PRODUCTIVITY OPPORTUNITIES WITH STEERABLE AXLES

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ABSTRACT

Setting aside the primary (front) steering axles fitted to trucks and prime movers, a wide variety of steerables axles are available for use on multi-axle vehicles. These steerable axles are designed for both trailing (unpowered) axles and driven axles. All of these steerable axle types address, in different ways, the fact that vehicle tyres operate in a sub-optimal way as soon as a vehicle unit is fitted with more than two axles and/or more than one "fixed" axle. This degradation in tyre and vehicle performance can be exhibited in:

- Increased tyre wear
- Increased vehicle swept path
- Increased pavement surface wear
- Increased resistance to forward motion (and increased fuel consumption)
- Potentially undesirable effects on vehicle steering control.

Steerable axles offer performance improvements for all classes of heavy vehicle and provide direct benefits to transport operators who choose to use them. Such performance improvements also open the way to productivity gains in road freight transport operations because longer or heavier vehicles may be enabled within the constraints of the infrastructure, traffic and safety.

Steerable axles may also adversely affect certain areas of heavy vehicle performance, depending on the vehicle configuration and the characteristics of the steerable axle. To address these issues, the dynamic performance of selected vehicles fitted with steerable axles was compared with that of currently-operating vehicle configurations and with the performance parameters being developed in the Performance Based Standards (PBS) project being carried out by the National Road Transport Commission and Austroads.

This paper describes the results of an Australian study of current steerable axle practices, performance effects on a range of vehicle configurations, safety and geometric impacts, productivity benefits, net economic benefits and regulatory implications.

1 INTRODUCTION

The National Road Transport Commission (NRTC) commissioned Roaduser Systems Pty Ltd to carry out a study of the benefits, costs and potential for length increases under PBS and performance effects of steerable axles. The study included investigation of regulations affecting the use of steerable axles, and whether there are any current impediments to the use of steerable axles.

The study included investigation of:

- Current practices with steerable axles (including current regulations affecting steerable axle use)
- Benefits of steerable axles for a wide range of vehicle configurations (as perceived by key stakeholders)
- Benefits of marginal semi-trailer length increases
- Potential for productivity increases (through increased length and mass) with the wider use of steerable axles throughout the Australian fleet (as defined by the prime constraints of low-speed geometric performance)
- Geometric and safety impacts of these initiatives; computer simulation assessment of a wide range of vehicle configurations fitted with steerable axles was carried out
- Productivity benefits, costs and net economic benefits of a range of initiatives deploying steerable axles.

Setting aside the primary (front) steering axles fitted to trucks and prime movers, a wide variety of steerables axles are available for use on multi-axle vehicles. These steerable axles are designed for both trailing (unpowered) axles and driven axles. All of these steerable axle types address, in different ways, the fact that vehicle tyres operate in a sub-optimal way as soon as a vehicle unit is fitted with more than two axles and/or more than one "fixed" axle. This degradation in tyre and vehicle performance can be exhibited in:

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2 CURRENT PRACTICES WITH STEERABLE AXLES

While steerable axles come in a range of generic types, the most common are "automotive type" steerable axles used on semi-trailers; this type of steerable axle is also available for rigid trucks and prime movers. Other types include linked-articulation axle group steering systems for semi-trailers.

Steerable axles are not currently in widespread use in Australia. Current users of automotive-type steerable axles on triaxle semi-trailers report improved tyre wear and improved swept path. Linked-articulation steerable axles are new and are not currently being used in road transport, but offer a large improvement in swept path performance.

Current Australian regulations mitigate against the use of automotive-type steerable axles on trailers because the rear overhang dimension may be exceeded if the rearmost fixed axle is replaced with a steerable axle. There are no current regulatory impediments to the use of steerable axles on rigid trucks, but little use is currently evident on this vehicle type.

The literature suggests that steerable axles on rigid trucks may in certain cases adversely affect vehicle handling and control; this is much less likely on trailers. Most of the research involving steerable axles and vehicle dynamics has been carried out on potential "problem" areas for steerable axles, such as rigid trucks and "C-dollies" for multi-combination vehicles.

3 PERFORMANCE EFFECTS OF STEERABLE AXLES

In addition to the known benefits of reduced swept path and reduced tyre wear, steerable axles also affect vehicle dynamic performance. Provided that steerable axles have at least a threshold level of self-centring, their effects on dynamic stability and tracking behaviour of the common Australian freight vehicle configurations are modest. Only in road trains of conventional configuration were dynamic performance impacts found to be of concern.

In the case of linked-articulation steerable axle group systems, the effects on improving swept path performance can be dramatic. In the case of an automotive-type steerable axle introduced into a triaxle group, there is a modest but worthwhile improvement in low-speed offtracking and swept path.

When an automotive-type steerable axle is introduced into a triaxle group of a typical Australian articulated vehicle (A123), there is a dynamic performance trade-off in a lane-change manoeuvre: the high-speed dynamic offtracking increases (a negative) and the dynamic stability increases (a positive). As illustrated in Figure 1, this trade-off becomes more marked as the self-centring stiffness of the steerable axle reduces.

4 STEERABLE AXLE POTENTIAL UNDER CURRENT REGULATORY REGIME

Steerable axles have the potential to improve access of vehicle combinations in the road network and into sites and depots. This has the greatest potential for B-doubles, where access is often tight and the use of steerable axles could provide substantial gains. Operators should give more consideration to the benefits of fitting steerable axles to B-doubles. Figure 2 shows a typical Australian B-double and the effect on swept path performance of fitting one steerable axle to each triaxle group; this graph shows the effect of overall length (OAL), when caused by increasing trailer s-dimension (distance from kingpin to centre of axle group) on swept path. The steerable axles reduce swept path by approximately 0.5 m; alternatively, they allow the vehicle to become over 1.0 m longer for the same swept path performance.

Steerable axles could also be fitted to rigid trucks, leading to R13 and R23 configurations with increased GVM and productivity for mass-limited loads. Although not currently impeded by regulations, these applications currently find little uptake and there are likely to be useful gains available to some operators.

5 STEERABLE AXLES DRIVING ROAD FREIGHT PRODUCTIVITY

Steerable axles potentially offer productivity benefits in (i) increased cubic capacity for road freight vehicles and (ii) increased gross mass for road freight vehicles (within existing axle mass limits). Regulatory review or the introduction of Performance-Based Standards (PBS) is needed to realise the potential productivity benefits. A PBS regulatory regime is currently being developed in Australia (1). It is anticipated that this will provide an alternative to the current prescriptive limits and will require demonstration of compliance with certain measures and standards pertaining to dynamic performance and infrastructure performance.

Increased cubic capacity is related to increased trailer length and increased length of rigid trucks, leading to increased "load length" of the vehicle or vehicle combinations. Such length increases will be constrained in the first instance by low-speed geometric performance considerations, and may be further constrained by considerations of dynamic performance (tracking and stability behaviour or infrastructure impacts).

Increased mass is a less direct consequence of the use of steerable axles, but could arise from:

- The ability to place additional axles on existing configurations without incurring unacceptable tyre scrub; for example, a quad axle semi-trailer with one steerable axle in the quad group
- The ability to introduce heavier axle groups spaced further apart (to maintain compliance with bridge formulae) and still retain acceptable low-speed geometric performance.

Generally speaking, requirements to ensure that dynamic performance of a vehicle combination is not degraded by the fitting of an automotive-type steerable axle are straightforward. This may be achieved via steerable axle standards such as requiring that the aligning stiffness of the automotive-type steerable axle should be at least equivalent to the medium stiffness value used in this study, or simply by requiring certain vehicle PBS to be achieved. There should also be a limit of one automotive-type steerable axle per triaxle group, and the steerable axle should be fitted in the rear position. Consideration should also be given to the need for any specific requirements for load sharing performance of steerable axles when incorporated in an axle group.

Figure 3 shows a potential 15 m semi-trailer with an axle group comprising two fixed axles and one steerable axle in combination with the longest prime mover which will allow the vehicle to comply with the Austroads General Access Swept Path Specification. This 15 m semi-trailer has an s-dimension of less than 10.0 m, but the distance from the kingpin to the load-bearing centre of the triaxle group remains at 10.0 m in order to preserve effective load distribution. This combination exceeds the current limit 19 m in overall length and the wheelbase of the prime mover is less restricted.

Figure 4 shows a 50 t quad axle (steerable) semi-trailer combination which meets the Australian general access bridge formula for road-friendly vehicles, is capable of optimum load distribution for a water-level load and utilises a standard-length 14.6 m (48 ft) semi-trailer. This vehicle has the following characteristics:

- Gross combination mass of 50 t
- Overall length of 18.75 m (with a conventional prime mover of moderate wheelbase)
- Semi-trailer length of 14.6 m
- S-dimension of 9.5 m
- Rear overhang of 4.35 m (in excess of current limit).

In addition to good swept path performance, this vehicle improves on the current A123 (with fixed trailer axles) in terms of dynamic stability (see Figure 5); at the same time, the gross mass increases from 45.5 t to 50 t with only a modest increase in tare mass. The presence of the steerable axle assists swept path performance and reduces pavement wear and tyre wear.

In Australia, 25 m/68 t B-doubles currently operate on designated routes. In the future, major road freight routes will be better defined and designed for large vehicle combinations. Figure 6 shows a "super B-double" which utilises two automotive-type steerable axles and increases both mass and cubic productivity within major freight route performance parameters. This vehicle meets the current B-double bridge formula, increases gross mass to 77 t and increases the total deck length from approximately 19.5 m to approximately 24 m. Swept path performance is on the limit for major freight routes and stability is significantly improved relative to current B-doubles (see Figure 7).

6 ECONOMIC BENEFITS

The wider deployment of steerable axles offers substantial financial and economic benefits in cases where productivity gains are able to be exploited with high-utilisation vehicles. The net benefits to the Australian economy depend on the take-up rate of such initiatives, and take-up can only be estimated.

The economic benefits of minor regulatory change in relation to improved access and reduced tyre wear are difficult to estimate. However, as the necessary changes are small and no significant costs to agencies have been identified, such changes are recommended.

The nett contribution of steerable-axle enabled vehicle combinations to PBS-based regulatory reforms in Australia is conservatively estimated to be M\$60 per year (Australian dollars).

7 CONCLUSIONS

The use of automotive-type steerable axles in Australian vehicle combinations offers significant productivity and economic nett benefits with relatively little impact on vehicle safety performance. Steerable-axle-enabled vehicle combinations offer certain improvements in dynamic performance, provided some straightforward controls on steerable axle characteristics are introduced.

Steerable axles fitted to trailers in optimised vehicle combinations offer increases in both payload cube and mass, taking into account the physical constraints of road space and bridge strength.

Steerable axles also offer benefits when fitted to current (non-optimised) vehicle combinations. Such benefits include improved access, reduced tyre wear, reduced pavement wear and reduced fuel consumption and emissions. These benefits are considered to be worthwhile, although were not able to be quantified in the study.

8 REFERENCES

 Prem, H et al (2002) Performance characteristics of the Australian heavy vehicle fleet. NRTC Working Paper.

TABLES & FIGURES



Figure 1 – Dynamic performance trade-off for A123 vehicle with steerable axle in rear position, as a function of steerable axle stiffness





Figure 2 – Effect of steerable axles on swept path of 25 m Australian B-double (B1233)



Candidate 15m Tractor-semi-trailer (A123) with a steerable axle fitted

Figure 3 - Potential 15 m triaxle semi-trailer with automotive-type steerable axle in rear position

(A124) Tractor Semi-Trailer - (Increased mass capacity with additional steerable axle)



Figure 4 – Potential 50 t quad axle semi-trailer with automotive-type steerable axle in rear position (including axle spacing mass schedule analysis)



Figure 5 - Improved dynamic stability of A124 (with steerable axle) vs current A123





Figure 6 - "Super B-double" for major freight routes



Figure 7 - Stability of "super B-double"