determine.

Tracking Ability on a Straight Path describes the total width occupied by the vehicle and thus is directly related to the lane and road width requirements. There have been a number of studies relating road width and/or lane width to crash rate. These studies generally relate to two-lane roads (*i.e.* with opposing traffic). They have typically found that crash rates reduce with increasing width up to some point, typically a 3.7m lane width or 7.5m road width, and then either flatten out or in some studies increase. All of these studies are, of course, based on the mix of vehicles operating on the roads being analysed. It is difficult to use these findings to determine the safety impact of changing the width occupied by moving vehicles.

Braking Stability in a Turn is a similar measure as it describes the lane width occupied by the vehicle during hard braking while turning. There does not appear to be any information available on the relationship between crash rate and this performance characteristic.

Low-Speed Offtracking, *Frontal Swing* and *Tail Swing* all relate to the width requirements of the vehicle during low speed turning manoeuvres. These performance standards should be consistent with the standards for the geometric design of intersections and roundabouts and the associated lane markings. Again it is clear that a mismatch between the vehicle and infrastructure will increase the crash risk but it is difficult to quantify this effect.

The remaining measures are not so directly correlated with infrastructure standards. *Overtaking Time* is effectively a surrogate for overall vehicle length. In the absence of better information Milliken *et al* used a simplistic model for increased crash risk based on the additional exposure time to oncoming traffic but they recognised that this was a speculative approach. *Ride Quality (Driver Comfort)* represents the vehicle's response to the surface profile of the road but the relationship is complex. From a safety point of view it affects driver fatigue and alertness but this is difficult to quantify since there is no generally accepted method for evaluating this measure.

The final two measures, *Steer Tyre Friction Demand* and *Handling Quality (Understeer/ Oversteer)*, reflect the vehicle's handling performance during low speed and high speed manoeuvres respectively. Clearly, performance or lack of it in this regard will have an impact on safety but it has not been quantified. In the case of *Handling Quality* there is still debate over how it should be characterised and what constitutes acceptable performance.

Overall it is clear that there are a number of performance measures that impact on safety but for very few of them is there an established relationship between performance and crash risk. For some performance attributes that do affect safety there is not yet a generally accepted measure let alone standard.

Sustainability

"Sustainability" is a widely used term currently in relation to options for economic development and transport but there are a range of interpretations as to what this means. A landmark definition was given in 1987 by the World Commission on Environment and Development:

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

There is a challenge in converting this rather general philosophical definition into practical performance standards that can be applied to contribute to this goal. Safety is clearly a requirement of sustainability. Other obvious issues that arise are emissions, consumption of non-renewable resources in the form of fossil fuels, roading materials, metals etc as well as land use, impacts on communities, and economic development.

Market forces will encourage operators to use the most efficient vehicles possible. Thus, if a PBS regime enables operators to use larger, more efficient vehicles without compromising safety they will do so. This will have the positive effect (from a sustainability point of view) of decreasing the amount of fuel used per unit of freight and hence the emissions generated. However, if the improved efficiency of the transportation task leads to increased freight volumes, for example, through greater centralisation of processing or handling facilities, the sustainability gains are much less certain. Improved economic efficiency will be achieved but improved sustainability may not.

Performance measures specifying fuel consumption requirements have been used in the United States of America with limited success. The Corporate Average Fuel Economy (CAFE) requires vendors to sell a mix of vehicles whose weighted average fuel economy meets specified targets. Thus the performance standard applies to the fleet of vehicles rather than individual vehicles.

Some commentators have argued that the CAFE approach has had a negative effect on both fuel economy and safety. The argument is that CAFE has discouraged manufacturers from producing large family station wagons which have relatively poor fuel economy. However, large sports utility vehicles (SUVs) are classified as light trucks and are not subject to the same CAFE requirements and so these have become popular as the alternative to the station wagon for families requiring larger vehicles. SUVs have poorer fuel economy than the station wagons they have replaced and generally poorer safety performance being less stable and not as crashworthy in frontal impact. Although the causal link to CAFE is debatable, the substitution of station wagons by SUVs as family transport in the USA and elsewhere has occurred.

A recent white paper by the Martec Group (2002) compared the outcomes of the CAFE approach used in the USA with the taxation based approach used in Europe and concluded that the European approach has been more effective in achieving the defined public objectives of improved fuel economy. Although these results do not prove that a performance standard approach to achieving sustainability related outcomes does not work, they do show a need for a comprehensive approach as piece-meal measures can have undesirable side effects.

Infrastructure management

Pavement wear is generally controlled by prescriptive axle and axle group mass limits. This assumes that pavement wear results from vertical pavement loadings and that the same relationship between wear and vertical loads applies across all the pavement constructions on the road network.

While vertical loads are often a dominant component of pavement wear, horizontal loading can also be a source of pavement wear, particularly on inclines (grades) and on curves, where horizontal loads are generally greater.

In addition, pavement design recognises that a variety of failure mechanisms operate in practice, with unbound, asphalt, asphaltic concrete and concrete pavements all failing through different mechanisms. Consequently, the relationship between axle loads and critical vertical loads by axle configuration may differ substantially between different pavement constructions. Further, vertical loadings on pavements are influenced not only by axle load and configuration, but also by operating speed, tyre type and tyre contact pressure distribution. Work for the COST 334 project in Europe emphasised the importance of tyre considerations in resulting pavement wear (FEHRL, 2002). This work proposed a modification to traditional calculations of relative vertical load effects for different axle configurations to take account of different tyre constructs. Little is known about tyre contact pressure distribution, although it is believed to be a significant influence on pavement wear (NRTC, 2001).

Freight task

Prescriptive dimensions and mass regulations can impose restrictions on the size of a load or on how the load is distributed on the vehicle which may be sub-optimal from the point of view of either safety or efficiency or both. This situation typically occurs with freight that is made up of large discrete units. Performance based standards offer the opportunity for some of these vehicles to depart from the prescriptive limits and make these safety and/or efficiency gains.

For example, car transporters accommodate a relatively small integer number of cars. The situation can occur where a small increase in length, perhaps of only a metre or so, can enable two additional cars to be loaded. This results in substantial efficiency gains and also potentially safety gains through fewer vehicle trips being needed to complete the freight task. Under a performance based standards approach such a vehicle would be allowed to operate provided it could be designed to meet the performance standards that guarantee it can operate safely and with minimal impact on infrastructure.

A second example is provided by logging trucks. Logs are cut to various lengths depending on market requirements. For a given length of log, there is an integer number of packets of logs that can be placed on the vehicle. A 10m vehicle deck can accommodate two packets of 4.9m logs but only a single packet of 5.1m logs. The size of the load is determined by the mass limits so the single packet of logs is loaded to a much greater height than it would be if it could be split into two packets. The result is a much less stable vehicle. If, under performance based standards, a longer vehicle was permitted it could be considerably more stable and hence safer. This concept is discussed further, in relation to specific examples of developments in individual countries.

Many freight task–specific vehicles are currently built within the prescriptive envelope but the design focuses largely on the freight handling requirements with very little regard to stability. For example, many stock-feed and fertiliser vehicles have load spaces with a triangular shaped cross-section that results in a relatively high centre of gravity. With a performance based standards regime there may be advantages to designers to develop a more stable vehicle in order to gain some other benefits such as increased capacity.

Innovation

Most prescriptive dimensions and mass regulations define a set of acceptable vehicle configurations. Configurations that are not defined are not allowed, although there may be a permit process by which these vehicles can operate. Thus under this regime there is limited scope for innovation.

This does not mean that the introduction of a performance based standards regime for regulating heavy vehicles would immediately lead to a whole raft of radical new innovative configurations. The current configurations have evolved over a period of nearly 100 years and thus are quite well suited to most typical applications. In some niche applications there may be some significant innovative new configurations. For the more common applications it is more likely that there will be a gradual process of innovation as designers develop systems to improve the vehicle's performance while increasing its size.

The sorts of developments that are likely to occur are increased use of steerable axles in trailer bogies to improve low speed directional performance and to reduce horizontal tyre forces. This will enable longer vehicles to meet the performance standards and will facilitate the use of axle groups with more axles and hence greater capacity. Electronic control systems will be used to improve vehicle stability. These include active control of electronic braking systems to improve dynamic stability during evasive manoeuvres and active suspensions to improve stability during steady speed cornering. These systems may enable some vehicles to meet the performance standards that they would otherwise not be able to.

When has a performance-based approach been more applicable

For some aspects of vehicle performance, performance standards are almost universally used and there are no sensible prescriptive alternatives although there may be additional prescriptive requirements. For example, braking requirements are usually defined in terms of stopping distance or deceleration capability. Manoeuvrability requirements are typically defined in terms of a turning circle or envelope.

Performance based standards have also been used in a number of countries to assess vehicles that do not fit within the prescriptive limits for permit operations. A number of examples of these will be outlined, later in this section. This has been a successful approach and has a number of advantages. The alternatives under the prescriptive limits regime are to either not allow the vehicle to operate or to modify the prescription so that the vehicle complies. There is a third alternative of issuing a special permit but in democratic countries it is then very difficult not to issue a similar permit for every other vehicle that exceeds the prescriptive limits in the same way. Thus this is effectively the same as modifying the prescription.

By using a performance based standards approach, the process is transparent, the public and other road users can be reassured that the vehicle performs as well or better (depending on the levels set for the performance standards) than other vehicles, operating conditions can be set to ensure good performance and other operators can apply for similar permits if they can meet the standards.

Country examples leading to improved outcomes

Canada

Many of the performance measures that are currently used evolved from the Road Transport Association of Canada (RTAC) study conducted in the mid 1980s. The Saskatchewan Department of Highways and Transportation used vehicle performance criteria in reviewing their over-dimension permit system (Borbely *et al* 2000). This review recommended a less complicated system for dimensional variations which would include them in General Operation Regulations and would eliminate approximately 90% of over-dimension permits. The authors report that it has been difficult to implement these vehicle performance based criteria as functional and enforceable regulations. Saskatchewan's vehicle size and weight regulations and permit policies are generally based on vehicle performance criteria. The key benefits for Saskatchewan has been consistent technical criteria that can be used as a measure of safety.

Europe

The adoption of a performance based standards approach to size and weight regulation in Europe has been limited. One exception is "road-friendly" suspensions. Drive axles on trucks have been allowed a significant mass limit increase – from 10 tonnes to 11.5 tonnes – if fitted with air suspensions on the basis that air suspensions are "road-friendly". Suspensions other than air can qualify as equivalent-to-air for the purposes of this mass limit if they have a natural frequency of less than 2 Hz and a damping ratio greater than 20% of critical with at least half the damping coming from viscous dampers. Three alternative test procedures are defined to measure these parameters. This clearly is a performance standard, but interestingly air suspensions are assumed to comply without having to be tested.

In practice almost all new European trucks are fitted with air suspensions on the drive axles and very few steel suspensions meet the standard. It is difficult to know whether this is because air suspensions are superior, or because it is too difficult to design a steel suspension that meets the standard or because the compliance testing is too onerous.

The thinking behind this policy is obviously that the reduction in pavement wear from the use of "road-friendly" suspensions can be offset by an increase in mass which improves productivity. Based on current knowledge of the effect of dynamic loading on pavement wear, at the individual vehicle level the additional mass would be expected to generate more additional wear than the "road-friendly" suspension saves. In terms of the transport system as whole the outcome may be beneficial as the total cost may be reduced. There appears to be little information available on whether this measure has achieved a positive outcome.

Australia

Since the mid 1990s performance based assessments have been used in Australia to justify a range of permit vehicles and variations to dimensions and mass regulations for specific configurations. An extensive summary of these is given by Prem *et al* (1999). Broadly, most of these applications of performance measures can be split into three categories: innovative long combination vehicles, dimension and mass limit variations for truck-trailer combinations and height limit variations. In addition Australia has introduced mass limit concessions for "road-friendly" suspensions with criteria similar to the European measures described above. The major differences in the Australian approach are that:

- The concessions apply to all axle groups not just drive axles.

- Air suspensions do not qualify as of right. They have to be tested just like any other suspension.

- A public domain list of suspensions that have been tested and passed is maintained so that suspensions are not re-tested unnecessarily.

As with the European situation there is little information on whether the outcome of this measure is positive. In the Australian case this measure has only been in place for a relatively short time.

Performance criteria have been used in Australia to assess larger innovative vehicles for suitability to operate in limited access situations at high masses (Bruzsa and Hurnall 1996, Sweatman *et al* 1997, Bruzsa and Hurnall 1998, McFarlane 2000). Australia has four levels of access defined with different dimensions and mass limits for each. For general access the maximum combination length is 19m and the maximum mass is 42.5 tonnes. There are two types of restricted access vehicles, the medium combination vehicle (MCV), which is up to 25m long with a combination mass of up to 62.5 tonnes and the long combination vehicle (LCV), which can be up to 53.5m long and up to 115.5 tonnes in weight. LCVs, which are also called road trains, are split onto two types, the type 1, which is up to 36.5m long and 79 tonnes and the type 2, which are to the maxima defined above. Performance assessments have been used since the early 1990s to evaluate innovative combinations, which utilise B-coupled trailers and tri-axle and sometimes quad axle groups. These carry higher masses than the comparable road trains while performing at least as well in the key performance measures. The assessments have used to obtain permits to operate on specified routes.

A number of these vehicles have been operating for some time in several states. They are clearly economically efficient because they continue to be used but there is limited information available on their safety performance. In any case the relatively small numbers of these vehicles means that unless they were disastrous from a safety point of view there would be insufficient data to draw conclusions with reasonable confidence.

Performance assessments have also been used to validate mass limit and some dimension changes particularly for truck-trailer configurations. These have largely been undertaken by individual states and the resulting configurations generally cannot operate interstate. Examples are:

- Truck-trailer combinations in Victoria where a 3-axle truck 4-axle trailer combination is permitted to have a GCM of 50 tonnes at 19m overall length (VicRoads 1997a). If carrying logs, this vehicle is allowed to have 22m overall length (VicRoads 1999). The 3-axle truck 3-axle trailer combination is allowed 45 tonnes and 19m overall length (VicRoads 1997b).

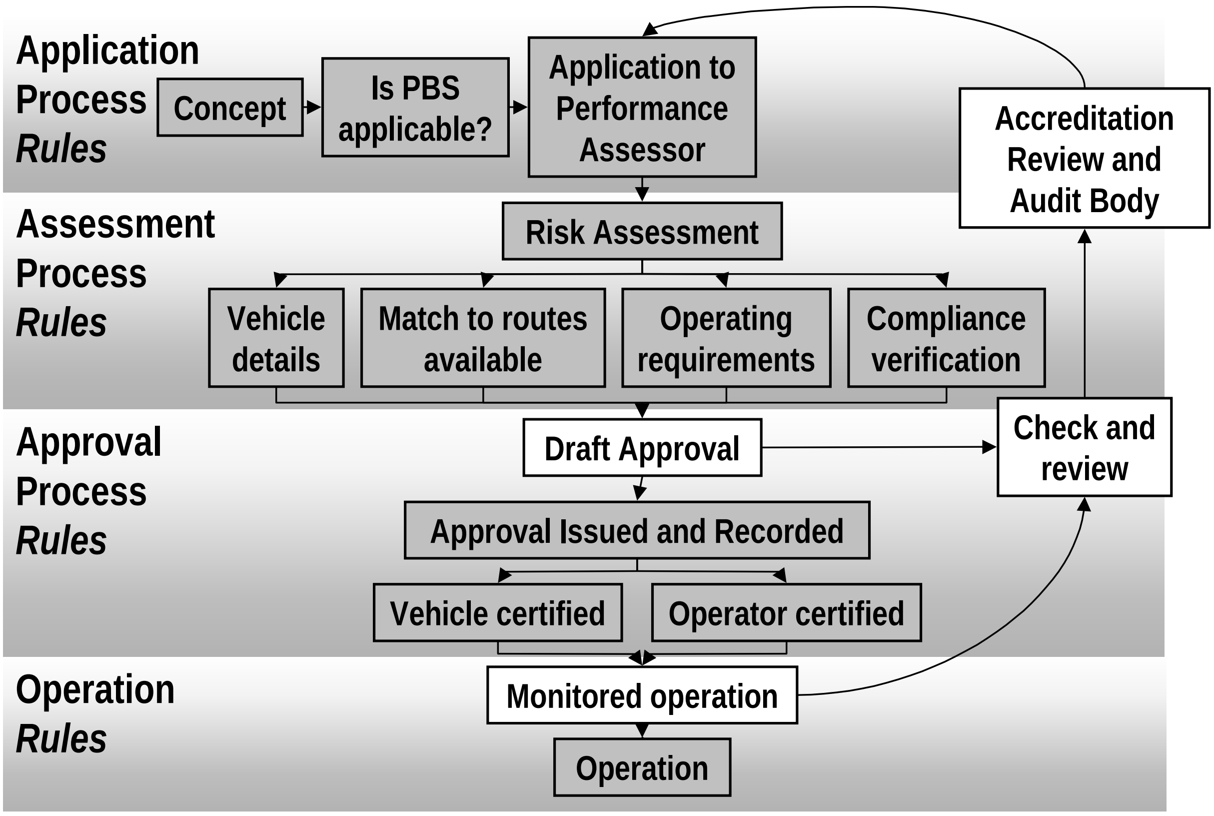
- In Queensland, the 4-axle trailer combination has a GCM of 49.5 tonnes while the 3-axle trailer is being considered for 45 tonnes.

- In New South Wales, the limits are 50 tonnes and 48 tonnes respectively.

The mass increases permitted are clearly intended to increase productivity while maintaining adequate safety performance. The length increase for log trucks in Victoria is to accommodate the longer logs. The potential productivity gains are obvious but it is difficult to determine whether or not the safety outcome has been achieved.

The third category of dimensional limit changes based on performance assessments are height variations. In Victoria, vans and semi-trailers are allowed to operate at 4.6m height (rather than 4.3m) provided the deck is low enough and the mass is at least 10% below the maximum. A similar height concession is given to hay trucks if their deck height is low enough. Queensland allows the same height concession for semi-trailers as Victoria subject to the same deck height restrictions but without the mass restriction. These concessions are all based on a series of tests conducted by Elischer *et al* (1997) and Elischer and Prem (1998). The intended outcome is to improve the productivity of volume limited vehicles without compromising their safety. No information has been found on whether this objective has been achieved.

Figure 4.4. **Outline of Australian regulatory framework for performance-based standards**



Source: NTRC 2003a

In addition, Australia has developed a performance–based regulatory system to operate as an optional alternative to prescriptive rules on mass, dimension and configuration. This system incorporates explicit safety criteria, infrastructure protection standards and environmental protection requirements. Vehicles meeting these requirements are not required to meet specified prescriptive limits on mass, dimension and configurations. Twenty safety and infrastructure protection standards have been developed and some of these vary to ensure that risks are adequately controlled across differing road and traffic conditions. Four levels of performance requirements have been specified where these variations were appropriate. For example, low speed swept path, which determines whether a vehicle can safely fit around a corner at low speed will vary across four categories of roads, reflecting differences in the typical or design capabilities of corner and intersection design on different segments of the road network.

These standards apply through a complete regulatory system which embodies compliance and enforcement mechanisms that are risk based and provide high guarantees that the expected outcomes are achieved. Figure 4.4 provides an outline of how the approach operates. It relies on a risk assessment process undertaken by an accredited performance assessor, followed by an approval process to check that vehicles to be used under a PBS approval match the design that was assessed and that operators have in place the appropriate management and other systems to ensure that they meet the compliance verification and operating requirements.

New Zealand

New Zealand was probably the first country to adopt the use of performance standards for regulating size and weight. They have been used in New Zealand within a generally prescriptive regulatory regime since about 1989 to allow gains in heavy vehicle productivity. Until 2002, safety regulations for heavy vehicles in New Zealand were based on prescriptive legislation for size and weight limits, and equipment. However, there was provision for variations to the legal requirements where departure from the prescriptive requirements may be justified by productivity improvements whilst maintaining safety levels equivalent to the prescribed regulations. The provisions developed in the regulations depend on the complexity of the performance standard and the number of vehicles involved. In some instances individual cases were considered. Cost benefit analysis was applied to all new proposals considered (Edgar 1995).

In 2002 the dimensions and mass regulations were reviewed and a new dimensions and mass rule (Land Transport Safety Authority, 2002) came into force. This new rule did not bring in any significant increases in the size and weight limits but rationalised the regulations for greater consistency. A number of the dimension limit changes were based on performance assessments and were designed to encourage better performing configurations. In addition for the first time anywhere in the world a rollover stability requirement was brought in for all large heavy vehicles (de Pont *et al*, 2002). To facilitate the implementation a public domain simple-to-use computer programme (Land Transport Safety Authority, 2002) to calculate stability was developed.

Vehicles assessed and approved under the pre 2002 regulations include 44 tonne A-doubles. A-doubles approved to operate at GCMs exceeding 39t and up to 44t were required to achieve levels of stability defined principally by three performance measures (static roll threshold, dynamic load transfer ratio and high speed transient offtracking). Compliance is determined by computer simulation as practical tests were considered either too dangerous because of the required test manoeuvres and the risk of rollover if the vehicle performs below the standard, and iterative redesign of an actual vehicle to gain compliance would be difficult. A range of conditions applied to this policy, such as: vehicle shall be simulated in the fully laden condition; vehicle designs shall be such that the simulated loading conditions cannot be exceeded; maximum speed capability shall be controlled; the type of produce carried shall be specified; each approval is valid only for the units specified in the combination.

The policy was developed specifically to meet the needs of the dairy industry for farm milk collection. Compliance costs and technical complexity have discouraged other industries, but the policy does not exclude other types of operation.

The policy is considered a qualified success 18, and twenty combinations were put into operation. The operations have reported strong driver support for these vehicles and reduced operating and maintenance costs. However, very high prototype development costs and initial compliance costs have discouraged a number of operators from using this policy.

The overall outcome of this policy has been to encourage the use of configurations with superior stability and handling.

A second example of assessment under the pre-2002 regulations is that for truck-trailer combinations up to 20m and 44t. A 44t GCM limit became available in February 1989 for B-trains and some 19m truck-trailer combinations. A new policy released in January 1992 allowed truck-trailer combinations to operate up to 20m overall length (Land Transport Safety Authority, 1997).

The introduction of 20m truck-trailers was preceded by demonstration trials that identified it was necessary to ensure the swept path and off-tracking did not exceed the road space parameters. It was also necessary to ensure that inter-vehicle spacing was controlled to avoid vehicle bodies/loads touching during general manoeuvring. A computer programme for assessing vehicles was developed that simulates performance in a low-speed turn. The programme calculates inter-vehicle spacing (shortest distance between rear of truck and front of trailer) and off-tracking (Land Transport Safety Authority 1997*a*). Compliance was a requirement of obtaining a permit to operate at 20m overall length.

As an extension of this, the forestry industry wanted to operate tri-axle drive and other similar tri-axle truck-trailer combinations at 44t and 20m length. Safety and productivity goals were demonstrated in trials, and performance and stability predicted by computer simulations were verified in the field. Successful results from these trials have meant that tri-axle drive and other similar tri-axle configurations are approved combinations operating up to 20m and 44t.

To address the high rollover crash rate of two, three and four axle full trailers carrying logs, restrictions were imposed on load height to bring stability within safer limits (Land Transport Safety Authority 1997*b*). For two and three axle trailers the load height has been restricted to 3.5m when carrying logs of any length. The corresponding load height restriction for four axle trailers was 3.8m. These height values were determined from computer simulation based performance assessments of the rollover stability of typical logging trucks. These height restrictions have been superseded by the 2002 Rule, which specifies a stability requirement for all large heavy vehicles. Further measures to improve the rollover stability of logging trucks were introduced in 2002 with the permitting of 22m log truck-trailer combinations. This length increase was permitted to allow longer lengths of log to be carried as two packet loads on the trailers, thus reducing the height and improving the stability. In order to operate at 22m length the vehicles are restricted to 3.2m load height and have considerably enhanced stability. The justification for this variation from the regulations was based on an extensive performance assessment of the vehicles followed by monitored road trials. As part of its own efforts to address the problem the industry has established a rollover crash database to monitor all rollovers. This has been operating for about three years now. Although the absolute number of rollover crashes has remained relatively constant, the industry has grown by 70-80% over that time and so the rollover crash rate has reduced very significantly.

Most of the variations to the regulations that had been allowed under special permit were incorporated into the new dimensions and mass rule in 2002. The 44 tonne A-double requirements were not included but there have been no new permits issued for a number of years. Existing vehicles will continues to operate under “grandfather” rights. The 20m truck-trailers are incorporated in the rule. The height restrictions on log trailers are covered by the stability requirements. The 22m length allowance for log trucks still exists as an exemption to the rule.

The rule was developed using extensive performance–based assessments using computer simulation analyses. Steady speed rollover stability is required through an explicit performance assessment, which is made possible through the development of a simple easy-to-use method for undertaking this assessment. No similar simple method has yet been developed to assess dynamic rollover stability. However, the rule itself has a number of dimensional requirements that, together with the SRT requirement, are designed to encourage more dynamically stable vehicle configurations. The rule was designed to achieve significant improved safety outcomes but it is too soon to say whether these have been achieved.

Compliance and enforcement systems

Objectives

The objectives of enforcement systems are often unclear. In the heavy vehicle regulation sector, they are frequently to detect as many breaches of prescriptive rules that apply to heavy vehicles as possible. But is this an appropriate objective? The outcome that the regulations seek to achieve are more important than simply detecting breaches of the regulations. These relate to safety, infrastructure protection, traffic management, amenity, efficient transport outcomes.

If the prescriptive rules perfectly achieved these objectives, an appropriate objective of enforcement would be to achieve 100% compliance. If the prescriptive rules do not perfectly achieve them, the policy outcomes would not necessarily be achieved by 100% compliance – performance that is better than compliance with the prescriptive rules might be needed in some instances. Full compliance might be possible if there is a sufficient combination of the following to provide a strong deterrent effect:

- Enforcement resources to detect non-compliance.
- Penalties and sanctions.
- Likelihood of receiving these penalties and sanctions.

This is often hard to achieve, as the commercial benefits of non-compliance with mass and dimension rules are often substantial and penalties often relatively minor in comparison. The level of enforcement resources is also often insufficient to provide a significant deterrence effect.

An ideal system would provide incentives for compliance without the need for deterrence through enforcement. This may not be achievable in the arena of controls over vehicle loading, due to the size of the potential commercial benefits of non-compliance noted above. However, new technologies in compliance systems and new monitoring tools mean that a range of different approaches is now possible.

Regulatory approaches

For compliance and enforcement systems to be effective and efficient it is essential that:

- Those responsible for compliance understand the regulatory requirements.
- They must also be willing to comply.

- They must have the ability to comply (OECD 2000).

Under a traditional, prescriptive, 'command and control' approach to regulation, the first and last of these are not always easy and the second is more difficult to achieve. Under the exemption, hybrid and holistic approaches to performance–based regulation, the first is still difficult, albeit simpler than under a prescriptive approach to regulation, but the latter two are relatively easy.

Regardless of which approach to regulation is adopted, improved results can be achieved by moving towards an outcomes–oriented, risk–based approach to compliance and enforcement. Under such a system, the compliance arrangements might be described as performance–based, as much as the regulations for which compliance is sought. This might comprise (NRTC 2000*a*, Jaguer Consulting 2003):

- Completion of a risk assessment.

- Intensive compliance effort (for example, constant electronic monitoring) required for high risk factors, and less intensive (for example, road side detection) for low risk factors.

- Shifting of responsibility for monitoring and demonstrating compliance to those responsible for outcomes.

- Applying responsibility for compliance across the whole chain of decisions that leads to the compliance or non-compliance results. That is, extending the chain of responsibility beyond the vehicle's driver to all others involved in deciding how it is operated. This might include packers, loaders, dispatchers, the vehicle owner, manufacturers, purchasers of freight services and so on. This approach can ensure that the burden of compliance and penalties for non-compliance falls where there is greatest potential to achieve the results sought.

- Establishing a hierarchy of penalties and sanctions that enable the responses to non-compliance to match the offence. More serious offences should attract a higher penalty, and more deliberate or persistent non-compliant behaviour should attract more severe penalties and sanctions.

Vehicle compliance

Traditional systems apply a single set of rules to all vehicles. This is still the case under a performance–based regulatory system that provides greater flexibility, although the design of vehicles may differ from case to case. Consequently, vehicle compliance may appear more complex under a regulatory approach based on performance standards. The emphasis of vehicle compliance shifts from checking compliance against a single set of rules to checking that:

- A proposed vehicle design meets the required performance rules.

- All vehicles to be operated under the performance rules have the design features identified in the proposal which were key to the proposal meeting the performance rules.

- Trailers and motor vehicles are combined or configured in the manner intended, which was found to meet the performance rules.

Under standard prescriptive rules, trailers are generally assessed as meeting the rules and can then be operated with a tractor/prime mover or rigid truck. When the performance of a vehicle is examined, the whole vehicle must be considered, including both motor vehicles and any trailers. Consequently, it is important that the trailer used is the same as that which was assessed as allowing a vehicle configuration to meet the performance rules.

This becomes a communications issue to make sure the design features that are key to the vehicle meeting the performance criteria are known and understood. The normal mechanisms of checking vehicle compliance can then apply, albeit to a different set of criteria.

There are currently two major approaches to checking vehicle compliance, one operated in the European Union and the other in the United States of America. Systems used in other countries reflect minor variations on these two major approaches:

- The type approval system requires the manufacturer to offer the system for approval before production. Conformance of production checks are also an integral part of type approval.

- The self-certification system requires the manufacturer to retain records of compliance and be prepared to prove to the regulatory authority that the system complies with any regulation should that authority decide to do conformance of production checks. Self-certification allows the manufacturer to enter a new vehicle in a market without prior approval.

The downside to increased variation in what is allowable in vehicle design is that this increases market segmentation. This may lead to a loss of economies of scale in vehicle production and may reduce the on-sale value of vehicles. This is because highly specialised vehicles have reduced scope for use in other purposes or by other operators. Nevertheless, these factors may be outweighed by the productivity advantages that can be gained through more flexible regulations.

Operations compliance

The key operational factors that may need to be controlled to ensure that performance standards are met by vehicles in use include:

- Loading — Loading is a key factor in issues relating to vehicle stability. A number of the performance measures that have been developed and used in various countries relate to stability of vehicles. These measures are sensitive to vehicle loading, not just in terms of axle masses, but also in relation to the factors that influence centre of gravity. These include the density of the freight being carried, how the freight is distributed over the loading area (both horizontally and vertically), and the load height.

- Route choice — Clearly route choice is a significant operational issue in compliance with performance standards if the standards that are required to be met vary across the road network. This may be a particular issue with bridge loadings.

- Speed — A variety of the safety performance standards developed in Australia and elsewhere are also highly sensitive to speed. This includes some stability measures, and also includes measures of the amount of lane space a vehicle occupies in higher speed manoeuvres.

- **Vehicle maintenance** Vehicle maintenance becomes a major factor where it is important for a component or part to be replaced with an item that performs in the same manner. For example, the ability of a vehicle to meet the necessary stability standards may depend on the performance of its suspension system. If different shock absorbers were fitted and this resulted in a change in the performance of the suspension system, the vehicle may no longer be able to meet the stability requirements.

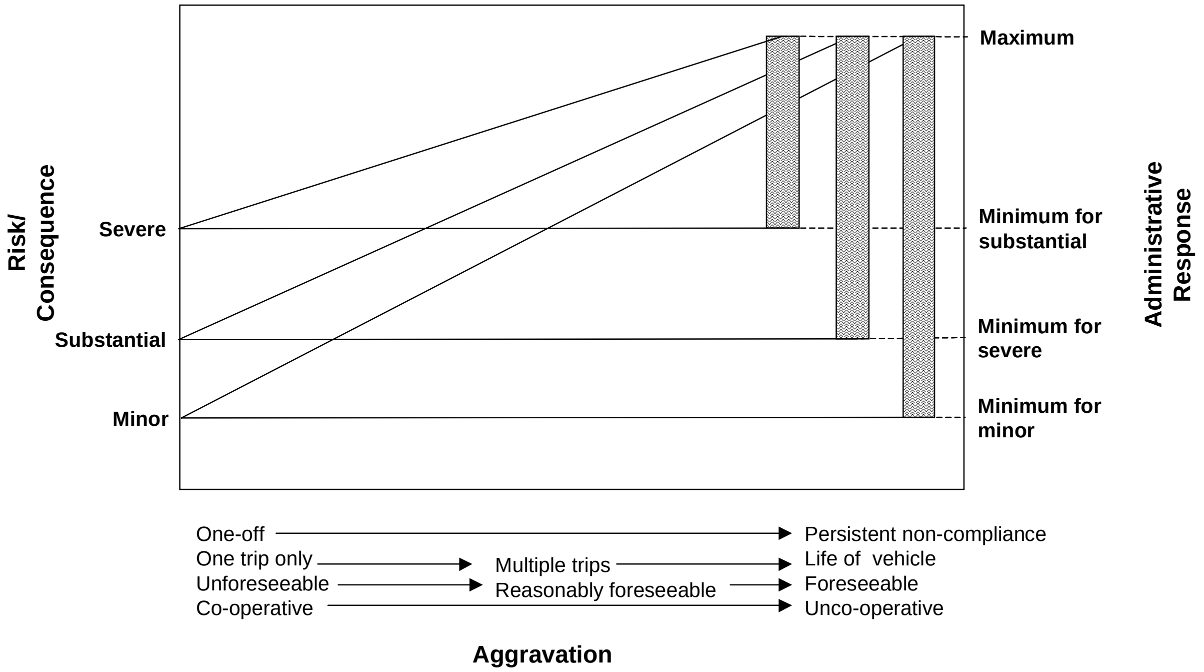
- **Driver choice and vehicle choice** The importance of vehicle choice has been noted above, as it is the combination of both trailer and motor vehicle that determines how a vehicle will operate. The driver is the greatest unknown in the equation: the safest and most skilled driver is probably better to have behind the wheel of a poorly performing truck than a dangerous driver behind the wheel of a safe truck. Nevertheless, driver choice is a significant factor; it may be inappropriate for a driver who is unfamiliar with a highly specialised vehicle to drive it without adequate training.

Australia has developed a risk–based approach to ensuring compliance which is expected to be more effective than a traditional approach that focuses on single events and the driver only. One aspect of this proposed approach is illustrated in Figure 4.5. The United States of American and Canadian safety ratings systems which attempt to identify risky trucking operators and concentrate enforcement effort on them has a similar impact of focussing attention on those operators who are found to repeatedly breach their operational requirements. The Australian proposal goes further, however, by seeking to match penalties and sanctions with the risks and consequences of non-compliance. This includes the potential for penalties to recover costs to infrastructure of additional wear from overloading and to be matched to the financial benefits of overloading.

It also includes imposing compliance verification requirements on operators that match the likelihood and consequences of non-compliance. Highly risky factors would be accompanied by compliance verification requirements that deliver a high degree of certainty that compliance is achieved. For example, this might be achieved through electronic monitoring and either real time or regular reporting of every breach, however minor. Less risky factors might be subject to audit arrangements and the least risky factors might rely on traditional on-road enforcement arrangements only.

These types of arrangements largely transfer the burden of ensuring compliance to those who benefit from the additional flexibility and potential productivity gains associated with moving to performance standards.

Figure 4.5. **Risk-based responses to breaches of performance standards requirements proposed in Australia**



Source: NRTC 2003.

Chapter 5

PERFORMANCE BASED MEASURES AND STANDARDS

Measures

A *performance measure* quantifies how a vehicle performs for a specific circumstance or manoeuvre. In other words, a *performance measure* is 'an objective quantity used to evaluate a system, derived by a specific method of analysis or computation from a specified test method, procedure or practice.' (NRTC, 2000*b*). The manoeuvre and the test method for measuring the vehicle's performance must be specified in detail in order for the *performance measure* to be objective.

This chapter provides examples of performance measures in order to illustrate the potential range of performance measures and different ways in which they might be applied. In doing so, examples are drawn from two countries that have developed very similar performance measures, but applied them in different ways. The two countries used in this comparison are Australia and Canada.

In preparing the alternative regulatory approach being developed in Australia, considerable effort has been expended in developing a national set of performance measures by which to assess heavy vehicles. These standards will form the criteria for establishing whether proposals for vehicle operations meet the required safety and infrastructure protection standards to operate under the Australian PBS approach to regulating heavy vehicle operations. This approach is being developed as an optional alternative to existing prescriptive rules on vehicle mass, dimensions and configuration.

Similarly, considerable effort has been expended in Canada to identify the performance outcomes that provinces seek to achieve through prescriptive regulations. In doing so, a number of performance measures have been identified. Prescriptive rules for heavy vehicles are based directly on the performance measures.

Performance measures developed in these two processes are presented here by way of examples of the range of performance measures that might be used to describe the outcomes required of vehicles in a regulatory system. A range of other examples exist, although not in such a comprehensive manner as these two sets of examples.

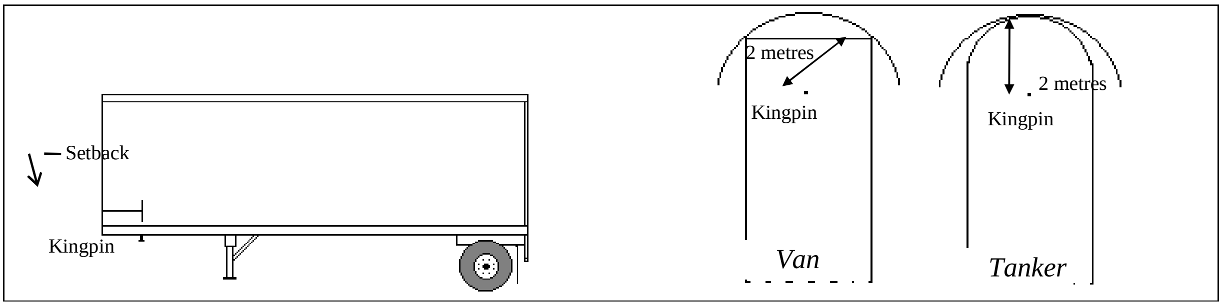
For safety outcomes

Both Canada and Australia have developed a range of performance measures designed to address safety outcomes. Examples of these are discussed here.

Front swing out

Under Canada's prescriptive standards, the distance from the kingpin to any point forward of the kingpin on the semitrailer must not be more than 2 m (using a radius around the kingpin), as shown in Figure 5.1.

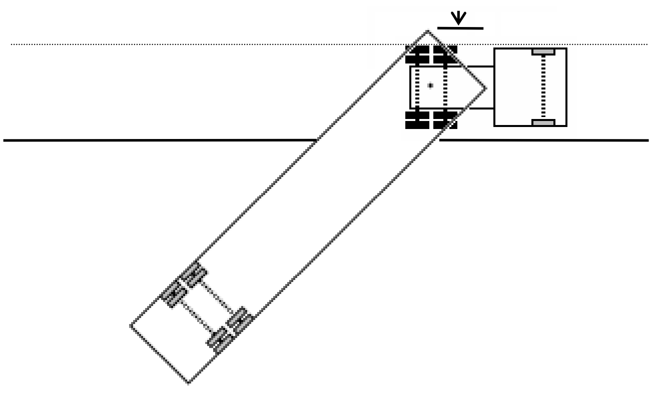
Figure 5.1. **Front swing out prescriptive rules**



Source: Pearson, 1996.

The objective of this limit is to reduce the likelihood that the front corner of the trailer will project into the adjacent lane of traffic when a tractor-trailer combination turns onto a highway, as illustrated in Figure 5.2. In this example, the performance measure is the extent to which the front corner of the trailer projects beyond the centre line.

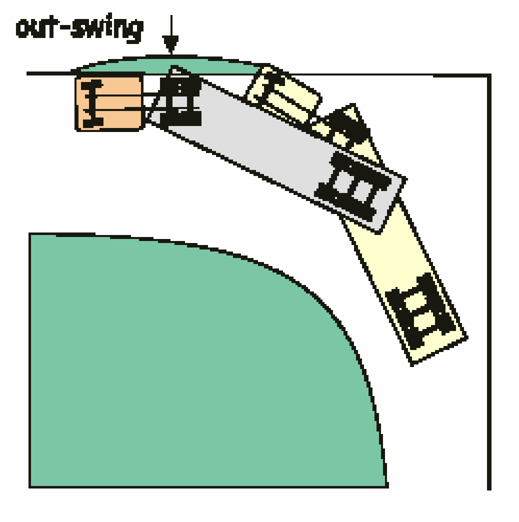
Figure 5.2. **Front swing out performance measure underlying Canadian prescriptive rules**



Source: Pearson, 1996.

With this control, the maximum amount of front swing out which could occur would be no greater than about 0.8 metres. The front corner of the trailer is visible to the truck driver through the turn, and extra precautions can be taken to ensure that there is no intrusion into the adjacent lane. A very similar performance measure is proposed in Australia (see Figure 5.3), in this case to apply as a direct performance standard rather than as the basis of prescriptive rules.

Figure 5.3. **Frontal swing out performance measure used in Australia**



Source: ARTSA, 2003.

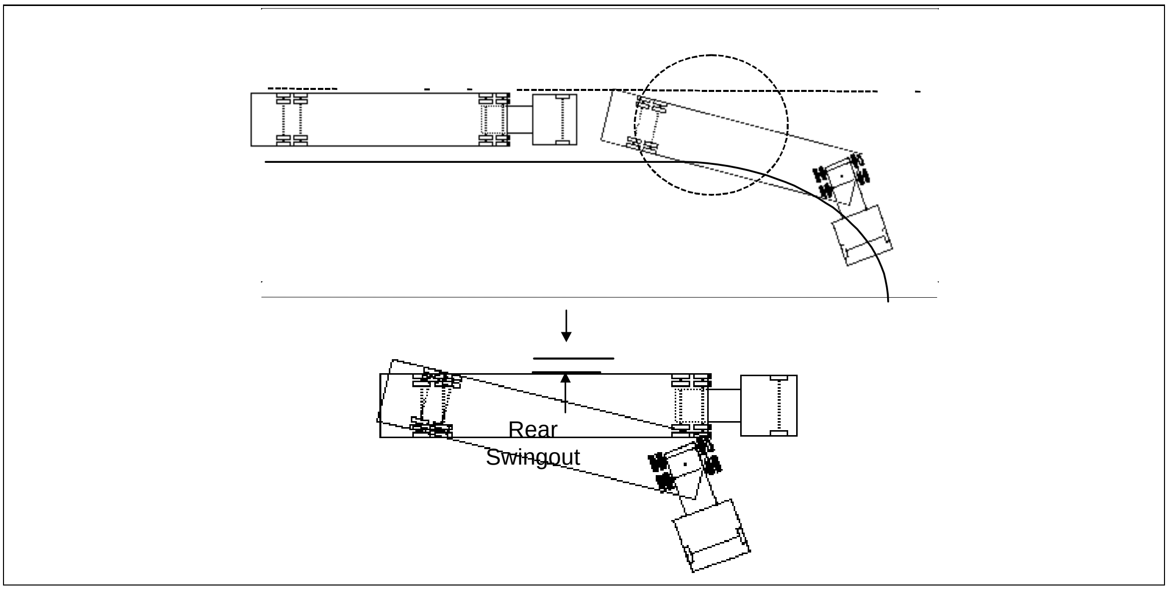
Rear swing out

When a tractor trailer combination makes a turn, the rear outside corner of the trailer follows a path outside the path taken by the trailer axles. The amount of "swing out" which occurs is a function of:

- The rear overhang on the trailer (distance from the axles to the rear bumper).
- The wheelbase of the trailer (distance from the kingpin to the trailer axles).
- The radius and duration of the turn.

To be able to operate safely on the highway, the rear corner of the trailer should not swing out so far that it crosses the centre line into the adjacent lane of traffic. In contrast to front swing out, the driver cannot see swing out at the rear of the trailer during turning manoeuvres. For typical Canadian highways used by trucks up to 2.6 metres wide, the maximum acceptable rear swing out would be about 0.46 metres (18"). This is illustrated in Figure 5.4.

Figure 5.4. **Rear swing out performance measure underlying Canadian prescriptive rule**

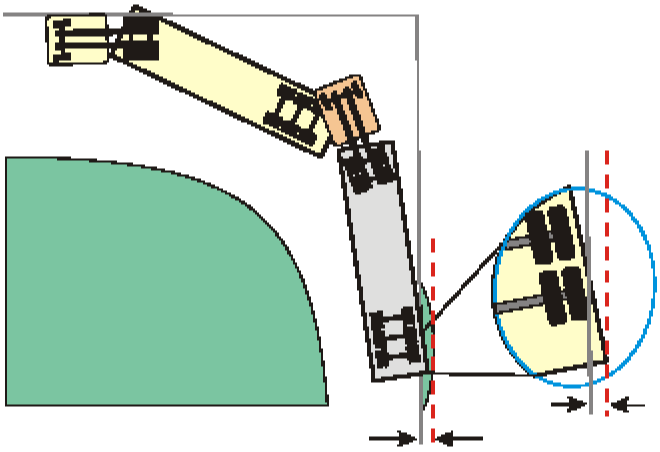


Source: Pearson, 1996.

To ensure that this limit is not exceeded, the Canadian national standards restrict the effective rear overhang to no more than 35% of the wheelbase of the trailer. With this control even the longest allowable trailer in Canada (16.2 m or 53’) should be capable of turning off a typical two–lane highway without the rear corner crossing the highway centre line.

Again, a similar performance measure has been developed in Australia to apply as regulatory performance standard under the alternative PBS regulatory system, as shown in Figure 5.5.

Figure 5.5. **Tail swing performance measure: Australia**

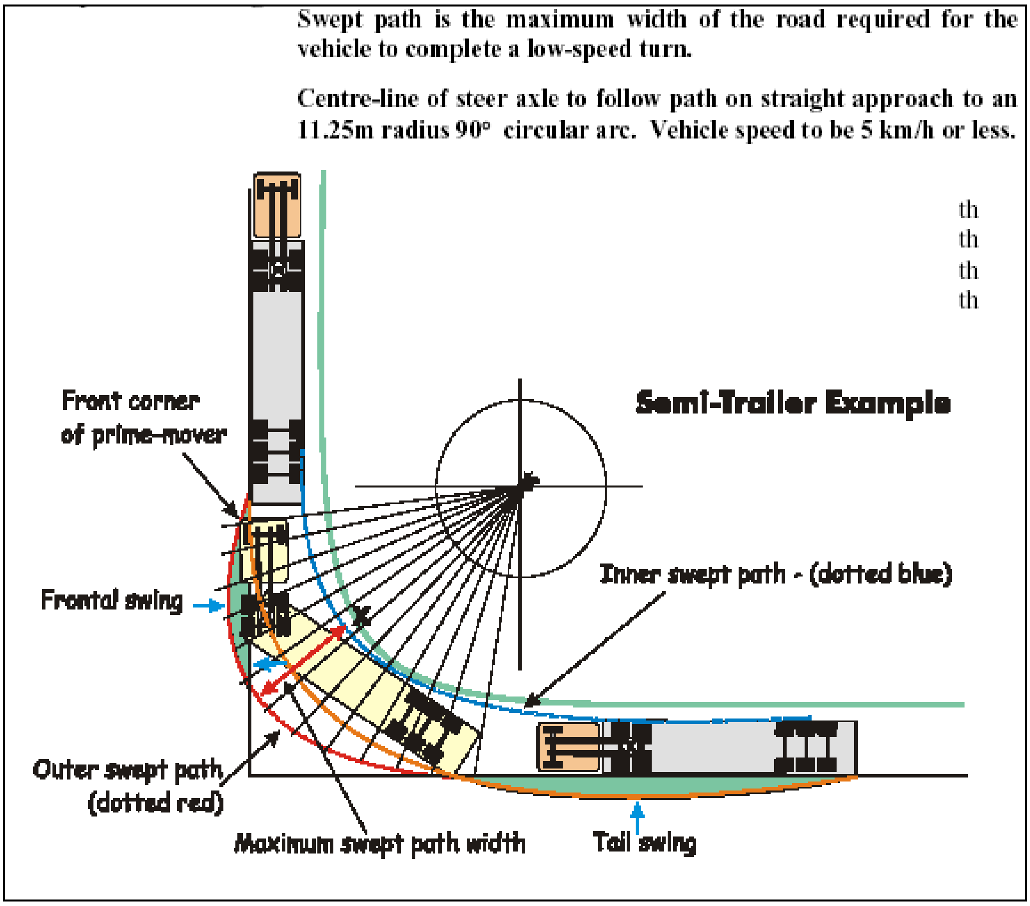


Source: ARTSA, 2003.

Off tracking/swept path

The amount of space required by a vehicle to make a turn is directly related to the length of its wheelbase. For tractor-semitrailer combinations, the wheelbases of both the tractor and the semitrailer influence the amount of turning space required. The Australian performance measure developed to control this safety outcome is illustrated in Figure 5.6.

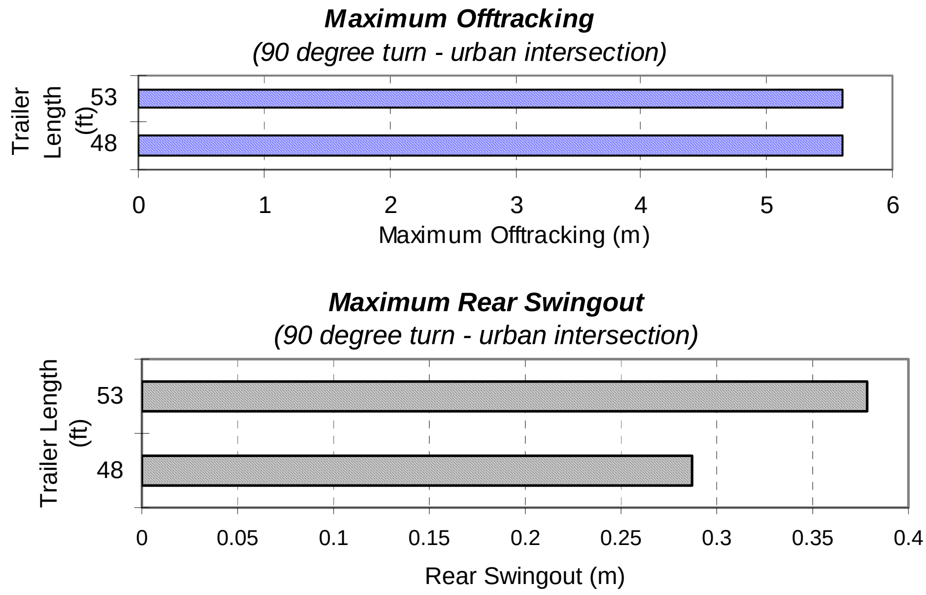
Figure 5.6. **Low swept path performance measure: Australia**



Source: ARTSA, 2003.

To limit the amount of "offtracking" which occurs with tractor semitrailers, the Canadian national standards limit the wheelbase of tractors to a maximum of 6.2 metres and the wheelbase of semitrailers to a maximum of 12.5 metres. As these limits apply to all lengths of semitrailer, the turning space required by a 53' trailer is no greater than for a 48' trailer. However, because the rear overhang is longer with a 53' trailer, the rear swing out is greater than with a 48' trailer (see Figure 5.7).

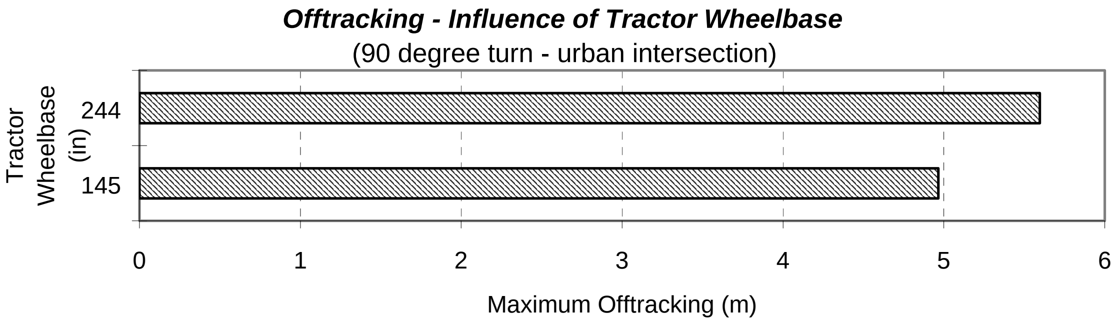
Figure 5.7. **Impact of Canadian Length Limits on Offtracking Performance and Rear Swingout**



Source: Canadian National Standards.

The length of the wheelbase of the tractor also impacts the turning space requirements of tractor-semitrailer combinations, as shown in Figure 5.8. At urban intersections, the difference in offtracking between a long tractor and a short tractor towing the same trailer is illustrated below. In the Canadian national standards the limit of 6.2 meters for tractor wheelbase was based on the objective of ensuring that the turning space requirements of all tractor-semitrailer combinations could be accommodated within the existing highway geometry.

Figure 5.8. **Influence of Tractor Wheelbase on Canadian Offtracking Performance Measure**



Source: Canadian National Standards.

These examples illustrate the difference between basing prescriptive rules on performance measures and using these measures as the rules themselves. Under the Australian performance standards, there is no specific limit on trailer length or tractor wheelbase, but a tractor-trailer combination must be able to meet the low speed swept path performance criteria for the measure illustrated. In Canada, prescriptive rules about trailer length and tractor wheelbase are set. The appropriate rules are determined by examining the impact on performance using much the same performance measure as has been developed in Australia.

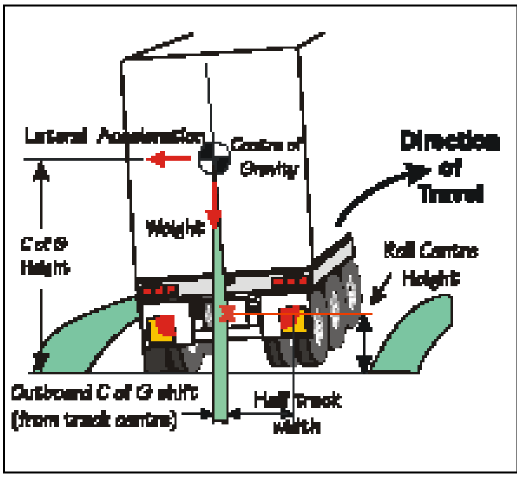
Importantly, in both examples the criteria used to judge what level of performance is acceptable is based on the capacity of the road infrastructure.

Stability and other safety outcomes

A range of further performance measures can be used to describe or control performance achieved by heavy vehicles that impacts on safety outcomes. This section provides examples of these drawn from the Australian work. The Australian examples have been selected, as visual representations of the measures have been developed to help explain them.

Under the PBS arrangements being developed in Australia, vehicles are required to demonstrate they can stay upright and not sway around excessively. For example, they should be able to stay upright and not sway excessively while driving along a straight road, changing lanes or turning at high speed, as illustrated in Figure 5.9 and Figure 5.10. PBS vehicles will also need to show they can fit in the available road space and do not obstruct other traffic, as illustrated in Figure 5.11, Figure 5.12 and previously in Figure 5.6. Explicit performance measures for these objectives were not available from Canada. As noted earlier, however, New Zealand has implemented a fleet-wide mandatory requirement to control static roll threshold, based on the same performance measure as adopted in Australia.

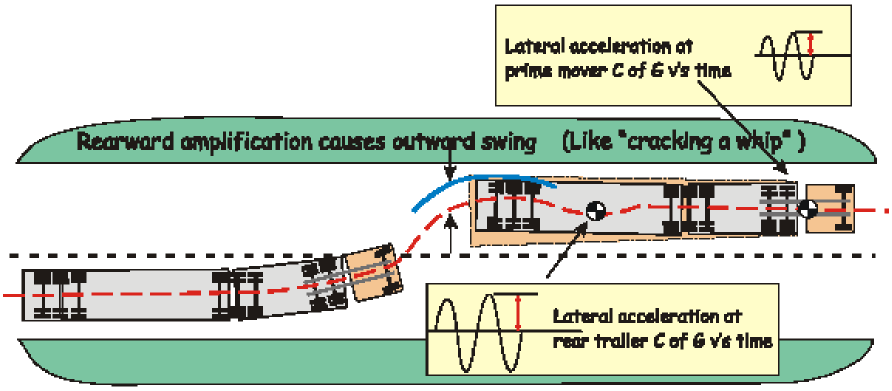
Figure 5.9. **Static roll threshold performance measure: Australia**



Source: ARTSA, 2003.

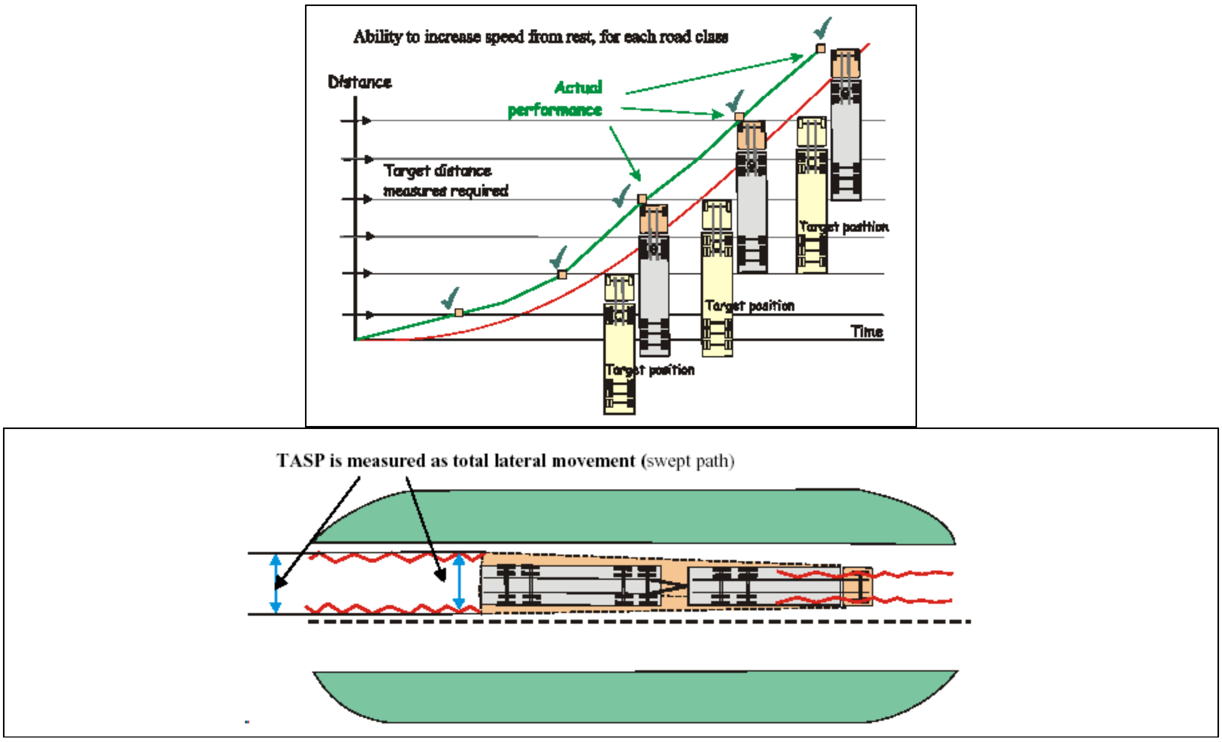
A complete listing of the safety–related performance measures proposed in Australia is provided in Appendix B.

Figure 5.10. **Rearward amplification performance measure: Australia**



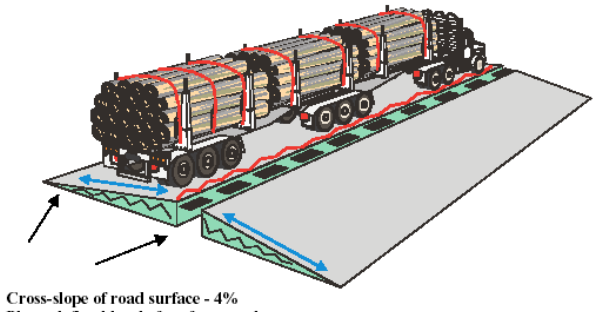
Source: ARTSA, 2003.

Figure 5.11. **Acceleration capability performance measure: Australia**



Source: ARTSA, 2003.

Figure 5.12. **Tackling ability on a straight path performance measure: Australia**



Source: ARTSA, 2003.

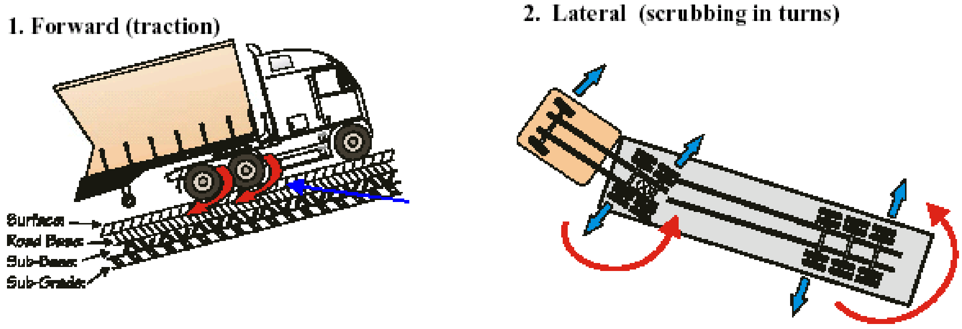
For infrastructure outcomes

The Australian approach also encompasses measures of the impact of heavy vehicles on road infrastructure. A series of constraints have been developed that ensure bridges and pavements are adequately protected. These constraints are aimed at providing reduced infrastructure wear overall. In some cases a performance measure could not be established and prescriptive requirements have been identified to apply until appropriate performance measures can be devised.

Other countries have not described their approaches to controlling infrastructure wear as being performance based. However, it could be argued that 'bridge formulae', which control axle mass spacings of heavy vehicles, such as that used in the United States and other countries, are performance-based approaches. Similarly, development of differential road use charges for vehicles using road-friendly suspensions in the European Union are based on differences in the performance of vehicles using these suspensions compared to other systems in terms of road wear. The OECD DIVINE study provided considerable insight into the impact of suspension systems on dynamic loading and its link to infrastructure performance (OECD, 1998).

In two areas prescriptive requirements are being proposed in Australia for the time being, with the aim of developing performance measures in the future. These two areas relate to horizontal pavement loading (see Figure 5.13) and tyre contact pressure distribution.

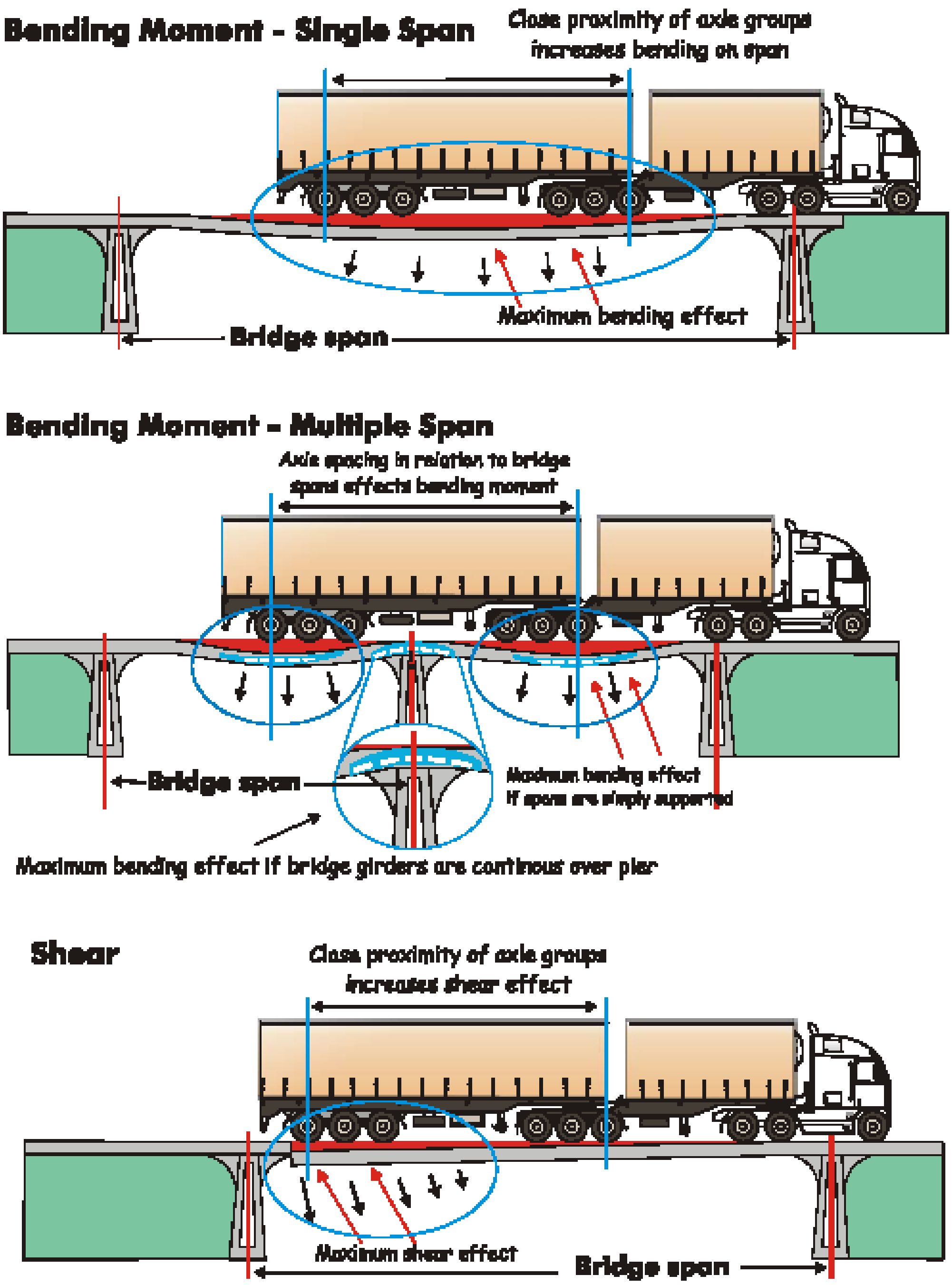
Figure 5.13. **Pavement horizontal loading**



Source: ARTSA, 2003.

Performance measures have been established, however, to control pavement vertical loading and bridge loading. The bridge loading measure, which is based around bending moment and shear forces envelopes, is illustrated in Figure 5.14.

Figure 5.14. **Bridge loading performance measure: Australia**



Source: ARTSA, 2003.

Further details of the infrastructure protection measures and prescriptive proxies being proposed in Australia are presented in Appendix B.

Other

The national set of safety and infrastructure protection performance standards being developed in Australia is to be accompanied by additional standards for noise and emissions, the details of which are still under development. These additional standards are intended ensure that PBS vehicles are quieter and cleaner than other heavy vehicles.

International implications

Key issues in the derivation of performance measures are the need for consistent definitions, test specifications and measurement methodologies to apply across international boundaries. This would:

Avoid duplication of effort in developing performance measures.

Allow pooling of data on performance versus crash outcomes to provide a better base for identifying appropriate performance thresholds for local circumstances.

Allow vehicle manufacturers or others to avoid duplication of performance assessments.

The emergence of global vehicle production markets emphasises the importance of international harmonisation of test specifications and procedures.

Performance standard thresholds

Each *performance standard* or *performance threshold* assigns a numerical limit (*performance level)* to a *performance measure,* defining a boundary between what is acceptable and unacceptable.

Outcomes Required

In both the Canadian and Australian examples used to illustrate the range of performance measures, an important issue arises when it comes to defining what is acceptable and what is not acceptable performance. That is, what is acceptable depends closely on the capacity of the road infrastructure available.

Four levels of performance thresholds are being proposed in Australia, to match different conditions prevailing on different parts of the road network. The national set of safety performance standards proposed in Australia requires a higher degree of safety from PBS vehicles than many existing vehicles in exchange for greater flexibility in vehicle design. The infrastructure protection standards ensure that PBS vehicles cause no more road or bridge wear than their prescriptive equivalents.

The experience of Australia in developing these performance thresholds emphasises the importance of taking account of local conditions in setting performance thresholds. Consequently, for some performance measures the same threshold value will not be appropriate country to country. For other measures (such as Static Roll Threshold which is essentially linked to physical properties and the effects of gravity which do not vary country to country), the same thresholds may be appropriate across provincial and national boundaries. This is illustrated by the evidence of the variety of studies of Static Roll Threshold discussed in Chapter 4. These decisions need to be made on a case-by-case basis.

Another significant factor to be considered is the level of risk that is appropriate to the prevailing conditions. Higher risks might be acceptable in some circumstances, such as where the level of traffic is extremely low, or where the likelihood of a vehicle being subject to an extreme situation in which good performance is essential is very low. For example, where the terrain is more benign, the need for vehicles to perform well against measures such as yaw damping or rearward amplification may be less significant.

Public perceptions

Work in Australia to develop a comprehensive set of performance standards to regulate heavy vehicles has also shown the importance of public perceptions in this process. Similarly the Canadian and New Zealand experience emphasises the importance of these factors. Acceptance of vehicles that are longer, wider or higher, regardless of whether they take up more or less road space than existing vehicles and can be driven more safely have led to the establishment of a demanding set of performance standards in the Australian work. In addition, factors that are highly significant to public acceptance, such as emissions and noise performance, have led to the development of additional standards to control these factors and ensure that PBS vehicles are more acceptable by virtue of being cleaner and quieter than the majority of other vehicles in the fleet.

The importance of these factors will clearly differ from community to community, and will be highly dependent on the policy context in which they are situated. Consequently the experience of one country may not translate to the experience of another on these issues.

Chapter 6

IMPLEMENTATION ISSUES

In recent years interest in the concept of performance-based regulations has been steadily growing in many areas of public policy. This has been spurred by broad-based efforts to eliminate unnecessary regulation, harmonise regulations between jurisdictions, reduce economic intervention to focus on safety, and at the extreme, to deregulate where possible and practical. In this context, performance-based regulations can provide a means for clearly articulating the expected outcome of the public policy requirement. This approach holds the promise of coupling an explanation of why a requirement exists with the more traditional "command and control" description of specific regulated limits or conditions.

The practical applications and implementation issues surrounding performance-based regulations have evolved over the last few years as technology has developed. Concepts that were once viable only in theory are now enforceable through the use of new technologies, such as global positioning systems and on-board weighing systems. Although there is much promise for performance-based regulations, that promise brings many challenges.

Public perception

Perhaps the most significant consideration in determining whether performance-based regulations will provide viable alternatives to prescriptive regulations will be public perception. Public acceptance, or lack of acceptance, will depend upon a proper information campaign. Through increased awareness of the concerns about performance criteria and the need to balance between the economic and technical issues, the public will have a greater appreciation for the vehicles using the highway system. Through a public information campaign, regulatory agencies can minimise the impact of negative feelings toward big trucks. If the public is made aware of the factors affecting truck safety they may better understand that regulators are minimising their risks and not simply yielding to the wishes of industry.

As public awareness of performance criteria increases, there will be less reluctance by the legal system to recognise tabular or pictorial based regulations that more accurately reflect the performance thresholds. Simplified presentation of the regulations will benefit both the public and industry by reducing confusion, thereby reducing the need for interpretation and the possibility of inconsistencies arising from those interpretations. Public perception of performance-based regulations will be most positive if the regulations are explained in simple and clear language that all users can understand.

Political

While the performance criteria associated with vehicle stability and handling characteristics can provide evaluations on the basis of sound engineering principles, subsequent regulation and policy development must also consider whether the application of the criteria is practical and in the general public interest. Good public policy must be based upon the overall safety and efficiency of the roadway system. The policy maker must balance between the theoretical thresholds and the practical realities.

Political acceptance will also depend upon public perception. Elected officials tend to dislike highly technical answers to seemingly simple questions. For example, an elected official might feel uncomfortable responding to the question "What is the longest dimension at which a vehicle can operate in your jurisdiction?" with the response "It depends upon a combination of factors". Although the answer may appear to make sense from a technical perspective and it may be correct, it does not provide a response to the question. Broad political acceptance of performance-based regulations will require some generalisations, such as tables illustrating typical scenarios, to provide simple guides for responding to the seemingly simple questions.

Institutional

While it may be difficult to dispute the logic of performance-based regulations, on closer examination, the implications for implementation can become quite daunting. Highway design standards, road and traffic conditions and geographic factors can vary widely within public road networks. Election of prescriptive criteria suited to the entire network would, by necessity, have to address the most restrictive conditions within the system. Alternatively, portions of the road network could be grouped by standard or condition, with different performance targets established by class or grouping of roads. At first consideration, this may seem awkward, but many jurisdictions already impose similar restrictions on the basis of vehicle mass (*e.g.* bridge restrictions). Restrictions affecting vehicle dimensions are more complicated because a vehicle operator may be able to remove part of a load to comply with the mass restrictions, but they are less likely to be able remove sections of their vehicle if required to do so to comply with dimensional restrictions. Under these scenarios, performance criteria may be used to support permit policies rather than regulations.

The traditional approach to harmonisation has involved upgrading infrastructure to recognised standards. This approach requires substantial financial resources. Regulatory agencies must change their approaches to issues such as harmonisation, if they are to achieve the desired standards within the current fiscal reality. For example, harmonisation of performance criteria may be possible where harmonisation of the actual vehicle size and mass limits is not. Differing road standards may limit size and mass of trucks in some jurisdictions. By harmonising at the performance criteria level, jurisdictions may be able to resist pressure for larger and heavier vehicle which may cause unwanted wear to the roadway.

The regulations governing truck size and mass include limits designed to ensure the performance of heavy truck combinations meets or exceeds performance targets. These targets are reflected in a number of areas, including resistance to rollover in turning and evasive manoeuvres, braking performance, space required to negotiate turns, front and rear swing-out in turning, and trailer sway. Effective implementation of performance-based regulations will require regulatory agencies to broaden their capacity to address specific configurations within a revised regulatory framework.

In the European Union, vehicle dimensions for certain vehicles are governed by Directive 96/53/EC, which all member states have to embody in their own territory – with no national alternative. The accession of Sweden and Finland in the mid 1990s required some flexibility in the directive to allow the continued use of their longer and heavier combinations. However, it appears that in practice the alternative 24/25m long combinations are too large to be acceptable in other member states. In effect, this means EU member states have little scope to introduce performance-based standards. Any changes to the Directive would have to be initiated by the European Commission (the only body allowed to make proposals for directives by the Treaty of Rome) and get the agreement of the member states.

Harmonisation (flexibility vs. interoperability)

From a regulatory agency's perspective, the regulations must maintain the integrity of the roadway system and the safety of the general public without placing unnecessary restrictions on the trucking industry. This requires careful balance between the need for an efficient and productive truck transportation industry, and the obligations to protect the safety of the highway system while managing the extensive public investment in the infrastructure. It is also recognised that these regulations directly influence the design of trucks, their stability and handling characteristics, the space required for turning and the compatibility of trucks with other vehicles on the highway.

Performance-based regulations provide flexibility for industry to operate innovative vehicles that optimise benefits associated with specific haul requirements. For example, vehicles specifically designed to haul heavy products may be redesigned and configured to optimise the haul potential for those products. Heavy haul operators will not be constrained by the "industry average" vehicles.

However, the benefits generated by harmonised performance criteria may have adverse effects on harmonisation at the vehicle level. Vehicle configurations will have to be approved as specific units. Towing units will have to be "married" to specific trailing units if they are to provide consistent performance. Also, the loading characteristics must be consistent. In some instances, industry will lose flexibility as a cost of increased efficiency.

Fleet impacts

The trucking fleet around the world consists of different configurations and combinations of vehicles. Industry may have difficulty with regulations that could see them having to delay shipments because the proper combinations are not readily available. For example, a long wheelbase towing unit may be able to comply with offtracking requirements only when connected to a short wheelbase trailer. If a load is available only on a longer trailer, the towing unit may not be able to connect to that trailer and still comply with the performance threshold. A shipper may find himself in a position where he has equipment available, but it cannot be used for the loads he has to haul. In this situation simplicity may be sacrificed in the interest of optimising efficiency.

Performance-based regulations provide a means for allowing industry to be innovative with their fleets. By helping the industry to understand the basis for the performance-based regulations, regulators can assist them in appreciating the implications of violating the regulations. Industry will have an alternative to simply applying pressure for bigger vehicles to carry more capacity. They will be able to adjust their fleets to reflect their specific haul requirements.

Enforcement

The engineering principles provide a safety-oriented means for optimising the use of existing infrastructure. However, in some instances, the complexity of those principles does not easily lend itself to simple regulations. For example, a maximum hitch offset dimension is required to ensure that the vehicle is not configured such that the "tail wags the dog". However, as the mass of the trailing unit decreases relative to the towing unit, the hitch offset can increase without reducing the safety performance of the vehicle.

Complete application of this principle requires specific measurements to determine the legality of a vehicle. According to strict interpretation of the performance criteria, compliance with some thresholds can depend upon a combination of dimension and mass. In these instances regulatory compliance cannot be associated with the vehicle in general, but only with the vehicle under certain loading conditions.

Regulations and policies must be easily understood if they are to be enforceable. Enforceable regulations must address vehicle parameters that are once removed from the primary inputs affecting vehicle stability characteristics. For example roll stability is highly dependent upon the centre for gravity height, suspension width and suspension type. Factors such as centre of gravity heights may not be easily measurable in the field. From an enforcement perspective, performance-based regulations may be cumbersome to implement.

Computer modelling can provide easily usable templates, but the models depend upon input values that can vary significantly in the field. Accurate representation of spring factors associated with tyre and suspension type can lead to misplaced faith in the output values. While the models may be based upon information provided by manufacturers, the vehicles operating in the field may not be maintained at the level necessary to provide the same performance over time. Also, programmes such as central tyre inflation impact on the operational characteristics of the tyres. Failure to recognise the potential differences between theory and practice can lead to a false sense of security with the performance criteria.

Many aspects of truck performance cannot be determined through normal inspection procedures. Assessing swept path, swing-out at front and rear, roll stability, pavement or bridge impact performance requires careful consideration of appropriate tests. As such, tests could not likely be undertaken at normal inspection facilities, alternative means of assessing compliance would be required. The “type certification” approach used for certifying aircraft performance may be possible in applications where the vehicle configuration and payload do not change. However, the flexibility which characterises trucking can bring daily changes in equipment (different towing units with different trailers) and widely different types of payload, implying changes in performance which would have to be understood.

Effective enforcement in the field will require a combination of technical skills that are not generally evident with field enforcement staff operating under prescriptive regulations.

Legislative systems

As managers of the road transportation system, highway agencies must ensure the long term sustainability of the network for future generations while supporting economic development and social well-being. Performance-based regulations satisfy this balance by identifying the requirements for safe operation while allowing freedom for industry to explore new configurations that suit specific needs. Through this process, industry will understand the issues that must be considered before a new configuration is allowed to operate on the highway system.

Performance-based regulations represent a shift in the provision of highway infrastructure. The traditional approach in developed nations has been to provide infrastructure required in order to support economic development. This economic development has driven the development of more efficient and productive vehicles. As the economy shifts and fewer funds are available for infrastructure development, policy makers are seeking ways to optimise existing facilities. Performance-based regulations support this approach to providing safe infrastructure.

Performance-based regulations have been recognised in many areas, but the performance criteria and thresholds are not necessarily consistent in all applications around the world. Although much research has been done to identify key criteria and appropriate threshold values, the criteria are not universally recognised. Some jurisdictions consider specific criteria to be more important than other criteria. More work is required to ensure universal recognition of the key criteria as well as agreement upon the acceptable threshold values. Consistent legislation is essential for manufacturers to be able to efficiently supply individual markets around the world.

Information exchange

Harmonisation and consistent application will rely upon strong communications. As with any regulatory regime, failure to consider the implications of local change on neighbouring jurisdictions will reduce the integrity of the system. Jurisdictions must work toward common standards, then maintain open communication links to ensure that the common basis for regulations is not compromised by unilateral action by one jurisdiction.

Any regulatory regime that relies upon technology raises its own implementation issues. Concerns over potential loss of freedom or misuse of competitive corporate data must be addressed. Regulators must recognise that any technology is only as reliable as the people who are using it.

Performance-based regulations rely upon accurate access to design details that may be considered “corporate secrets”. A degree of trust must be established between industry and regulators if the system is to work for all parties. While programmes can be put in place to support the need for confidentiality, trust can only be established through close working relationships that are established over time.

In general terms, implementation of performance-based regulations will be daunting. However, the process can be made easier by tailoring the approach to respond to the individual jurisdiction. For example, some jurisdictions may be ready to move directly to performance-based regulations while others may consider performance-based prescriptive regulations with full performance-based options available under their permit policy regimes. No matter what the approach, the successful implementation of performance-based criteria will depend upon consistent application of recognised scientific principles in combination with an education program aimed at all users of the road system.

Chapter 7

POTENTIAL OUTCOMES

Safety

Safety is a major focus point of the performance-based standards approach. Most of the performance measures that have been developed target safety and where the PBS approach has been applied it has generally been to ensure adequate safety or to improve safety. There are a number of approaches that can be used in including PBS in the regulatory system and the improved safety outcomes that may be achieved vary with these approaches.

Permit vehicles

The simplest and most widely used application of PBS to date is as part of the approval process for special permit vehicles. With this approach vehicles which do not meet the requirements of the regulations when applying for a permit to operate are required to undertake a PBS assessment to show that they have adequate safety. In some cases adequate safety may mean that the vehicles have a performance that is no worse than vehicles which are allowed under the regulations. Although it may appear that this does not enhance safety, generally speaking the vehicles being evaluated are more efficient than the "as-of-right" vehicles with which they are being compared and so there will be a reduction in the number of trips required to complete the freight task. Reduced exposure means improved safety. In other cases, the approach has been to require permit vehicles to achieve better performance than the minimum levels of the existing fleet. In this situation the individual vehicles are safer than those they replace and there may be further gains from reduced exposure if it occurs.

An example of this use of PBS for evaluating permit vehicles in Australia is given by McFarlane (2000). In this case the innovative vehicle being evaluated carries nearly 40% more payload than the standard vehicle with which it is compared. For some performance measures it is worse than the reference vehicle while for others it is better. McFarlane combines the performance measures using weightings and finds that overall the innovative vehicle has 10% better performance than the reference vehicle. The performance improvement should lead to reduced crash risk but this is difficult to quantify. However, the 40% gain in payload capacity relates directly to a 40% reduction in crash risk through reduced exposure.

In New Zealand, the approach has been to require the permit vehicles to have a performance that is significantly better than the reference vehicle. The reason for this is that the productivity gain is usually small or non existent (permits have not been issued for very large vehicles in New Zealand) and so the safety gains must come from improved performance rather than reduced exposure. Two examples of this approach which are detailed in Section *0* are the 44 tonne A-double combinations and the 22m log trucks. The 44-tonne A-doubles do gain 20%-25% in payload capacity over the 39-tonne A-double that is permitted "as-of-right". However, this capacity gain can also be obtained "as-of-right" by using a truck-trailer configuration. The 22m log truck has no load capacity advantage over the standard 20m vehicle. In both cases the rollover stability of the vehicles is substantially better than the reference vehicle. In the case of the 22m log truck it was estimated that if the 22m option was utilised to maximum capacity so that all loads that could be carried in this configuration were carried, the rollover crash rate for log trucks could be reduced by 40% or more.

This approach of using PBS for permit vehicles can lead to significant safety improvements for the vehicles concerned. Two of the examples above indicate reductions in crash risk of the order of 40% or more. Generally the permit regime is only used for a small number of vehicles in the system and so the safety gains for the whole road transport system are relatively small. The 22m log truck case from New Zealand is an example of perhaps the most widely applied form of the permit approach as it relates to a whole sector, but even in this case log transport makes up only 5% or so of the total transport volume.

PBS as a basis for prescriptive limits

Performance measures have been used in a number of jurisdictions as a basis for developing their prescriptive limits regulatory framework. Typically computer simulations and sometimes physical experiments are undertaken to determine how performance changes with changes in dimensions, mass and vehicle configuration. The prescriptive limits are then formulated to encourage configurations that have good performance. Because the prescriptive limits must still retain sufficient flexibility to meet the diverse operational requirements of the transport industry and allow for innovation, it is not possible or desirable to set up a foolproof prescriptive limits framework.

The advantage of this PBS-based prescriptive approach is that compliance and enforcement are straightforward and relatively low-cost. Although the safety gains per vehicle may well be relatively small, the prescriptive limits regime applies to the whole fleet and all vehicles must comply. Thus the safety gain for the road transport system as a whole may be greater than with the permit approach. Even though this approach has been used in Canada and in New Zealand, it is difficult to quantify the safety gains that have been achieved.

PBS in conjunction with prescriptive limits

With this approach performance requirements are included in dimensions and mass regulations alongside and in addition to the prescriptive limits. Many countries already use this type of approach for their braking requirements where, in addition to requirements for the braking systems physical characteristics, there is a performance requirement which specifies a deceleration or stopping distance that must be able to be achieved. In the area of size and weight regulations, New Zealand has recently introduced a minimum Static Roll Threshold (SRT) requirement for most large heavy vehicles in addition to the prescriptive limits. Poorer performing vehicles may find that this SRT requirement reduces their mass capacity or load height capacity below the limits specified in the prescriptive limits. It was estimated that the introduction of this requirement could reduce the number of heavy vehicle rollover crashes by up to 25%. This requirement was still being phased in and expected to be fully implemented by December, 2003. It is therefore too early to say whether the expected safety gains have been realised.

The PBS only regime

At the theoretical level, the concept of regulating size and weight through PBS requirements only is attractive. In Australia, the National Road Transport Commission (NRTC) and Austroads have undertaken a substantial research project to develop an alternative regime based on PBS. The PBS-based regime has been introduced as an optional alternative to the prescriptive limits regime. Some of the prescriptive limits such as height and width will remain in force even for PBS vehicles. This approach is similar in principle to the permit vehicle approach but the procedures for PBS assessment and approval are more explicitly defined. The process should be much more accessible and it is likely that more PBS vehicles will operate.

There are two ways in which the use of PBS vehicles may lead to safety gains. The first is that individual vehicles may be safer. This depends on the acceptability levels set for the performance standards. If the acceptability levels are set at the minimum levels achieved by existing prescriptive limit vehicles, PBS vehicles at the individual vehicle level will not be safer and, in fact, are likely to be less safe because they can increase size and weight until their performance drops to these minimum levels while the prescriptive limit vehicles are constrained. If the acceptability levels are set very high the PBS vehicles will be significantly safer than existing prescriptive limit vehicles but it is likely that the PBS requirements will be so demanding that it will be very difficult to design a PBS vehicle that has any economic advantage. In this case very few PBS vehicles will exist and, although the safety gain per vehicle will be high the safety benefits to the system will be very small. The second way that safety gains will be achieved is through PBS vehicles being more efficient and thus requiring fewer trips to undertake the required freight task. The magnitude of this gain depends on the size of the efficiency gain per PBS vehicle and the number of PBS vehicles in the fleet.

Although it can be argued that allowing PBS vehicles which are a little less safe than existing prescriptive limit vehicles but have large efficiency gains can lead to an overall system safety gain, it will be very difficult to get public acceptance for allowing less safe vehicles to operate. The acceptability levels for PBS then have to be set so that PBS vehicles will be at least as safe as the existing vehicles they replace. Setting the standards higher than this then becomes a trade-off between the safety of the individual PBS vehicle and the efficiency gains (reduced travel) from all the PBS vehicles that will operate. If the aim is to maximise the system safety gains optimum values for the acceptability levels will exist but it will be a difficult task to determine what these are.

Underlying the proposition that more efficient vehicles will lead to reduced exposure is an assumption that the magnitude of the road freight task is not influenced by these efficiency gains. If the efficiency gains in the road transport sector lead to increased demand for road freight through either a modal shift or more centralised manufacturing or warehousing then some of the benefits from reduced exposure may not accrue.

Sustainability

The key area where PBS potentially contributes to improved sustainability is improved fuel efficiency and hence reduced emissions. There are also potentially some gains from reduced infrastructure wear and possibly reduced congestion but these will be discussed in the next section. Sustainability gains from PBS will be at the system level for the freight task rather than at a per vehicle level.

At the individual vehicle level improvements in fuel efficiency and emissions are being achieved as the vehicle manufacturers respond to the requirements imposed upon them by governments. Although some of these requirements, such as the acceptable emissions levels, could be classified as performance standards they are outside the scope of the PBS being considered in this report. Regulating dimensions and mass through PBS will open the door for more freight efficient vehicles which will lead to reduced fuel consumption and emissions from a system point of view. For example, the innovative vehicle described by McFarlane (2000) carries 40% more payload than the reference vehicle. Its gross mass is 34% higher. Taking a fairly simplistic view, at highway speeds approximately 15% of the work energy is used for the power train and auxiliary loads, 53% overcoming aerodynamic drag and 32% overcoming rolling resistance (Woodrooffe, 2003). Increasing the vehicle gross mass will increase the rolling resistance proportionately but will have no effect on the aerodynamic drag or auxiliary loads. Thus a 34% increase in gross mass will lead to an increase in fuel consumption of approximately 11%. However, the payload carried has increased by 40% so the fuel used (and emissions) per unit of payload decreases by 21%. If we consider the 44 tonnes

A-double example from New Zealand (section 3.2.3), we see that the gross mass increases by 13% so the fuel consumption will increase by 4.1%. The payload carried increases by 20%-25% so the fuel used per unit of payload decreases by 13%-17%.

Although this analysis is very approximate it indicates that an increase in payload capacity is likely to result in a reduction in fuel consumption per unit of payload of at least half that magnitude.

Market forces will encourage the development of more payload efficient vehicles within the PBS environment and thus fuel efficiency improvements and emissions reductions will occur. The extent to which it occurs will depend on the ease and cost of accessing the PBS compliance regime and how demanding the PBS requirements are.

Infrastructure provision and maintenance

The PBS approach opens the way for larger, more productive, vehicles provided that they achieve acceptable levels of performance. This means that fewer vehicle trips are needed to undertake the same freight task.

Traffic congestion depends primarily on the number of vehicles rather than the size of the vehicles (for small to moderate variations in size). Thus reducing the number of vehicles through greater freight efficiency will ease congestion. Hassall (2003) showed that if the introduction of a PBS regime allowed an increase of one tonne mass and one metre length for PBS compliant urban rigid trucks with a GVM of 15 tonnes or more, then with an 80% uptake rate, the growth in urban rigid truck kilometres could be held to 0.1% per annum compared to about three times this rate without PBS. Thus there may be a congestion reduction through the introduction of PBS. However, the main contributor to urban congestion is usually passenger cars and so this effect will be relatively small.

There are potentially also effects on infrastructure wear and hence road construction and maintenance costs. This further impacts on sustainability because road construction materials are a finite resource. However, what this impact will be is not clear-cut. Unless there is a road pricing mechanism that reflects infrastructure wear, market forces will not optimise the infrastructure wear from a system efficiency point of view.

The NRTC/Austroads PBS project has developed several performance measures aimed at protecting the infrastructure. The aim of these measures is to try to ensure that the PBS vehicles cause no more wear than the standard reference vehicles. However, it has proved to be very difficult to develop performance measures that accurately reflect this aim at least partly because of debate about the appropriate models to use for infrastructure wear. For the PBS vehicles to have a positive effect on sustainability of the infrastructure it is necessary for them to cause less wear per unit of payload.

The most widely used model for pavement wear is the so-called fourth power law, which states that the amount of pavement wear generated by the passing of an axle is proportional to the fourth power of the axle load. Although it is widely recognised that this fourth power model is flawed and does not represent the behaviour of most types of pavement well, it is still widely used particularly for determining equivalencies between different axle group and tyre configurations at different loads.

The load equivalency approach uses the concept of an equivalent standard axle (ESA) which in Australia and New Zealand is an 80kN single axle fitted with dual tyres. For other axle and tyre configurations there are loads that have been calculated to cause equal wear. Thus for the single axle with single tyres the reference load is 53kN, for a tandem axle group with dual tyres it is 135kN, and for a tridem with dual tyres it is 181kN. For axles with other loads, the number of ESA is equal to (axle load/reference axle load). Using this model, in most jurisdictions, the steer axle generates a disproportionately large contribution to pavement wear. For example, consider a standard US 5-axle tractor-semi trailer combination with a GCM of 36.29 tonnes (80 000lbs). The steer axle can be loaded to 5.44 tonnes (12 000lbs) while the two tandem axle groups can be loaded to 15.42 tonnes (34 000lbs). Thus the steer axle contributes 1 ESA, which equates to 0.184 ESA/tonne while the tandem axle groups contribute 1.58 ESA each, which equates to 0.102 ESA/tonne. In the US a normally spaced tridem axle group is typically allowed to be loaded to 19.73 tonnes (43 500lbs) which corresponds to 1.31 ESA or 0.066 ESA/tonne.

Clearly if the application of PBS leads to larger, heavier vehicles with more tridem axle groups, the pavement wear per unit of payload, based on this model of pavement wear, will decrease. As noted, it is widely accepted that the fourth power exponent in the pavement wear model is not correct for many types of pavement and for different forms of wear. However, as most of the alternative models still use a power law relationship but with different exponents, the effect described above where larger vehicles with more multi-axle groups cause less wear per unit payload will still apply.

The infrastructure protection performance measures should accurately reflect the pavement wear effects of the vehicles. The PBS measures proposed by the NRTC/Austroads project are based on the notion that the PBS vehicles should cause no more infrastructure wear per unit of gross mass than existing legally permitted vehicles. However, they are based on a mixture of fourth power and twelfth power pavement wear models and it is not clear that they achieve this intended aim. Furthermore it is quite possible that a better rating in the performance measure does not necessarily mean the vehicle generates less pavement wear. This is an undesirable feature for a performance measure and further research is require to better understand the infrastructure wear mechanisms and to develop suitable performance measures that reflect these.

Freight Productivity

Market forces will lead to more productive vehicles under a PBS based size and weight regime provided the regime is flexible enough to allow more productive configurations to be developed. If the PBS acceptability levels are set too high, it may not be possible to design a more productive vehicle that meets the targets. On the other hand if they are set too low, there will be larger more productive vehicles but they may be unsafe or unacceptable in some other way. Clearly the acceptability levels for the performance standards are the key to success.

Under the current use of PBS for special permit vehicles in Australia, New Zealand and Canada, which has been described in section 4 of this report, significant productivity gains have been achieved for some vehicles, for example the vehicle described by McFarlane (2000) carries 40% more payload than standard vehicles. Operating costs for this vehicle will be slightly higher through higher capital costs and higher fuel consumption but overall the vehicle will be significantly more cost-efficient.

Community Confidence

A significant benefit from the PBS approach that has perhaps been underestimated is improved public confidence that changes to size and weights of heavy vehicles are not at the expense of safety.

Despite the substantial contribution that road freight transport makes to economic well-being particularly in developed countries, there is, in many countries, a public antipathy towards heavy trucks. There are a number of possible reasons for this poor public view of the road transport industry. The road freight industry is unusual in that it conducts its business operations on a publicly owned facility, the highway network, which it shares with the public. Safety within the road freight industry is of greater public concern that in many other industries because poor safety impinges directly on them as road users. For crashes involving a truck and another vehicle the outcome for the occupants of the other vehicle is often serious because of the relative masses of the two vehicles. This is the case whether the truck driver is at fault or not. Thus other road users are nervous of trucks.

In many countries, truck size and weights have increased over the decades by a process that some commentators have called “incremental creep”. That is, with each review of size and weight regulations, small increments in size and/or weight are allowed. Generally the scale of these changes is sufficiently small that no perceptible difference in safety performance is expected or measurable. However, over time the cumulative effect of all of these small changes leads to very significant increases in allowable size and weight but the effect on safety is never properly evaluated. The timeframe over which these changes have occurred also means that major technology developments leading to safety improvements have taken place at the same time. It is quite likely that the modern large high-technology truck is a safer vehicle than the much smaller trucks of, say, 50 years ago. However, the public perception is that trucks are getting bigger and bigger all the time and thus must be less safe.

The PBS approach to size and weight regulation specifies safety related performance in an objective way with quantitative measures. Thus the safety performance of a new, possibly larger, vehicle configuration can be determined and compared directly with existing vehicles in a transparent and independent way. Most of the performance measures relate directly to vehicle operating scenarios that are easily understood and can be related directly to personal driving experience. The public can therefore have confidence that the safety of the new vehicle has been assessed and know how it compares to other vehicles. Public acceptance is a critical factor in the introduction of more productive vehicle configurations. Technical issues relating to safety and performance are usually resolvable but without public acceptance, no politician in a democracy will countenance allowing larger vehicles to operate.

Improved Compliance

The extent to which this will occur depends on the way that the PBS regime is implemented. If PBS is implemented as an optional alternative compliance regime where vehicles approved under the PBS regime are given a permit to operate, there are significant opportunities for ensuring improved compliance. The PBS permit would specify the critical vehicle parameters that need to be met to ensure the performance standards are achieved. The regulators have the ability to specify monitoring and auditing procedures to ensure compliance with the operating conditions. This could include the use of new technologies for on-board or remote monitoring of weight, speed, location etc.

Using a permit-based regime means that the permit can be withdrawn if compliance with the conditions is poor. PBS vehicles would normally be expected to have a significant economic advantage (otherwise the operator would not have gone through the PBS process) and thus the loss of the permit would result in a significant economic loss.

Other options for implementing PBS will not necessarily have the same gains in compliance. Using PBS to develop a more performance–oriented set of prescriptive regulations will result in better performing vehicles but there is no reason why compliance with this new set of regulations will be any different from the compliance with the previous set. Similarly, incorporating specific performance standards into the prescriptive regime as New Zealand has done with its SRT requirement should improve the performance characteristics of the fleet, but there is no reason why it would improve compliance rates.

Conclusions

Regulations controlling heavy vehicle use to protect road safety and infrastructure impacts are generally characterised as prescriptive. These regulations set rigid limits on vehicle size, weight and configuration. These prescriptive regulations are in place to meet objectives relating to safety and infrastructure impacts. For example, they are intended to ensure that vehicles can safely negotiate turns, can remain within a given road space, do not intrude on the road space of other road users and do not lead to undue infrastructure wear or damage. However, prescriptive regulations on mass, dimension and configuration are only indirect (and sometimes imprecise) controls for these objectives.

Performance-based regulations, on the other hand, are designed to directly control these objectives, without specifying how the objectives are to be achieved. Performance-based regulations specify what a vehicle must be able to do, instead of what it must look like (for example, its dimensional envelope).

The development of performance criteria as the basis for regulations controlling heavy vehicle road use is expected to:

- Improve performance of the transport system (by providing better controls on safety and infrastructure wear).
- Encourage innovation.
- Provide a better match between vehicles and roads.
- Increase regulatory transparency by providing a more consistent and more rational regulatory approach.
- Improve compliance.

However, it should be recognised that:

- PBS requires a different mental approach to prescriptive regulations.
- Lack of understanding of performance may lead to regulations that move further from the desired targets, rather than closer.
- Using PBS tools is better than not focussing on outcomes.
- PBS tools will be more readily adopted if there are international examples to draw on.
- Vehicles are produced in a global economy where regional differences add to the cost, which can be reduced if common performance tests are used.
- There is an increasing need to provide for international traffic, *e.g.* containerisation.
- Developing economies are looking for targets while developed countries need ways of dealing with increases in truck traffic and ambitious targets for crash reductions.

- Measures and tests need to be common, even if the acceptable vehicles differ between countries.

- PBS provides methods of defining issues in a common way.

Whilst performance-based improvements to the regulatory system must be appropriate for the particular circumstances, in all cases they will require the specification of performance criteria, measures and thresholds (standards) and a shift to 'smarter' compliance and enforcement systems as described in this report.

In order to progress this work, the important steps from here on would include a joint international research effort to:

- Improve the specification of an agreed list of performance standards.

  - Further research is needed to identify the relationships between different aspects of vehicle performance and safety outcomes. This requires access to data on both performance and crash history. Better understanding of these relationships is essential to improving safety outcomes, improving the outcomes of prescriptive regulations and in establishing performance–based regulations.

  - Vehicle/infrastructure interaction is a key consideration in designing performance standards for infrastructure design, but is also central to regulation of heavy vehicles that is intended to ensure asset management outcomes. Some aspects of vehicle infrastructure interaction are little understood, such as the relationships between various pavement, surface and bridge failure mechanisms with vertical and horizontal loading. Differences in these relationships for different assets (for example, for different pavement types and climatic conditions) also need to be better understood.

  - Regulations controlling the environmental performance of vehicles are generally already performance based in many countries, particularly in relation to noise and gaseous emission controls. A review of the effectiveness of existing environment protection standards applied to heavy vehicles should be carried out and consideration given to whether there is a need to establish any further internationally consistent performance measures and test procedures.

- Identify the net community benefits of performance-based approaches, incorporating the experience of member countries.

- Design improved compliance and enforcement systems necessary to support a performance-based regulatory system.

Note: Working Group members who contributed to this study of performance-based standards for the road transport sector are listed in Appendix C.

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Appendix A

PERFORMANCE-BASED STANDARDS FOR THE ROAD SECTOR: TERMS OF REFERENCE[1]

Expected outcomes

- Development of more sustainable transport systems through improved road vehicle regulations controlling vehicle safety and infrastructure impacts, and better environment outcomes.
- More flexible road transport regulations that provide for increased innovation and more rapid adoption of new technologies.

Outputs

- Co-operation towards developing internationally accepted measures for assessing the safety of heavy vehicles in terms of the way they behave on-road, their interaction with other vehicles in the traffic stream, and for assessing their impact on infrastructure.
- Identification of criteria for acceptable performance to apply to each of the measures under varying road and traffic environments.
- Guidance on the appropriate institutional framework to support the introduction of performance-based regulations for road transport as part of regulatory reform initiatives.
- Progress on regulatory reform within the transport sector by developing high-quality regulatory approaches that provide flexibility in how compliance with regulations is achieved.

Goals

Identify measures that have been developed or used in various OECD countries to assess the safety of heavy vehicles in terms of their on-road behaviour and their interaction with other traffic, and to assess their impact on infrastructure. Pool expertise and data internationally to:

- Recommend which of these measures should form the basis of "best-practice" regulations for road use.
- Help establish internationally recognised definitions for and procedures for applying each measure.
- Determine performance criteria that might be applied for each of the measures.

1. The Working Group members who contributed to this study of performance-based standards for the road transport sector are listed in Appendix C.

Technical motivation

Regulations controlling heavy vehicle use to protect road safety and infrastructure impacts are generally characterised as prescriptive. These regulations set rigid limits on vehicle size, weight and configuration. These prescriptive regulations are in place to meet objectives relating to safety and infrastructure impacts. For example, they are intended to ensure that vehicles can safely negotiate turns, can remain within a given road space, do not intrude on the road space of other road users and do not lead to undue infrastructure wear or damage. However, prescriptive regulations on mass, dimension and configuration are only indirect (and sometimes imprecise) controls for these objectives. Performance-based regulations, on the other hand, are designed to directly control these objectives, without specifying how the objectives are to be achieved. Performance-based regulations specify what a vehicle must be able to do, instead of what it must look like (for example, its dimensional envelope).

For example, innovative ideas for axle configurations and coupling arrangements are often restricted by existing prescriptive regulations. Some innovations may perform better than traditional configurations in terms of their stability (resistance to rolling over) in different manoeuvres and their ability to safely travel in the lane space available (in both a straight line and negotiating a turn).

In other areas, specific operational requirements (*e.g.* placement of refrigeration or air conditioning units) may mean that a different distribution of mass across axle groups is desirable. This may be able to be achieved without leading to additional road wear by compensating reductions in axle loads elsewhere on the vehicle. However, prescriptive mass limits do not allow this flexibility. Performance criteria, in contrast, would specify the allowable amount of road wear and allow flexibility as to how this is achieved.

Traditionally, road wear is controlled through prescriptive limits on axle, axle group and gross masses, and some general limits on tyres. While this approach provides some control over pavement fatigue, pavement surfaces may not be so well protected.

Direct controls on the amount of allowable pavement wear and the impact of heavy vehicles on pavement surfacings might provide better control on the impact of heavy vehicles on some roads.

This is another example of how a performance approach might lead to improved infrastructure management, resulting in more sustainable transport systems.

The development of performance criteria as the basis for regulations controlling heavy vehicle road use is expected to:

- Improve performance of the transport system (by providing better controls on safety and infrastructure wear).
- Encourage innovation.
- Provide a better match between vehicles and roads.
- Increase regulatory transparency by providing a more consistent and more rational regulatory approach.
- Improve compliance.

There are international moves to introduce regulatory reforms, which include moves to improve the quality of regulations by introducing performance-based regulations in place of more rigid prescriptive controls. This is a significant component of the OECD's work, as evidenced by the 1997 Report to Ministers on Regulatory Reform (OECD, 1997).

Existing prescriptive mass, dimension and configuration controls on heavy vehicle use have generally evolved over long periods of time, and are not always scientifically based. Their rigid nature provides little opportunity for vehicle operators or vehicle manufacturers to introduce innovations that can achieve the same (or better) outcomes as these prescriptive controls, while also providing opportunities for productivity, environmental or other advances.

Variations in prescriptive regulations on mass, dimension and configuration controls within and between countries are not always soundly based, reflecting real operational differences. The development of performance-based regulations provides a framework for establishing regulations that match the environment in which they apply in a sound, verifiable manner. Australia and New Zealand have initiated a major project to investigate the potential for regulatory systems controlling heavy vehicle use based on performance criteria. Similar approaches are being developed and trialled in Canada. In other countries, performance criteria underlie regulations on heavy vehicle use, but are not explicit in regulations.

Economic motivation

Because road transport is a vital component of all economies, the potential for performance criteria approaches to improve transport regulation is significant. There is continuing pressure to improve safety and amenity in relation to heavy vehicles, and little room under most existing prescriptive regulations for significant across-the-board relaxation of prescriptive regulations as has occurred in the past in many countries.

Many OECD Member countries report road traffic is expected to increase, presenting significant challenges for management of road infrastructure. Forecasts of freight and passenger transport demand in many countries also signify that significant growth is expected in heavy vehicle traffic, in some cases exceeding growth in private car travel. While methods of influencing demand for road use must be explored, optimising the use of existing infrastructure will also provide an important means of coping with the expected growth in heavy vehicle traffic. Performance-based regulations of heavy vehicle use provide a regulatory framework in which optimisation of infrastructure use can be achieved.

This is at a time when many countries face significant difficulties in expanding infrastructure investment, making management of the existing infrastructure a high priority. The development of performance criteria for controlling heavy vehicle safety and their impacts on infrastructure provides the basis for a better system of regulation (improved regulatory quality). This approach is also able to better match roads and vehicles, to take account of differences in the capabilities of road infrastructure and variations in the performance of vehicles. Matching the capabilities of roads and the heavy vehicles using them can be expected to deliver an improved transport system.

At the same time, this approach to regulation provides the flexibility for infrastructure users to be innovative. This means they have the opportunity to minimise the costs of their operations, to the benefit of the broader economy.

The development of explicit criteria for the way in which heavy vehicles behave on-road and the way they interact with other traffic provides an opportunity to improve the safety performance of these vehicles. Better matching of road and vehicle capabilities and the productivity improvements flowing from the adoption of technical advances and innovations made possible under more flexible regulatory systems are also expected to result in reductions in environmental impacts of heavy vehicle use, and therefore reduced environment costs.

Reasons justifying international co-operation

Internationally agreed performance criteria would provide an environment in which vehicle and component manufacturers are encouraged to develop equipment and vehicle designs intended to improve performance. For example, the vehicle performance enhancing properties of tyres, suspensions, couplings and chassis would be likely to improve more rapidly than under the current nationally based prescriptive controls.

Heavy vehicles are sourced internationally. Many countries, such as Australia and New Zealand, have no substantive domestic manufacture of heavy vehicles. While vehicles are assembled and modified locally, specified to local conditions, they are largely based on designs and components developed overseas. Even in nations where there is a significant local heavy vehicle design and manufacturing industry, these nations also utilise vehicles or components sourced from other countries. Consequently, individual countries have little opportunity to influence the design and manufacture of heavy vehicles. This means that the opportunities for innovations in any one country are limited. As a result, the benefits to be obtained from a country unilaterally developing performance criteria as the basis for heavy vehicle regulation are substantially smaller than if this approach was to be adopted internationally.

In order to make substantive progress in establishing performance criteria for vehicle/road interaction, data and expertise must be pooled internationally. Often, insufficient information is available locally to allow a single country to determine appropriate performance criteria to control the safety and infrastructure impacts of heavy vehicle use.

Performance criteria approaches underlie regulatory approaches in many countries. However, the extent to which they are formally and explicitly stated varies considerably. Some countries are moving to formalise and adopt performance criteria as the basis for heavy vehicle regulation (often as part of broader regulatory reforms). Their abilities to do so unilaterally are limited. Unnecessary duplication of effort and inconsistencies that arise with unilateral development of performance measure definitions and specification of measurement procedures can be avoided through an international process.

International collaboration and agreement on performance criteria for heavy vehicle/road interaction (to control both safety and infrastructure impacts) would provide much greater opportunities than can be achieved by individual countries.

Tasks

This proposal represents a substantive project that would be undertaken over a three-year period. It would be undertaken under the guidance of an expert working group. The following tasks are proposed for consideration by the expert working group:

- Survey existing practice to set regulations for mass, dimension and configurations and for allowing exemptions from these regulations.

- Convene an expert working group to consider which performance measures are fundamental to establishing best practice regulations for heavy vehicle road use. The expert working group would ensure that there is no duplication in the measures selected, that the selected measures provide for high quality regulations etc., and that performance criteria for each of the measures selected would jointly provide sufficient control on road safety and infrastructure impacts.

- Document methods and procedures developed or used at present to apply performance measures in individual countries.
- Review and compare existing procedures and methods of applying the selected measures.
- Co-operate internationally towards developing, through the deliberations of an expert working group, methods and procedures for applying the measures that can be internationally recognised and adopted.
- Survey Member countries to establish variations in safety and infrastructure outcomes associated with variations in the performance of heavy vehicles against the selected measures.
- Establish, on the basis of sound scientific research and risk management approaches, suggested performance criteria for each measure and how these criteria should vary with varying infrastructure and traffic conditions applying in Member countries.
- Compare and assess approaches used in various countries to certify that vehicles, components or their operation meet regulatory standards.
- Identify possible approaches to certifying internationally that vehicles, components or their operation meet the appropriate performance criteria.
- Consider the need for international certification procedures for assessors accredited to undertake assessments of whether vehicles/operations meet performance criteria.
- Identify opportunities for innovation that are presented by adopting more flexible performance-based regulations for heavy vehicle use.
- Prepare a report providing guidance for Member countries to use in improving the quality of regulations on heavy vehicle use.

Most appropriate working method

Steering group plus expert working group and international collaboration on supporting research. As its first task, the expert working group would develop:

- A project plan and milestones over a three-year period.
- An indicative budget for each of the three years.
- More detailed project oversight arrangements.

Appendix B

PERFORMANCE MEASURES AND STANDARDS PROPOSED IN AUSTRALIA (NRTC, 2003b)

Performance standard	**Performance measure**	**Performance level for each road type**			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Longitudinal performance (low speed)					
Startability	Ability to commence forward motion on specified grade	at least 15%	at least 12%	at least 10%	at least 5%
Gradeability	Ability to maintain forward motion on specified grade.	maintain forward motion on grade			
		at least 20%	at least 15%	at least 12%	at least 8%
		minimum speed on 1% grade			
		80 km/h	70 km/h	70 km/h	60 km/h
Acceleration capability	Ability to accelerate either from rest or to increase speed on a road (no grade).	Acceleration no worse than specified by the distance-time curves in Fig 2(a) of NRTC (2003a)			
Longitudinal performance (high speed)					
Overtaking time	Time taken for a passenger car to safely overtake the subject PBS vehicle to be no greater than can be accommodated by overtaking opportunities provided by the road as the specified traffic flow level of service (*LoS*).	Level of Service C	Level of Service C	Level of Service B	Level of Service B
Tracking ability on a Straight Path	The total swept width while travelling on a straight path, including the influence of variations due to crossfall, road surface unevenness and driver steering activity.	no greater than 2.9m	no greater than 3.0m	no greater than 3.1 m	no greater than 3.3m
Ride Quality (Driver Comfort)	*The level of vibration that a vehicle's driver is exposed to during a working shift that leads to reduced comfort and decreased proficiency, and contributes to fatigue.*	*Subject to further development.*			

Performance standard	**Performance measure**	**Performance level for each road type**			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Directional Performance (low speed)					
Low Speed Swept Path	The maximum width of the swept path in a prescribed 90° low speed turn	no greater than 7.4m	no greater than 8.7m	no greater than 10.1m	no greater than 13.7m
Frontal Swing	The maximum lateral displacement between the path of the front outside corner of the vehicle (or vehicle unit) and: (a) the outer edge of the front-outside wheel of the hauling unit or mobile vehicle; or (b) the outside part of a semi-trailer during a small radius turn at low speed.	Part (a) for trucks and prime movers no greater than 0.7m for buses no greater than 1.5m Part (b) no greater than 0.40 m Trailer value not to exceed prime mover value by more than 0.20m			
Tail Swing	The maximum lateral distance that the outer rearmost point on a vehicle unit moves outwards, perpendicular to its initial and final orientation, when the vehicle commences and completes a small-radius turn at low speed.	not greater than 0.30 m	not greater than 0.35 m	not greater than 0.35 m	not greater than 0.50 m
Steer Tyre Friction Demand	The maximum friction level demanded of the steer tyres of the hauling unit in a tight-radius turn at low speed.	Not more than 80% of the maximum available tyre/road friction limit.			
Directional performance (high speed					
Static Rollover Threshold	The steady-state level of lateral acceleration that a vehicle can sustain during turning without rolling over.	Road tankers hauling dangerous goods in bulk and buses – no less than 0.40g All other vehicles – no less than 0.35g			
Rearward Amplification	Degree to which the trailing unit(s) amplify or exaggerate lateral motions of the hauling unit.	Rearward amplification no greater than 5.7 times the static rollover threshold of the rearmost roll–coupled unit taking account of the stability of the roll coupling			
High Speed Transient Offtracking	The lateral distance that the last-axle on the rear trailer tracks outside the path of the steer axle in a sudden evasive manoeuvre	no greater than 0.6 m	no greater than 0.8 m	no greater than 1.0 m	no greater than 1.2 m
Yaw Damping Coefficient	The rate at which ‘sway’ or yaw oscillations of the rearmost trailer decay after a short duration steer input at the hauling unit.	No less than 0.15 at the certified maximum speed			

Performance standard	**Performance measure**	**Performance level for each road type**			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Handling quality (Understeer/Oversteer)	*Ratio of the response to steering (change of vehicle direction) to the steering wheel input, and its dependence on vehicle speed and severity of the manoeuvre.*	Subject to further development			
Directional Stability Under Braking	The ability to maintain stability under braking.	(a) A vehicle must not exhibit any wheel lock when it is braked at a deceleration rate of 0.45g from an initial speed of 60 km/h on a high friction pavement in both unladen and unladen states (momentary wheel-lock associated with ABS brake modulation is acceptable); and (b) A vehicle must meet the stopping distance performance levels in the relevant versions of ADRs 35 and 38 (as applicable); and (c) Auxiliary brakes (if fitted) must not apply automatically if the computed friction utilisation at any wheel can exceed 0.1 when the vehicle is braked from a road speed corresponding to three quarters (3/4) governed engine speed (unless the motive vehicle has an acceptable ABS).			
Infrastructure related performance measures-pavement related					
Pavement Vertical Loading	Degree to which vertical forces are applied to the pavement	a) The Average Road Wear Per Axle Group (SARs/AG) shall not exceed the level calculated for a vehicle with the same number of rigid parts and the same number of axles on each rigid part as is permitted by prescriptive (or equivalent) regulations. (b) All axles on each rigid part of a vehicle (apart from the steering axles of a motor vehicle) must be joined by a load sharing suspension system (for the purposes of this standard, the drawbar of a dog trailer is considered a separate rigid part).			
Pavement Horizontal Loading	*Degree to which horizontal forces are applied to the pavement.*	*(a) Steerable axles* *(i) at least one axle of any two axles joined by a load sharing suspension system and greater than 2 metres apart must be steerable; and* *(ii) with all other groups of axles joined by a load sharing suspension system with a spread of greater than 3.05 metres, all axles beyond the 3.05 metre spread must be steerable.* *(b) Driving axles* *(i) the maximum gross mass of a vehicle with either one or two driving axles are detailed.* *(ii) all driving axles must distribute tractive forces equally between the axles within +/- 10% of the proportion of the tractive force delivered by the driving axle.*			
Tyre Contact Pressure Distribution	*The maximum local vertical stress under a tyre's contact patch for a given vertical load type and tyre inflation pressure.*	*Subject to further development. Existing prescriptive requirements relating to maximum pressure be retained and applied to PBS vehicles.*			

Performance standard	Performance measure	Performance level for each road type			
		Level 1	Level 2	Level 3	Level 4
Infrastructure related performance measures-bridge related					
Bridge Loading	The maximum effect on a bridge measured relative to a reference vehicle.	Bending moments and shear forces no greater than the moments and forces induced in the bridge by representative ABAG configured vehicles with axle group loadings set at GML or HML as appropriate for the road class or route.			

Appendix C

LIST OF WORKING GROUP MEMBERS

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Performance-based Standards for the Road Sector

This report focuses on arrangements and approaches to the regulation of road transport. Traditionally, heavy vehicles have been regulated by tightly defined prescriptive limits (such as mass and dimension/size limits), which provide little scope for innovation and lead to "one size fits all" outcomes. However, there are significant variations in road and traffic characteristics across road networks, and between urban and inter-city or inter-region routes. Many existing vehicle regulations only indirectly ensure that vehicles are able to operate in a safe manner and control the amount of road and bridge wear they cause.

The report examines existing regulatory approaches and then explores how performance standards might be used to improve regulatory outcomes. Under a performance-based approach to regulation, standards would specify the performance required from vehicle operations rather than mandating how this level of performance is to be achieved. More flexible performance-based regulations provide for increased innovation and more rapid adoption of new technologies. The report explores the regulatory reform processes in some countries that have led to more direct, outcome-oriented approaches to regulating road transport vehicles.

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