

REVIEW AND RISK ASSESSMENT OF INCREASING VEHICLE LENGTH

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Abstract

Overall vehicle length is a primary driver of freight vehicle productivity. The Performance Based Standards (PBS) scheme aims to increase productivity and safety by matching the right vehicles to the right roads. It steers away from prescriptive vehicle limits, however the complexities related to parameters of network elements, for instance, intersection clearance times, stacking distance, traffic flow and overtaking ability, have given rise to de-facto maximum length limits being applied for the purposes of network classification. There are also issues concerning public perception of longer vehicles.

This project highlights the outcomes from Austroads project FS1675 which aimed to review the PBS Level 1 length limit and determine the optimum limit by developing a risk-based assessment methodology. Fifty five representative sites, from a number of jurisdictions, were assessed as part of the refinement and evolution of the methodology. Using the methodology outlined, it has been found that a maximum length of up to 23 m for PBS Level 1 vehicles could be considered for implementation.

Keywords: Performance based standards, PBS, length limit, network access, risk assessment, heavy vehicles

1. INTRODUCTION

Overall vehicle length is a primary driver of freight vehicle productivity. In Australia, the Performance Based Standards (PBS) scheme aims to increase productivity and safety by encouraging innovative vehicles, while not compromising on safety. It steers away from prescriptive vehicle limits such as length; however de facto length limits are applied for the purposes of network classification. There are also issues concerning public perception of longer vehicles.

The PBS Level 1 network is the least restrictive of the four PBS levels and is closely mapped to the current General Access networks. The Level 1 length limit is currently 20 m, an increase of one metre over the 19 m General Access prescriptive vehicle maximum length limit. The one metre increase was justified on the basis that:

- it was a relatively minor increase
- it provided some productivity benefit
- any increased safety risk would be offset because PBS vehicles are inherently safer than those in the general fleet.

However, there was no benefit-cost analysis (BCA) performed on the various trade-offs between the potential of increased vehicle productivity, and increased safety and infrastructure risks.

The objective of Austroads project FS1675 was to review the current PBS Level 1 length limit of 20 m, and determine the optimum limit by developing a risk-based site assessment methodology. This paper outlines the final methodology that was refined through an iterative process of assessment of 55 representative sites from a number of jurisdictions (Eady and Elischer 2011a, Eady and Elischer 2011b). A high level BCA was also undertaken as part of this project.

1.1. Background work

Consultation with stakeholders resulted in an initial network assessment methodology being developed. This initial methodology was applied to five sample sites which had characteristics where it was expected that the longer vehicles would perform poorly, with the aim of analysing the outcomes and refining the methodology as necessary. A number of recommendations were made following the examination of the original sample sites, which were subsequently acted upon.

Following on from this initial examination of the five sample sites, work continued on the refinement of the methodology and the effect that the longer vehicles would have upon the general road network, as opposed to only the complex cases. To this end, a further 50 sites were examined, with the findings detailed in this paper. The BCA was also performed at this time on three sites representing a range of characteristics.

2. METHODOLOGY

The assessment methodology evolved through several stages and only the final stage will be documented here.

2.1. Assumptions

There are two very important assumptions that underpin this work. These are:

1. **Current PBS Level 1 vehicle standards are unchanged and adhered to.** For instance, a 24 m PBS Level 1 vehicle examined here would still need to meet the same swept path requirements as a 20 m long vehicle.
2. **Current rules on mass remain unchanged.** That is, an increase in length does not mean an increase in mass. All vehicles examined are assumed to have a maximum of 50 t gross combination mass (GCM) (50.5 t with 0.5 t steer axle allowance) as is currently set for PBS Level 1 vehicles.

2.2. Vehicle Lengths Examined

Current PBS level 1 vehicles have a working maximum length limit of 20 m. Although longer vehicles may meet all Level 1 requirements, these vehicles are usually only allowed to operate on specific routes on PBS Level 1 networks after an individual assessment. This work looks at the relative effects of increasing the length in 1 m increments to a maximum of 26 m, which is the current working maximum length limit for PBS Level 2A networks. There was also an interest in examining the relative differences for 19 m vehicles.

2.3. Network Assessment

The methodology proposed for use in the assessment of length increases and their potential impacts, is a risk-based approach that aims to determine a base ‘score’ for each assessment criterion, which is then multiplied by a ‘severity factor’ dependent on the criterion being assessed, and aimed at capturing the severity of the potential consequences. It should be noted that the risk scores generated are all *relative* to the risks faced by ‘baseline’ 20 m long PBS Level 1 vehicles already operating on the network. The scores do not provide an indication of the likelihood of this event occurring, rather, the relative risk of an altered maximum vehicle length compared to the risk of a 20 m vehicle at that intersection or midblock segment. An intersection with an average annual daily traffic (AADT) of (say) 50 vehicles will end up with the same risk score as an identical intersection with an AADT of (say) 50 000 vehicles.

Assessment Criteria and Relative Risk Levels

The assessment criteria and their relative levels of risk were originally proposed based upon current PBS network classification guidelines (NTC, 2007). These were further refined, as per the project scope, through the sample network assessment of five sites and are shown in Table 1.

Table 1: Assessment Criteria and Severity of Risk

Issue	Number	Criteria	Severity of risk	Severity factor
Overtaking	1	Establishment sight distance	Low	0.4
	2	Continuation sight distance	Low	0.4
	3	Overtaking opportunities	Low	0.4

Issue	Number	Criteria	Severity of risk	Severity factor
Intersections	4	Signal timings	Low-medium	0.6
	5	Intersection length and effects of grade	Medium	1.0
Railway crossings	6	Signal timings	High	1.6
	7	Crossing length and effects of grade	High-medium	1.4
Stacking distance	8	Stacking distance	High	1.6

Application of Methodology

The methodology is to be implemented over particular sections of interest in the network. These can be midblock segments, though they are far more likely to be intersections. A relative risk factor (RRF) was developed for each assessment criterion, based largely on the increase or decrease in the requirements as the vehicle length was changed in one metre increments between 19 m and 26 m (e.g. the number of extra seconds required for a longer vehicle to traverse an intersection). The RRFs are all compared to the current Level 1 maximum vehicle length of 20 m.

Using these RRFs, a weighted average denoted as the Criterion Score (CS) (Equation 1) for the midblock segment or intersection can be determined for each criterion. The weighted average is based on the AADT that enters each approach of the intersection or midblock segment. The weighted average is utilised so that approaches that are more heavily used contribute more heavily to the Criterion Score. Each maximum vehicle length that is examined will potentially have a different Criterion Score at each midblock segment or intersection.

$$CS_i = \frac{AADT_1}{\sum AADT} \times (RRF_1) + \frac{AADT_2}{\sum AADT} \times (RRF_2) + \dots + \frac{AADT_n}{\sum AADT} \times (RRF_n) \quad 1$$

where

CS_i = the Criterion Score: the average relative risk factor for each assessment criteria (i.e. CS_1 refers to the Criterion Score for assessment criterion 1 (establishment sight distance) while CS_2 refers to the Criterion Score for the second assessment criterion and so on)

$AADT_n$ = is the AADT for each approach (i.e. $AADT_1$ refers to the AADT on the first approach, $AADT_2$ refers to the AADT on the second approach and so on)

$\sum AADT$ = is the sum of the AADT for all approaches

RRF_n = the relative risk factor for the appropriate criterion for each approach.

Once the Criterion Score has been calculated at the site for each applicable criterion (not all criteria will apply to each site), each Criterion Score is multiplied by a Severity Factor (SF), outlined in Table 1, with the sum of these products resulting in the risk score (Equation 2).

The risk score will provide an indication of the level of relative risk of the maximum vehicle length limit for each site, with higher values implying greater risk.

$$\text{Risk Score} = SF_1 \times CS_1 + SF_2 \times CS_2 + \dots + SF_i \times CS_i \quad 2$$

where

SF_i = the Severity Factor: the severity associated with each assessment criterion as seen in Table 1

Risk Score = the total risk for the examined site for a given vehicle length.

It was found during some site assessments that all the data required to calculate a risk score was unavailable or impractical to be collected. In these situations, a conservative estimate was used.

Risk Score Banding

After the sample site assessments, it became clear that the overall risk scores generated for each site needed to convey more meaning to allow a useful comparison, and hence a banding approach was derived.

Risk scores were divided into bands by reconciling the expected risk at these intersections based on engineering experience with the risk score that the intersection achieved. The sites examined were considered to be representative of a range of intersection types, and therefore the range of risk scores generated was also a factor in determining the risk bands outlined in Table 2.

Table 2: Risk score bands

Risk band	Definition	Example
Low	Risk scores less than or equal to 10	Extra intersection signal timing is required
Medium	Risk scores greater than 10, but less than 20	Extra time is needed to cross railway lines
High	Risk scores equal to or greater than 20	Stacking distance issue where a longer vehicle may be encroaching into oncoming traffic lanes

The risk bands refer to the relative risk of incidents occurring due to longer vehicles operating at the sites, and provide a cue for easily identifying which sites are at higher risk, and what maximum length would be suitable for each site.

Likelihood of Risks

The methodology has primarily concentrated on the consequences of the risks of operating longer vehicles. Likelihood or risk exposure is usually linked to AADT values in transport studies, and as such, investigation into using the site's overall AADT values to represent the likelihood of incidents occurring was undertaken. This proved inadequate for this study for a number of reasons, primarily due to the large range of AADT values for the sites analysed exaggerating the outcomes, and the fact that AADT data was not always available for the site, let alone the areas and channels through the intersections affected by the particular risk. The

composition of the traffic (percentage of heavy vehicles) was also considered to be relevant, as it would likely have an effect on the behaviour of drivers at the site and influence the likelihood and consequence of any potential incidents.

Another point that became evident was that the proportion of PBS Level 1 vehicles to the overall AADT would be very low, and furthermore, those vehicles longer than 20 m would likely be a small percentage of that. This, however, does not reduce the need to factor in likelihood. It was decided that sites be split into two categories, low AADT and high AADT.

3. SITE SELECTION

Data was supplied by road owners for road intersections and rail crossings deemed to be typical of the road network, rather than the 'worst-case' intersections examined in the original five sites. Similar to the analysis of the initial five sample sites, details were obtained from the relevant authorities with only easily obtainable information requested. Information which required collection was not requested (e.g. AADT for specific intersection flow) as this was considered to be impractical for any potential future large-scale assessment.

Fifty-five sites were chosen and split into high and low traffic volumes, with low traffic volumes being sites with an AADT of less than 5000 vehicles, and high traffic volumes being sites with an AADT of greater than 5000 vehicles. Thirty-six sites were determined as having high traffic volumes, while the remaining 19 sites were determined as having low traffic volumes.

4. ASSESSMENT RESULTS

Each of the 55 sites was assessed using the network assessment methodology. Six were listed as high risk and 15 as medium risk for at least one vehicle length. Of the six high risk sites, three were high risk for all vehicle lengths including a 19 m vehicle.

Figure 1 illustrates the risk scores compared to maximum vehicle length for each site. This figure clearly highlights that there is a general increase in risk as the maximum length is increased, however, there is no clear trend or indicator as to an optimum maximum length across the entire network.

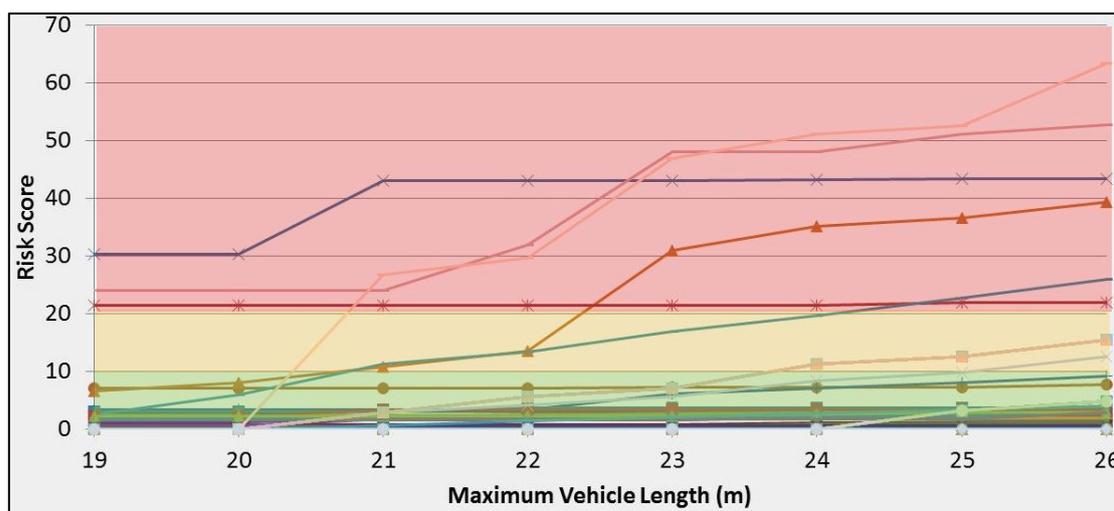


Figure 1: Risk score against maximum vehicle length for all sites

4.1. Effect of AADT

The effect of low or high AADT at each site was examined, with the percentage of the sites at each maximum length in each risk band.

The percentage of the risk scores of either low AADT or high AADT sites that fall into each risk band can be seen in Table 3 and Table 4 respectively.

Table 3: Percentage of risk scores of low AADT sites by risk band

Risk band	Maximum vehicle length (m)							
	19	20	21	22	23	24	25	26
Low	95%	95%	89%	89%	89%	47%	47%	42%
Medium	0%	0%	0%	0%	0%	42%	42%	47%
High	5%	5%	11%	11%	11%	11%	11%	11%

Table 4: Percentage of risk scores of high AADT sites by risk band

Risk band	Maximum vehicle length (m)							
	19	20	21	22	23	24	25	26
Low	94%	94%	89%	89%	89%	89%	89%	89%
Medium	0%	0%	6%	6%	3%	3%	0%	0%
High	6%	6%	6%	6%	8%	8%	11%	11%

Of the low AADT sites, in terms of percentage of sites within each risk band at each maximum vehicle length, there is no difference between a maximum length of 19 and 20 m vehicles, no difference between 21, 22 and 23 m vehicles, and no difference between 24 and 25 m vehicles. There is a clear point at 24 m, where a large number of sites switch from low risk to medium risk. The proportion of sites in the high risk band has an increase at 21 m from 5% of sites to 11% of sites, however, there is no increase from 21 to 26 m.

Of the high AADT sites, there is no difference between 19 and 20 m vehicles, 21 and 22 m vehicles, and 23 and 24 m vehicles. At high AADT sites, there is only a slight difference in the proportions of sites within each risk band with increasing maximum length. At high risk sites, the percentage increases from 6% of sites at 19 m, to 8% of sites at 23 m, to 11% of sites at 25 m.

It can also be seen that, compared to the low AADT sites, the high AADT sites possess similar or higher percentages of sites in the low risk band. This is likely to be due to the higher AADT sites requiring a higher design standard in order to accommodate these extra vehicles. It should be noted that the risk rating of the site does not take into account the volume of vehicles through the site, and that two identical sites with different AADT volumes will result in the same risk score.

5. BENEFIT-COST ANALYSIS

The current length limit of 20 m was set without any BCA, however, significant productivity benefits arise from running longer but fewer vehicles, including travel time savings, crash cost savings and reduced emissions. Potential costs include the increased likelihood of risks of certain crash types, time delays from longer vehicle clearance and greater congestion due to impacts on vehicle performance at high-risk areas.

Three high-risk sites of the worst likely conditions across the network covering both urban and rural areas with varied traffic and road characteristics were targeted for the BCA, which covered situations for free-flow traffic, and interrupted traffic at an intersection or railway crossing, the details of which are covered in Austroads (2012). The conclusions drawn from the BCA are as follows:

- **Benefits from running 25-26 m vehicles in higher AADT areas.** There are benefits in running 25-26 m vehicles in higher-trafficked areas. This applies even when issues such as vehicle clearance times and stacking distance are considered. Productivity gains from running the lower vehicle numbers are sufficiently large to override the costs.
- **Costs from running 23-24 m vehicles in all areas.** Regardless of traffic characteristics or road conditions, the benefits from running 23-24 m vehicles did not appear large enough to outweigh the costs. For all three sites, the BCRs for 23-24 m are less than 1 with the exception of free-flow traffic in a highly-trafficked urban intersection. It should be noted, however, that the operating costs for these vehicles were the most difficult to estimate based on available data and have a lower confidence. It is suspected that the true operating costs would be lower.
- **Benefits from running 19-20 m vehicles in low AADT areas with no traffic delays.** A 19-20 m vehicle appears to be the better choice for rural areas with a lower AADT in the absence of time delays. However, when complications arising from time delays at signalised crossings are considered, running 25-26 m vehicles is the better choice.

6. DISCUSSION

Through the development of the methodology, it was found early on that stacking distance is the most influential factor in determining the overall risk score of a site. This issue was also the most difficult to quantify, as there is very little research or empirical data to provide a basis. This had a number of ramifications, for instance, the question of whether encroachment across two lanes of opposing traffic carries twice the risk of encroachment across a single

lane is difficult to answer, yet the overall results will be quite sensitive. This difficulty of quantification also had a bearing on the setting of relative differences in risk factors between criteria. An example being the difference in risk between partial encroachment into a lane of opposing traffic, as compared to signals being (say) 5 seconds too short for a longer vehicle to traverse.

Given these challenges, and whilst it is recognised that improvements could be made to the values used, this work has applied a pragmatic and comparative process to refine the inputs and methodology of the assessment process.

It became apparent that there was a distinction between low-trafficked sites and high-trafficked sites. The low AADT sites examined exhibited, on average, a higher risk score, and a greater rate of increase in risk as the maximum vehicle length increased. This is likely due to differences in the standard of road design. It should be noted that the low-high split for AADT was nominally set at 5000 vehicles. Particularly from a policy perspective, it may be that more than one split is appropriate as this number will affect the likelihood of exposure, and hence the overall level of acceptable risk for jurisdictions and other road owners.

A second consideration is the number of longer PBS Level 1 vehicles that will likely be operating. Should they be given access, it is envisaged that PBS Level 1 vehicles greater than 20 m in length would represent a fraction of a percent of the total traffic volume.

6.1 Level of Acceptability

It has also been shown that some sites (approximately 5%) are considered to be high risk for the current 19 m and 20 m vehicle lengths. Some of these sites hold the same (albeit high) risk for 26 m vehicles. This raises the question as to what is acceptable. It could be argued, on the basis that the current network is operating at an already accepted level of risk, that a high risk site for a current 20 m long vehicle, could cater for a longer vehicle at a similarly high, but accepted risk. The alternative is to remove high risk or unacceptable sites from the PBS Level 1 network, thus reducing access by some, likely small, amount. This may allow the capacity of the remaining network to be increased, potentially with a net benefit. Again, the location of key sites will be critical in allowing those judgements to be made.

The question as to what is acceptable has two broad responses:

1. The greatest length increase possible at the same levels of risk currently accepted for 20 m long PBS Level 1 vehicles. This would retain the current level of network access with a potentially slight increase in productivity.
2. A slight increase in risk in order to realise potentially increased productivity benefits. This would decrease the size of the network, however allow for a potential net benefit in productivity.

Table 5 outlines the percentage of sites that do not allow vehicles of a particular maximum vehicle length, for each increase in risk score. These numbers highlight the potential reduction in network access.

Table 5: Percentage of sites disallowing access for each maximum vehicle length, based upon increase in risk score

Maximum length (m)	Increase in risk score				
	0% or 0 points	10% or 1 point	20% or 2 points	50% or 5 points	100% or 10 points
20	0%	0%	0%	0%	0%
21	38%	35%	31%	13%	4%
22	42%	38%	35%	22%	13%
23	45%	44%	36%	27%	15%
24	55%	53%	47%	31%	24%
25	73%	71%	67%	31%	25%
26	73%	71%	67%	33%	27%

For instance, if double the risk was accepted (100%), then setting a maximum vehicle length of 23 m would disallow access to 15% of the sites analysed. Conversely, if the same level of risk was assumed, 45% of sites would not accept vehicles with a maximum length of 23 m.

6.2 Caveats and Considerations

There are a number of points to note when interpreting the results of this work:

- Longer vehicles currently running under permit
- Degree of representation of the network for the examined sites
- Risk mitigation and treatments
- Practical and operational considerations

Longer Vehicles Currently Running Under Permit

Most jurisdictions currently have excess dimension vehicles operating under class permits and notices up to 25 m in length for indivisible loads and on the general access network. These vehicles are usually required to operate under additional conditions that can include time restrictions, and additional lights and signage. They would generally perform worse than PBS vehicles, particularly in geometry related areas (e.g. swept path).

The PBS Regulatory Impact Statement (RIS) indicates that the take-up for PBS vehicles will be minimal compared to the national heavy vehicle fleet. Although it is not possible to directly compare the forecasts, it may be that the risk accepted with the operation of the small number of current excess dimension vehicles is comparable to that of running the anticipated low number of longer PBS Level 1 vehicles. Crash data on the excess dimension vehicles was also sought, however none was found that would indicate an issue with these vehicles.

Degree of Representation of the Network for the Examined Sites

This is perhaps the single most important data that is unavailable – what proportion of intersections on the current PBS Level 1 network (nationally and jurisdictionally) is represented by those examined? This is unknown both at the level of the ‘types’ of intersections, and the distribution of them, and also at the more detailed level that includes the variance of the individual characteristics within similar ‘types’ of intersections.

This paper identified differences in the risk scores when sites were categorised based on AADT values. The degree to which the AADT distribution of the examined sites reflects the national distribution is also unknown.

If a change to the maximum vehicle length is implemented, it will be important to identify and individually assess sites on the network, particularly those of strategic importance.

If a decision was taken to retain the current network without change, consideration may need to be given to the definition of a Level 1B network specifically mapped for those PBS level 1 vehicles in excess of the current 20 m maximum. Alternatively, a method of managing the network by restriction may be considered. This could work in a fashion similar to mass restricted bridges, where certain intersections (or turns through an intersection) were length restricted.

Risk Mitigation and Treatments

There are a number of risk mitigation actions and treatments that could help lower the risk score of sites. These will depend on the site, and the deficient point(s) for the operation of longer vehicles. Although a site may be initially identified as medium or high risk through the assessment methodology outlined in this paper, consideration should be given where appropriate to treatments that may ultimately enable a net benefit to be realised.

It is expected that PBS level 1 combinations of increased length would be attractive to those freight operations that are currently volumetrically constrained and operating below maximum legal masses. However, an increase in length (and hence volume) may also hold a risk of a rise in overloading incidence as increased payload volumes approach maximum legal masses. PBS Level 1 combinations in the situation of operating at maximum mass, but with remaining payload volume currently exist and would hold a similar risk of overloading, therefore current compliance strategies should be considered to mitigate this risk.

Practical and Operational Considerations

Most of this work has looked at increases in vehicle length in 1 m increments. This may not fully align with practical and operational considerations. For instance, for freight using pallets that are usually 1.2 m square, a maximum length of 22.6 m (19 m + 3 x 1.2 m) may be more appropriate than 22 m or 23 m. More importantly would be where a step change in efficiencies could be realised if a certain increase was achieved. For example, B-doubles extended out to 30 m (Level 2B vehicles) are able to carry two 40 foot containers, resulting in a significant increase above that directly proportional to the increase in length.

Preliminary advice was sought from industry as to any cases where a step change may exist, however none were identified. Anecdotal information suggests that the current 20 m length limit is not practical for palletised freight, as one extra pallet would need 20.2 m to fit in a longer semi-trailer. Bulk freight, such as grain, would also benefit from an extra 0.2 - 0.3 m to reach maximum masses for truck-trailer configurations.

7. FINDINGS

Based upon the results of this project, there appears to be scope to increase the length limit of PBS Level 1 vehicles. It is generally recognised that longer vehicles can offer productivity benefits, particularly for volume-constrained payloads. This is supported by the BCA analysis which showed that vehicles around 25 – 26 m can provide considerable economic benefits in a range of scenarios. Vehicles with maximum lengths of 22 – 23 m were shown to

provide benefits in free-flowing traffic at high volume urban intersections, however, in other situations, they were not shown to provide benefits. It is believed this may be due to the operating costs used over-estimating those in reality.

Using the methodology described in this paper, it has been found that a maximum length of up to 23 m for PBS Level 1 vehicles could be considered for implementation. This is based on sites investigated in this project, where approximately 90% of sites remained in the low risk category. It was found that 55% of the sites would allow 23 m long vehicles at the current levels of accepted risk for a 20 m long vehicle. If low trafficked sites and those designated as low risk were also accepted, 96% of the sites would allow a 23 m long vehicle.

As the location of the sites will be critical in determining whether these numbers would be an acceptable basis for a decision to increase length, it is strongly recommended that all sites be assessed to account for the large variance in individual characteristics. Given that some sites were identified to be high risk for the current 20 m long vehicles, a maximum vehicle length of 23 m is not expected to work universally, and consideration should be given to applying treatments and measures where possible to mitigate and manage the risks. These may include modifications or upgrades to sites, or signage and compliance regimes to manage a network by exception.

The maximum length of up to 23 m identified above has been based on an analysis of the network, and is indicative of its maximum potential from a risk-based perspective. It is strongly recommended that consultation with industry be undertaken to determine the level of demand for longer vehicles under the operating conditions included in the PBS Level 1 Scheme. While it is understood that the current 20 m maximum length is limiting to some heavy vehicle combinations, it may be that industry would not see much demand for anything over (say) 21 m, in which case, there would be little incentive for defining an overly-restrictive 23 m PBS Level 1 network. This will be important to identify as it will be a key driver in deciding the method of any potential implementation.

8. References

- Eady, P. & Elischer, M. (2011a), Performance based standards length limit review: working paper: network assessment methodology, ARRB Group.
- Eady, P. & Elischer, M. (2011b), Performance based standards length limit review: working paper: network assessment outcomes, ARRB Group.
- Austroads (2012), Performance Based Standards Level 1 Length Limit Review by M Elischer, P Eady, F Tan, & G Aguiar, Austroads, Sydney, Australia.
- National Transport Commission (2007), Performance based standards scheme: network classification guidelines, NTC.