

Implications for road system management of emerging types of private passenger vehicles

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1. Introduction

The motor car has risen to a position of dominance in personal mobility in western society. It is now recognised as something that offers more than just a means of mobility, since it creates personal space, maintains autonomy and serves as an identity function (Mann and Abraham, 2006). However its position is being challenged by concerns over congestion, fuel availability and price, local air quality and global atmospheric impacts. While public transport will be called on to play a greater role, particularly in urban areas, there is no evidence that it will be able to cater for the mobility needs of all urban residents.

The desire for personal mobility continues to stimulate the creation of innovative vehicle designs. The motor car continues to evolve but it is being complemented by alternative means of independent motorised mobility including personal mobility devices, low powered two wheel vehicles and small footprint four wheel vehicles. For road network managers, the growth of alternative vehicles can have a variety of impacts and implications, from the design of individual elements of the road system, such as parking bays, to the refinement of the regulatory structures that govern vehicle use. The research reported here was undertaken to:

- Enhance understanding of the characteristics of emerging vehicle types
- Identify potential impacts, and
- Examine implications for road system management particularly in relation to regulation and design.

The structure of this paper is as follows. The spectrum of alternative private passenger vehicles is illustrated in Section 2. Section 3 outlines the assessment approach used to examine the extent to which the different types of emerging private passenger vehicles might contribute to the objectives which road system managers commonly seek to progress. Implications of the assessment are explored in Section 4 and the conclusions of the study are presented in Section 5.

2. The spectrum of alternative private passenger vehicles.

The title 'velomobile' describes a single or dual occupant vehicle, usually recumbent, commonly powered by a combination of pedals and an electric motor, with an enclosed shell to provide both aerodynamic benefits as well as weather protection. These vehicles are usually designed for speed and hence, have a low, slender stance with minimal frontal area in order to minimise drag.

Three wheel leaning vehicles have been in development since the early 1980s with the General Motors Lean Machine; an internal combustion powered, single occupant, single front wheel, leaning vehicle (Figure 5a) (Riley, 2004). More recent versions of this vehicle type are the Clever (Figure 5b) and Carver One (Figure 6). The Clever is a dual occupant, natural gas powered, three wheel design lead by Berlin Technical University (EU Transport Research 2004) and the Carver One (N.D.) was the first-ever commercially available tilting three-wheel vehicle with an enclosed passenger compartment (Carver Engineering 2006). Research has demonstrated that three wheels instead of four, coupled with a tilting capacity, can result in more stability, not less, as well as unparalleled performance when the design elements are balanced (Hollmotz et al, 2005).



(a) Segway



(b) T3 Motion



(c) Mobility scooter

Figure 2: Personal mobility devices



Figure 3: Power assisted bicycles



Figure 4: Velomobiles



(a) GM lean machine concept vehicle



(b) Clever concept

Source: www.3wheelers.com and www.clever-project.net

Figure 5: Three-wheel leaning vehicles



Source: <http://www.carver-worldwide.com/Home/Index.asp?nc=1>

Figure 6: Carver One (3 wheel leaning vehicle)



(a) Riley



(b) Aptera

Source: www.rqriley.com and www.aptera.com

Figure 7: Three-wheel non-leaning vehicles



Source: www.unisa.edu.au/solarcar/Trev/

Figure 8: Two-seater renewable energy vehicle (TREV) – three wheel, non-leaning



(a) Smart



(b) Reva



(d) Tango



(d) ZENN

Source: www.rqriley.com and www.aptera.com

Figure 9: Four-wheel non-leaning vehicles

Three wheel non-leaning vehicles such as the Riley and Aptera demonstrate clear benefits in weight reduction, aerodynamic performance and fuel efficiency over the traditional motorcar. These vehicles are often attributed motorcycle classification exempting them from crash testing before commercial release. The developers of the Aptera believe that its motorcycle classification and electric drive-train will make it legal to drive solo in California's carpool lanes (Woodyard, 2008). The crash test exemption has

implications for the development of the vehicle with the company's CEO (Mr C Fambro) quoted in Woodyard (2008) as saying that the "The testing and red tape required to market a motorcycle is less rigorous than for a four-wheel car. It allows us to leapfrog into the market". The trade off between crashworthiness and vehicle efficiency, performance and accessibility can present a challenge to road authorities particularly if the introduction of these vehicles resulted in deteriorated safety outcomes.

Four wheel non-leaning vehicles, such as the Smart, Reva, Tango and ZENN, represent a market segment known as 'microcars'. The term microcar describes a very small class of car, generally two-door, two-seater and less than 3 metres in length. The first vehicle in this class to capture a high profile is the Mercedes Benz SMART (Figure 9a) a vehicle whose length makes possible parking perpendicular to the curve virtually in the width of a normal parking space but other similar vehicles are emerging such as the Commuter Cars Corporation Tango (Figure 9d). Vehicles in this category can be powered by either petrol or electricity and in Europe some are limited to low speed zones. Microcars also have a potential application as station cars where they are intended for travel from a suburban home to bus or rail transit for city commuting and may involve pooled rather than individual ownership.

3. Assessing Impacts on key outcomes area

In developing an approach to systematically examining the implications of these vehicles, regard was paid to the work of Oxford Systematics (2000 and 2005), which reviewed motorcycles as a transport mode and adopted a planning balance sheet approach for developing a cost and impact assessment framework. A planning balance sheet establishes a framework of objectives, possibly with sub-attributes, and then scores each item for each option. Interpreted in the context of this study, the options are not distinctive 'either or choices' per se, as would be the case when considering alternative infrastructure options in a planning study, but the different vehicle categories under investigation. Here the individual vehicle categories are scored on the basis of their impact on the key objectives. This is equivalent to the approach adopted by Missikos & James (1997) when assessing policy options for electric wheelchairs and scooters.

The objectives considered in the planning balance sheet framework relate to the impacts that are of particular concern. Here they are cast in terms of key outcomes that are of relevance when new or innovative vehicle types are considered. Those key outcome areas are identified in Table 1. The approach taken was to base the assessment in each key outcome area on relevant literature, where available, regarding individual vehicle categories. Details of that literature, along with an elaboration of the basis of the assessments for each vehicle category, is provided in Rose and Richardson (2009). At a workshop held in Melbourne, representatives from state road and local government authorities, consultants and the private sector, provided feedback on the assessment of individual vehicle categories and helped to refine the assessment presented in this paper.

Table 1: Key outcome areas

Key outcome area	Sub-attributes
Improving transport system efficiency	- Movement: congestion and road space use - Parking.
Improving safety	- User/rider. - Interaction with other vehicles and road users specifically pedestrians and motor vehicles.
Reducing use of non-renewable energy	- Reducing reliance on non-renewable energy and potential to make greater use of renewable energy.
Reducing environmental impacts	- Use and disposal.
Maximising accessibility and mobility benefits	- For users and non-users. - Consider where relevant extent to which mobility via active transport means (walking, cycling) may be reduced with consequent negative health impact. - A distinction is drawn between short, medium and long range mobility benefits.

A scoring or rating scheme facilitates a summary assessment being made, on the basis of the information available, as to the extent to which a particular vehicle type impacts on the key outcome areas. Since the outcomes relate to underlying objectives which could be set for the transport system, a justifiable basis for that scoring would be the scale used as part of the Strategic Merit Test in the *National Guidelines for Transport System Management in Australia* (Australian Transport Council, 2006). The National Guidelines suggest that the achievement of each objective be rated on a seven point scale which could be interpreted on a numerical scale from -3 to +3 as follows:

- 3 (*large negative*): major negative impacts with serious long term and possible irreversible effects leading to serious damage, degradation of the physical, economic or social environment.
- 2 (*moderate negative*): moderate negative impact. Impacts may be short, medium or and most likely respond to management strategies.
- 1 (*slight negative*): minimal negative impact. Possibly short term, able to be managed or mitigated, and does not cause substantial detrimental effects. May be confined to a small area
- 0 (*neutral*): no discernible or predicted positive or negative impacts.
- +1 (*slight positive*): minimal positive impact, possibly only lasting over the short term. This impact may be also confined to limited areas.
- +2 (*moderate positive*): moderate positive impact, possibly of short, medium or duration. Positive outcome may be in terms of opportunities and outcomes for enhancement or improvement.
- +3 (*large positive*): major positive impacts resulting from *substantial* and improvements or enhancements to the existing environment.

A 10 year time frame was considered when framing the impact assessment. Reflecting the level of uncertainty, even over that period, a band of scores (low and high) is used to indicate the likely level of uncertainty in the impact assessments. Marginal impacts are indicated by increments of 0.5 on the scale.

Table 2 summarises the impacts assessed for each of the vehicle categories on key outcomes of interest. This table can be used to develop an appreciation of the trade-offs associated with the different vehicle categories in terms of their relative contribution to key outcomes. The shaded cells in the table correspond to the maximum positive impact on each outcome area.

Table 2: Assessment summary for all vehicle categories

Outcome	Segway	MMS	Power assisted bicycles	Three-wheeled vehicles	Micro/Moped cars
Improving transport system efficiency (congestion, parking)	0 to 0.5	0	0 to 0.5	0 to 2	-0.5 to 2
Improving safety	-1 to +0.5	-1 to +1	-1 to 0.5	- 2.5 to +0.5	-2 to +0.5
Reducing non-sustainable energy use	0 to +0.5	0 to +0.5	0 to 0.5	1 to 3	1 to 3
Reducing environmental impacts	0 to +0.5	0 to +0.5	0 to 0.5	1 to 3	1 to 3
Facilitating accessibility and mobility	-1 to +1 (short to medium range)	-1 to +3 (short to medium range)	-0.5 to 1 (short to medium range)	0 to 1 (medium to long range)	0 to 1 (medium to long range)

It is clear that the three-wheeled vehicles and micro/moped cars present the greatest opportunities to progress key outcomes in relation to transport system efficiency, energy consumption and environmental impacts. The downside is that safety outcomes could deteriorate considerably if the risks are not adequately managed. The large negative scores could be interpreted in one of two ways. It could be taken to indicate that serious consideration needs to be given to whether that type of vehicle should be introduced into the vehicle fleet. Alternatively, it could be interpreted as flagging that considerable attention is required to manage the integration of that type of vehicle into the fleet and the road system. With an effective response to those vehicle categories, the scope exists to achieve enhanced outcomes. Given the discussion of risks and safety outcomes, a key issue relates to the inherent crashworthiness of some vehicle types and their speed along with their speed differential and relative crashworthiness against other vehicles on the road. Fundamentally there is an issue of the extent to which segregation versus integration should be pursued when accommodating new types of vehicles and the conditions or locations where either of those options might be most appropriate.

The examination of other categories considered, namely the Segway, motorised mobility scooters (MMS) and power assisted bicycles suggests that they are relatively benign in relation to most of the outcomes of interest. However, the MMS stand out because of their potential to substantially enhance the accessibility and mobility of their users. The niche nature of the vehicles in the first three categories means that they present neither substantial mobility opportunities nor dramatic safety risks. That does not mean, though, that those categories of vehicle do not require attention. A do-

nothing approach may result in deteriorated outcomes, particularly from the safety perspective.

4. Implications

This section synthesises the key implications from the analysis and identifies priorities for attention in the short, medium and longer term. In addition to identifying the range of responses of relevance to each category of vehicle, implications for both regulations/regulatory structures and geometric design are discussed.

4.1 Broad Responses

There are a range of broad responses available to manage the emerging vehicle types. These include:

Vehicle standards: These have an important role to play in relation to a number of the vehicle categories. Of particular relevance are the prescriptive nature of existing vehicle definitions (e.g. power assisted bicycles) and the inadequacy of the existing classification scheme to capture potentially emerging vehicle categories (such as the Segway and moped cars). The issue of standards can extend to the specification of mandatory safety equipment. In relation to the Segway, this could include a bell, lighting for night-time use, and a speedometre. In relation to vehicle standards, crashworthiness and provision of passive safety features are items of high priority particularly for the three-wheeled vehicles and the category of micro/moped cars. Some of the vehicles in those categories rely on an ultra lightweight design to lower their environmental footprint. Since that can have implications for the level of passive safety provided, this issue needs careful attention particularly for vehicles in those categories that are capable of high speed operation. There may be merit in considering restrictions on where and how a vehicle is operated (e.g. spatial or network access limitations to particular roads) along with perhaps specifying a maximum speed that would allow a trade-off in the level of passive safety provided in these vehicles compared to conventional motor cars.

Driver licensing or assessment: This response is particularly relevant to MMS where there are currently no uniform requirements for rider assessment in Australia despite the clear potential for some users to exhibit cognitive impairment, neurological disease or visual defects which could have implications for their ability to operate the vehicle safely. For the three-wheeled vehicles there is the issue of the most appropriate form of assessment and licensing and whether it should be based on existing requirements for two and/or four-wheeled vehicles.

Insurance: The primary insurance issues raised by this review relate to the adequacy of third party insurance arrangements, particularly for the Segway and Motorised Mobility Scooter (MMS). MMS, for example, are not currently covered in all Australian states under existing third party insurance arrangements.

Road rules: There is a range of potential implications for road rules. This can include the desirability of minimum rider age specifications for devices such as the Segway and power assisted bicycle through to the conditions under which lane sharing should be permitted for narrow three and four-wheeled vehicles. There is also the issue of whether the latter vehicles should be permitted access to high occupancy vehicle lanes when carrying a single person.

Compliance/enforcement: This is potentially an issue with all vehicle categories in relation to either compliance with vehicle standards or operating conditions. It is possible that for some of the vehicle types considered here there may be merit in restricting operations to certain road types: for example, prohibiting some vehicle types from operating on roads with higher speed limits. There would be scope to link with emerging technological developments to ensure greater compliance with operating conditions by incorporating on-board vehicle monitoring equipment. The Intelligent Access Project (IAP) is providing a compliance scheme for heavy vehicles to ensure they are operated in accordance with approved conditions (Transport Certification Australia 2005). That same technology could potentially be used to ensure compliance with operating rules for some of the vehicle categories considered here, for example for the micro/moped cars. More broadly, developments in the field of Intelligent Transport Systems, including driver assistance systems and collision warning or avoidance systems, could have the potential to enhance the safety of a number of the categories of vehicles considered here, particularly when those systems are fitted to other motor vehicles.

Fiscal: Infrastructure related expenditure could be directed at micro-level improvements in footpaths and shared-use paths. This would reduce the risks of falls, remove mobility impediments or points of conflict, and facilitate safe operation by Segways and MMS. On a larger scale, growth in numbers of narrow three and four-wheeled vehicles could require attention to broader infrastructure changes including the re-striping of existing lanes or provision of narrow lanes segregated from other traffic. Also included under the category of fiscal measures is the scope to use fees/charges to either promote or discourage some vehicle types. This could be done through adjustments to registration fees. Consideration may also need to be given to the potential implications of a loss of revenue if say moped two-wheeler riders (who currently have to pay to register their vehicle) changed to a power assisted bicycle that required no registration.

Training: This is potentially of relevance to each of the vehicle categories. While explicit licensing requirements have implications for the level of training required to pass the test, there may also be a need to work towards industry standards for appropriate training for categories of vehicles where there is no licensing requirement, e.g. for the Segway and MMS.

Advocacy: There is scope for advocacy to highlight issues that consumers need to be aware of when making vehicle purchase decisions and also when

operating vehicles considered here. Similar to the campaigns designed to raise awareness of the need for different existing road user groups to share the road safely, there would be scope for similar campaigns to promote safe sharing of the road by narrow three and four-wheeled vehicles as well as lower environmental footprint micro/moped cars. There are also existing campaigns in some States which focus on the importance of personal protective equipment for motorcycle riders and those campaigns could be broadened to address that issue in relation to the categories of vehicles considered here.

4.2 Regulatory Implications

At present in Australia, vehicles are classified as part of the Australian Design Rules (ADRs). Of particular relevance here are the vehicles classified as either Two-Wheeled and Three-Wheeled Vehicles and Passenger Vehicles (other than Omnibuses). Vehicles included in each of the ADR categories are identified in Table 2.

Table 3: ADR vehicle classifications

Vehicle category	Definition
Pedal cycle (AA)	Propelled solely by human power.
Power-assisted pedal cycle (AB)	Pedal cycle + auxiliary motors having a combined maximum power output < 200 watts.
Moped - 2 wheels (LA)	Not an AB, with an engine cylinder capacity < 50 ml and a maximum speed < 50 km/h.
Moped - 3 wheels (LB)	Not an AB with an engine cylinder capacity < 50 ml and a maximum speed < 50 km/h.
Motor cycle (LC)	2-wheels, engine cylinder capacity > 50 ml or max speed > 50 km/h.
Motor cycle and side car (LD)	3 wheels, engine cylinder capacity > 50 ml or max speed > 50 km/h.
Motor tricycle (LE)	3 wheels, 'Gross Vehicle Mass' < 1.0 tonne and engine cylinder capacity > 50 ml or a max speed > 50 km/h..
Passenger car (MA)	A passenger vehicle, up to 9 seating positions, including that of the driver.

(Source: Commonwealth Vehicle Standards [Australian Design Rule - Definitions & Vehicle Categories] 2005)

These nationally defined vehicle categories have associated conditions governing vehicle design and operation including requirements for drivers to be licensed for certain vehicles and for those vehicles to be registered, restrictions on where they can operate (e.g. on the road, on bicycle paths and on the footpath) and what level of protective equipment the rider/driver is required to use (e.g. bicycle helmet, motorcycle helmet, seat belts etc.). Only registered motor vehicles can be used on roads and in other open public areas.

Motorised mobility scooters are not defined as a motor vehicle category under the ADRs. Under state legislation 'motorised mobility devices', may not be classified as 'motor vehicles' and therefore may not be required to be registered. However, as noted earlier, there are variations across states in the requirements to register these vehicles. Essentially users of these devices must obey the same road rules as pedestrians.

The existing vehicle regulation framework, as reflected in the nominated vehicle categories, is based around a set of prescriptive standards that revolve around a set of defined vehicle categories. That framework relies on a comprehensive set of vehicle categories and the ability to classify an emerging vehicle type into one of those categories and therefore identify relevant standards for its design and rules for its operation. That approach is challenged when new vehicle types emerge which do not fit within the existing categories. The Segway is perhaps the clearest example, since it fits neither in the category of motorised mobility devices, which cater for users who need mobility assistance, nor is it a power assisted bicycle. At the other end of the scale, there is a single category for four-wheeled motor cars. Overseas regulatory frameworks include a quadricycle, or neighbourhood electric vehicle, category to accommodate low powered motor vehicles or moped cars.

Rigidly adhering to the current vehicle categories could be an option to exclude certain emerging vehicle types. While that may minimise possible safety risks, it also means there is no scope to capitalise on the potential opportunities in relation to enhancing system efficiency and reducing environmental impacts which some emerging vehicle categories present.

The option exists to evolve the existing regulatory framework to include additional categories where regarded as appropriate. For example, there would be scope to include a category for personal mobility devices, potentially covering Segways and Motorised Mobility Scooters or a quadricycle type category to accommodate moped cars. Alternatively existing categories can be revised by, for example, reviewing the power limit on power assisted bicycles. Such an approach has the benefit of building on the existing framework but it does not future proof the framework to cater for developments in vehicle technology that may only emerge in the years ahead.

An alternative would be to bring in a performance based standards (PBS) framework for regulating emerging vehicle categories. The concept of PBS has been adopted in relation to the regulation of heavy vehicles where there has been a move away from 'prescriptive' limits on masses and dimensions that were originally designed as an indirect way of achieving safety and infrastructure protection objectives. PBS focussed on the elements of vehicle performance, such as manoeuvrability, stability, effective impact on pavements, that most influence safety and infrastructure protection outcomes. As noted by Bennett et al. (2003), PBS 'provide vehicle manufacturers and transport operators with greater flexibility to vary vehicle designs and freight operations so as to improve productivity without detriment to road safety and infrastructure protection'. In the freight context, the benefits of PBS relate principally to the productivity improvements they offer to industry (Bennett et al, 2003).

There would be scope for considering a performance based framework through which alternative passenger vehicles could be assessed. The framework could draw a distinction on the basis of the environment within

which the vehicle is to be operated, when identifying an appropriate performance envelope, for example:

- Footpath environments could be governed by the performance of a pedestrian in terms of restricting vehicles to travel at walking speeds. This would essentially be a low speed environment.
- Shared paths and bicycle paths could be governed by the performance of a human powered bicycle. This would reflect a medium speed environment.
- Road environments could be grouped into the typical road classes with access to a given class of road dependent on the maximum speed of the vehicle and its safety characteristics. Where vehicles were only granted access to limited parts of the network, for example low speed local roads, their compliance could be monitored using advanced technology such as the Intelligent Access Project (IAP) (Transport Certification Australia 2005).

4.3 Geometric Design

Of the vehicle categories reviewed in this study, the narrow three and four-wheeled vehicles have the potential for the most profound implications for geometric design of the road system. As a result of a tandem seating configuration, these vehicles have a width of about one metre and consequently could operate in lanes roughly half the width of existing lanes. There could be scope to allow them to operate side by side in existing lanes although the maximum benefit in terms of enhancing system efficiency would be if separate, possibly segregated, facilities were provided for them. Their narrower guideway requirement and lighter weight could also translate into lighter and cheaper bridges and elevated sections of roadway if purpose built for that type of vehicle. There were also examples of three-wheeled cars that were narrower than existing motor cars and could provide scope to reduce lane widths although not by a factor of a half as in the case of the very narrow vehicles. While these narrow and very narrow vehicles have the potential to have the greatest impacts on geometric design, there was no evidence forthcoming in this research that they are likely to emerge in numbers that would justify infrastructure changes within a 10 year time frame. Should this type of vehicle gather some momentum in the market, there could be a more immediate opportunity to review the design and provision of parking spaces for small footprint vehicles (See Figure 10). Changes of that nature could be implemented relatively easily, even in the context of existing parking facilities. There is a need to continue to monitor developments with this class of vehicle and reassess the need for any changes in geometric design standards in say five years time.



Figure 10: Small spatial footprint vehicles offer opportunities for better utilization of parking spaces

4.4 Priorities

In response to the varying levels of uncertainty about the availability and uptake of differing emerging vehicle types, a series of prioritised actions are identified for road system managers to respond to the opportunities and threats presented by these vehicles.

In the short term, the priority should be to direct attention at motorised mobility scooters since the demand for these is certain to rise and will be determined by the ageing demographic. In that sense there is far less uncertainty about these vehicles being part of the mix than any other type of vehicle reviewed in this study. The use of these vehicles is set to grow not only in major urban areas but also in regional centres where they have the potential to become de-facto neighbourhood electric vehicles. In that context they are likely to be associated with greater on-road use arising either from lack of footpath facilities or poor maintenance of footpaths that are provided. Of particular relevance with these vehicles is the need for attention to geometric design standards which impact on the safety and convenience of users, specifically in relation to ramps and railway level crossings (Sinclair Knight Merz 2006). More broadly, there is scope to consider a consistent national framework for dealing with issues of driver assessment, licensing, registration and third party insurance arrangements.

One other short term priority is to ensure that road crash reporting systems are accurately recording vehicle types. For example, crash reporting forms should distinguish power assisted bicycles from conventional bicycles. This will ensure that data is available so that trends in injuries and fatalities can be adequately monitored.

In the medium term, there is scope to examine the regulatory framework for passenger vehicles through a performance based lens. This would be consistent with the approach taken to heavy vehicles and would hold potential to put in place a framework that would be future proofed against any emerging vehicle types. In a performance based standards framework, it would be necessary to identify performance criteria (in terms of maximum speed, crashworthiness, protective equipment etc.) that may enable a particular type

of vehicle to be considered as suitable for a certain road environment. This approach could provide a more holistic response to emerging vehicle types including the power assisted bicycle, the Segway and also quadracycles or micro/moped cars. As part of a broad based regulatory review, consideration should also be given to how field studies involving emerging vehicles could be facilitated in Australia. The prescriptive national basis used in defining existing vehicle types rules out the scope to conduct field trials with emerging vehicle types, such as the Segway or a range of power assisted bicycles, as were conducted in Germany and Canada (Lamy, 2000; Darmochwal and Topp, 2000; Castonguay and Binwa, 2006).

In the longer term there is a need to maintain a watching brief on three-wheeled vehicles. It remains unclear how either demand for, or supply of, these vehicles will evolve in the years ahead. The narrow variants could have the greatest implications for geometric design but there is a low probability that they will be part of the vehicle mix. If the narrow three and four-wheeled cars gained market acceptance, there would be scope to respond in the shorter term by reviewing design requirements for parking facilities and then reassessing the need for broader changes to geometric design standards relating to lane widths.

5. Conclusions

This study has identified that there is a range of emerging vehicle types that have implications for road transport system management. Those vehicle types span from human powered vehicles, to ones that combine human and motor power and those which are completely motor powered. In general, these emerging vehicle types have greatest implications for how the road transport system is regulated and operated rather than for geometric design standards.

Emerging types of vehicles have the potential to enhance system efficiency through reductions in congestion, or more cost-effective opportunities for capacity expansion, and in addition lighten the environmental footprint of independent motorised mobility modes. A proactive approach is needed for road authorities to capitalise on the opportunities that a number of alternative vehicles present to enhance system efficiency and lower environmental impacts while at the same time ensuring that safety outcomes are not compromised.

Acknowledgement

The authors gratefully acknowledge the support provided by Austroads for the original research which provided the foundations for this paper. However the views expressed in this paper are solely those of the authors and do not represent the views of Austroads or any of its member organisations. We gratefully acknowledge the feedback provided by the Austroads project steering committee along with the many individuals from state and local government authorities, consultants and the private sector, who participated in a consultation workshop held as part of the original project.

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