Regulations and safety for electric bicycles and other low- powered vehicles
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Contents

Executive summary

With technological advances and lower prices, electric bicycles (e-bikes) and other low-powered vehicles (LPVs) such as mobility scooters, self-balancing devices, e-skateboards and e-scooters are rapidly becoming more popular. Chapter 1 describes how such devices can be seen as having economic, environmental and/or personal health benefits, require less road space and consume less fossil-fuel, compared with traditional modes on a per person-trip basis. Many LPVs are blurring the lines between conventional vehicle classifications, and raising new questions about our existing legislation and infrastructure. Current New Zealand legislation principally refers to motor power and, unlike most other countries, does not limit the maximum motor-assisted speed. Regulations should be flexible enough to cover any new device that does not yet exist, help minimise harm to road and path users, and support the positive benefits of LPVs.

What is an LPV?

The various types of LPVs are introduced in chapter 2. The research focuses on electric-powered devices with a continuous power rating no more than 2,000 W and considers how these relate to existing legislation (including for petrol-powered mopeds). The devices may or may not include means of human propulsion. In New Zealand, the vehicles included in this research fall into one of the following classes:

- power-assisted pedal cycles (bicycle-style e-bikes)
- mopeds, including motor scooters with a maximum speed of 50 km/h and low-powered scooters (also known as power cycles or scooter-style e-bikes with pedals)
- wheeled recreational devices, which may have a motor of no more than 300 W
- mobility devices, including power chairs and mobility scooters, which may have a motor up to 1,500 W
- devices or vehicles with power above 300 W and up to 600 W officially declared to not be a motor vehicle, eg the Yike Bike.

Some of the LPVs studied do not currently fall into any New Zealand class. Overseas, some of the vehicles included in this research are grouped into categories such as personal mobility devices or powered mobility devices (PMDs), personal light electric vehicles (PLEVs), personal electric transportation devices (PETDs), other power-driven mobility devices (OPDMDs), or low-speed electric vehicles (LSEVs).

Methods

The results of an extensive literature review and internet research on existing and new technologies in development have been incorporated throughout this report. Chapter 3 summarises an online survey of 1,356 interested stakeholders (including LPV users, other road and path users, advocates, manufacturers, importers and retailers) undertaken to better understand the current climate of LPVs in New Zealand. Key stakeholders were consulted through telephone interviews, workshops in Christchurch and Wellington, a meeting with the RCA Forum Shared Footpath Working Group, and visits with retailers. The researchers also attended events such as the Motorhome Show and the Active Ageing Expo to learn about the marketplace from the perspective of older persons, and the Evolocity FESTT where high school students and engineers collaborate to innovate with electric vehicles. The research revealed a wide range of often conflicting views on issues such as the use of footpaths and whether throttle e-bikes should be permitted.

Market analysis

Chapter 4 describes a market prediction undertaken to predict sales of e-bikes and mobility scooters in future years, based on sales trends in New Zealand and other countries. Unit sales of e-bikes have climbed rapidly from about 2,300 in 2014 to about 14,000 in 2016. Based on a medium growth rate scenario, unit sales are predicted to be over 35,000 in 2026. In a high growth scenario such as we are currently experiencing, sales may exceed 65,000 units in 2026. For mobility scooters, about 6,000 are sold per year but a growth trend is not clear. It was not possible to forecast sales for other LPVs due to limited data.

Safety analysis

A safety analysis (chapter 5) based on overseas studies yielded inconclusive results, perhaps due to poor reporting methods and the relative newness of LPVs. Older studies in particular should be treated with caution as the devices included may have different characteristics than what is now becoming available. New Zealand's *Safer journeys strategy* (MoT 2010) sets out four principles of a Safe System:

- **Safe speeds** are associated with decreased likelihood and injury severity of crashes. Throughout this report, two main approaches to mitigating speed are discussed – controlling the speed capability of LPVs and encouraging or requiring users to travel at a speed appropriate to the conditions (eg when sharing space with pedestrians).
- **Safe vehicles** in the context of LPVs include features such as the ability of self-balancing devices to travel at very low speeds without wobbling, as discussed in chapter 7.
- **Safe road use** in the context of LPVs is addressed through an assessment of existing rules (chapter 8) and educational messages (section 9.1).
- **Safe roads and roadsides** such as geometric design for LPVs is covered in section 9.3. Longstanding issues of inadequate footpath width and surface smoothness are beyond the scope of this research.

E-bike safety research suggests there are both increased safety risks and safety benefits associated with e-bike use compared with unpowered bicycles. The higher average speed (about 3 to 8 km/h faster, refer section 5.1) and greater mass (typically 4 to 8 kg heavier) of e-bikes may increase the likelihood and injury severity of crashes. On the other hand, e-bikes help address many barriers to cycling and therefore are likely to support the 'safety in numbers' effect. If e-bikes replace car trips, then they may reduce the social cost of crashes as they cause less damage and injury to others than motor vehicles.

Mobility scooters have the highest involvement in fatal crashes (at least 20 deaths in the last 10 years). Most non-fatal incidents are related to falls from the scooter or crashes into stationary objects rather than collisions with motor vehicles.

Safety evidence for other LPVs is scant. One American study showed e-kick scooter injuries were over three times as likely to be severe than non-powered scooter injuries – although at the time the study was conducted, most scooters available in the US were the toy variants aimed at children. Collision modelling for self-balancing devices indicates lower head injury severities than the equivalent pedestrian collisions. Segways were not found to have a serious adverse safety record, and are permitted in most public places in the US and increasingly in Europe and Australia.

The ability of users to control LPVs is considered in chapter 6. As the human brain is not fully developed until adulthood, younger people are less equipped to make decisions and more likely to take risks. Conversely, elderly people suffer a decline in motor skill, sensory function and cognitive ability, which can affect their ability to operate devices. Unfortunately, the information available is not detailed enough to suggest upper and lower age thresholds.

Technological features

Chapter 7 presents the technical features affecting safety. Manufacturers often restrict speed and/or power to manage safety, comply with regulations and maximise vehicle durability. However, some users defeat these restrictions by tampering with software, sensors, or motors, or by using higher-voltage batteries. Most LPVs have permanently mounted lights providing a reliable means of seeing and being seen. Production e-bikes generally have powerful disc or hydraulic rim brakes in compliance with applicable overseas standards. Most other LPVs have adequate braking capability via the motor. Automatic curve speed reduction for certain mobility scooters reduces the probability of a tip-over injury. In future, autonomous technologies could reduce many perceived and actual safety issues with LPVs.

Regulation

Chapter 8 presents an overview of New Zealand's existing vehicle classes and current legislation by country for each LPV category. Chapter 9 assesses potential classes and rules. The three key criteria for vehicles are power, speed and presence/type of throttle control.

Maximum continuous power output is a useful regulatory criterion to (a) differentiate from other motor vehicle classes, (b) limit acceleration to a level compatible with other path and cycle lane users, (c) reduce the incentive for owners to tamper with speed restrictions set in the LPV system, and (d) ensure high power and weight systems are not fitted to bicycles that are not designed to cope with such additions. Some overseas jurisdictions allow power levels higher than New Zealand's current 300 W limit. Increasing the power limit would support the adoption of e-bikes in hillier locations, cargo e-bikes, and a broader range of LPVs designed for those overseas jurisdictions. Self-balancing devices require a higher peak power to ensure stability for sudden leans or bumps, so manufacturers do not publish continuous power ratings.

Maximum power- assisted speed is referred to in the legislation of all other countries reviewed. For e-bikes, three maximum motor assisted speeds commonly used overseas (25, 32 and 45 km/h) have been assessed. A limit of 25 km/h would be safest but would make e-bike users slower than many unpowered cyclists, reduce travel time competitiveness, limit model choices and reduce uptake of e-bikes. 32 km/h would be consistent with the existing ungoverned and US market e-bikes while reducing the incentive to tamper with speed restrictions. 45 km/h would be consistent with the EU's S-pedelec (a type of moped) and the US class 3 speed e-bike (a bicycle); offers New Zealand consumers an option that minimises the speed differential with other motorised modes in urban areas and makes longer distance commutes more viable. All countries with this class also have a lower speed e-bike class.

For other LPVs, three maximum motor assisted speeds (10, 15 and 25 km/h) have been assessed. The lower values maximise safety in pedestrian interaction situations but are lower than the capabilities of most LPVs, may be difficult to enforce and do not account for potential use on roads. A maximum vehicle speed of 25 km/h aligns with the capabilities of many devices while a maximum user speed of 15 km/h could be applicable to footpaths, in line with the speed of unpowered scooters and runners.

Throttles are perhaps the most contested component of LPVs. Major e-bike brands are moving towards mid-drive pedelec road and hybrid models, without throttles. All major brand e-mountain bikes are pedelecs (without throttles) due to the reduced surface erosion and superior control. Prohibiting throttles would increase the average e-bike cost and therefore reduce uptake and potentially the 'safety in numbers' benefit. Notwithstanding the market implications, a pedelec system (pedal assist with optional start-assist throttle limited to 6 km/h) is more desirable from an overall safety and health perspective than e-bikes with throttles.

Non-regulatory options

Chapter 10 presents ideas for positive, aspirational education and encouragement campaigns to boost safe usage and reinforce the 'safety-in-numbers' effect. With higher usage, improved engineering and increased facility capacity will be needed to support the desired safety outcomes.

Recommendations

It is recommended considering:

- including any LPVs intended for or primarily used by mobility impaired users within the definition of a mobility device
- classifications for e-bikes and other LPVs based on speed capability
- a maximum power-assisted speed and size for vehicles using footpaths
- relaxing maximum power limits for e-bikes and other LPVs designed for road use
- minimum age limits and driver licensing for higher speed e-bikes and LPVs
- helmet wearing by LPV users depending on speed capability
- further promotion of user behaviours that minimise conflict with existing path and roadway users (eg Road User Rule 11.1).

A more detailed summary of findings is presented in appendix A: Findings and indicative regulatory framework based on international experience.

The degree and nature of existing legislation varies greatly between the different devices and different countries. Aligning New Zealand legislation with that of other countries will clarify rules for the industry, the public, regulators and the Police. Australia and the UK are generally adopting the EU standard for e-bikes, but we could also adopt a framework that comprises the most appropriate components from various overseas rules. As no reviewed countries have rules covering the full range of other LPVs, the pros and cons outlined in this report may serve as a basis to create a regulatory framework that simplifies the process of approving or rejecting new LPVs. The next steps might be to consider the issues and recommendations included in this report as part of a policy-making exercise, with rule-making to follow.

Abstract

This research report presents a review of overseas legislation, technology trends, market and safety analyses for low-powered, low-speed vehicles. These vehicles include electric bicycles, mobility scooters, self-balancing devices and other personal mobility or wheeled recreational devices. Current New Zealand LPV legislation is based only on motor power and how certain LPVs may be used. In all other countries reviewed, top motor-assisted speed is regulated. The report assesses various regulatory and non-regulatory options for improving safety while supporting technological innovation and mode choice options in New Zealand.

1 Introduction

1.1 Context

Electric bicycles (e-bikes) and other 'low-powered vehicles' (LPVs), such as mobility scooters, e-skateboards and e-scooters, are rapidly becoming more popular worldwide. Such devices can be seen as having economic, environmental and personal health benefits compared with traditional modes that rely on fossil fuels and do not require human power input. The increase in their popularity is enabled by continuous advances in technologies and economies of scale driving lower prices. In New Zealand, import statistics indicate an exponential increase in demand, and specialty retailers for e-bikes in particular are opening across the country to cater for this demand.

Traditional transport policy has typically dealt with modes such as motor vehicles (cars, trucks, motorbikes), public transport, human-powered cycles and pedestrians (including 'wheeled recreational devices', a legal term for a wheeled conveyance (other than a cycle that has a wheel diameter exceeding 355 mm), human-powered or with a motor not exceeding 300 W). One consequence of this definition is that riders of skateboards, scooters and roller skates (ie unpowered, or with a motor power up to 300 W) have more options of where they can ride compared with bicycle riders and mobility scooter users; skaters can ride on most roads except motorways, provided they 'keep as close as possible to the edge of the roadway', and can also ride on the footpath.

New types of LPVs have blurred the lines between the conventional modes and raised new questions about our existing legislation and infrastructure. Many LPVs do not meet the requirements for motor vehicles and may not be intended for use on the general roadway; however, they also differ significantly to pedal-cycles and small wheeled recreational devices, especially in terms of achievable speeds. In contrast to most countries, New Zealand legislation only regulates motor power (which is somewhat flexible and can be skirted around by using a battery of higher voltage) and is silent on other performance criteria such as the maximum speed for motor assistance. Adding more powerful batteries and controllers to an otherwise legal motor can potentially enable it to propel an e-bike to speeds well in excess of 40 km/h if no speed limit is set in the controller.

Regulations should be flexible enough to cover any new device that does not yet exist, help minimise harm to road and path users, and support the positive benefits of LPVs. To help inform any legislative change, this research aims to clarify e-bike and other LPV definitions, discuss the range of technologies including motor types and controller features, and assess regulatory criteria commonly used overseas. In addition to regulation, there may be other alternatives to improving safety such as consumer education, skills training and modifications to infrastructure design guidelines.

The New Zealand Transport Agency (the 'Transport Agency') commissioned ViaStrada to research standards and safety for LPVs worldwide. This report presents a summary of findings and an assessment of regulatory and supplementary non-regulatory approaches to improve safety while supporting technological innovation and mode choice options. This report is intended to inform policy making and potential changes to the vehicle classification and road user rules for electric bicycles and other LPVs.

1.2 Devices covered

1.2.1 E-bikes

The Transport Agency has committed to increasing cycling trips by 10 million per annum by 2019, and is largely aiming to achieve this through the Urban Cycleways Programme (NZ Transport Agency 2015d). In 2014/15, there are currently 32 million bike trips per annum in New Zealand in the three reference cities of Auckland, Wellington and Christchurch (NZ Transport Agency 2015a). If it were to increase by one-third, cycling would become more normal. Such a cultural shift would be moving cycling towards being a more significant transport option, closer to where Europe is today. Electric-powered bicycles ('e-bikes') offer a solution to many of the common objections to cycling, such as minimum fitness requirement, headwinds, hills, distance, or inability to carry items (Koorey and Kingham 2011; Smith et al 2011). While e-bikes cannot overcome all weather issues and safety concerns, safety can be addressed through vehicle design, better infrastructure and lower urban operating speeds – areas where significant progress is currently being made.

New Zealand has seen significant growing interest in cycling and cycling safety over the past few years, with the New Zealand cycle trails, walking and cycling model communities, the Cycling Safety Panel, and increased government funding through the Urban Cycleways Fund (NZ Transport Agency 2015d).

As will be explored further in chapter 8, the existing e-bike regulation limiting motor power to 300 W is not consistent with any other country. This reduces the range of options available to importers and puts them in the difficult position of having to offer their customers an e-bike with a power rating lower than the threshold (eg a EU standard 250 W motor), and some may choose to import e-bikes with power ratings above the threshold. There is no restriction on the top speed of an e-bike in the expectation the continuous power rating will limit speed. A high-voltage battery and high-amperage controller can be added to enable a motor that complies with the legal power rating threshold to propel a bicycle to 40 km/h or more. Thus, many more riders than previously will now be able to cycle unassisted at these speeds. In addition, either commercially available S-pedelecs (refer sections 2.5 and 4.1.6) or user do-it-yourself (DIY) built e-bikes can travel at 45 km/h or more – virtually the same speed as the rest of urban motor vehicle traffic. The research aimed to determine if there is a safety rationale for changing the focus of legislation from power rating to speed (or other criteria).

1.2.2 Powered mobility devices/mobility scooters

This report uses the term 'mobility device' as it is an existing definition in New Zealand legislation. There is scope to review the terminology, as the term 'mobility device' may be limiting considering the range of uses for LPVs. For example, the term 'personal mobility device (PMD)' as used in Singapore evokes the idea that the devices are used to get around, not just for recreation. It also may be argued that devices such as a mobility scooter should not be limited only to those who are mobility impaired.

New Zealand has an ageing population, with the proportion of people over 65 years old (currently 14% of the population) expected to grow to be 22% by 2034 (Ministry of Social Development 2015) while the number of over-80s is expected to more than double by then. This has numerous impacts on society, including effects on transport and personal mobility. The *New Zealand positive ageing strategy* (Ministry of Social Policy 2001) acknowledges this by having 'affordable and accessible transport options for older people' as one of its 10 key goals.

Mobility scooters and, to a lesser extent, electric wheelchairs are a common tool for assisting older and physically impaired pedestrians to get around, particularly if they have forfeited their driver licence. Most people who use a mobility scooter would otherwise be in a wheelchair or housebound (Thoreau 2015a).

The *2014 report on the positive ageing strategy* (Ministry of Social Development 2015, p24) notes mobility scooter use has increased, while highlighting concerns about them: 'these vehicles don't require driver licences, warrants of fitness or registration. As they become larger and more powerful, agencies and councils may need to take action to ensure user and public safety'.

These concerns are reflected in New Zealand crash statistics, which typically record an average of more than one mobility scooter fatality a year and dozens of injuries. While not the only group making use of mobility scooters, the growing number of older people in New Zealand will only exacerbate the potential problems with this transport option.

1.2.3 Other LPVs

The past decade or so has seen a rapid explosion in the number of other LPVs or wheeled devices being used in New Zealand. Many of these have become more prevalent as lower-cost and smaller self-balancing mechanisms, batteries, and electric motors become more widely available. The high-profile introduction of the two-wheel Segway in 2001 has now given way to the arrival of other self-balancing one and two-wheelers, electric kick-scooters and electric skateboards.

While many of these appear to fall under the existing category of 'wheeled recreational devices', the status of others (such as the Yike Bike, electric unicycles, or e-assist mobility trikes) is less clear, particularly when they involve higher power or speed. Some falls and collisions have already been reported, and walking advocacy groups have also expressed concerns about sharing footpaths with many of these devices. As discussed further in chapter 9, the legal term 'wheeled recreational device' may need to be reconsidered so these other LPVs can be captured by a more inclusive legal term. New LPVs enter the market at a fast rate and all this points towards the need for legislative reform.

1.3 Benefits of e-bikes and other LPVs

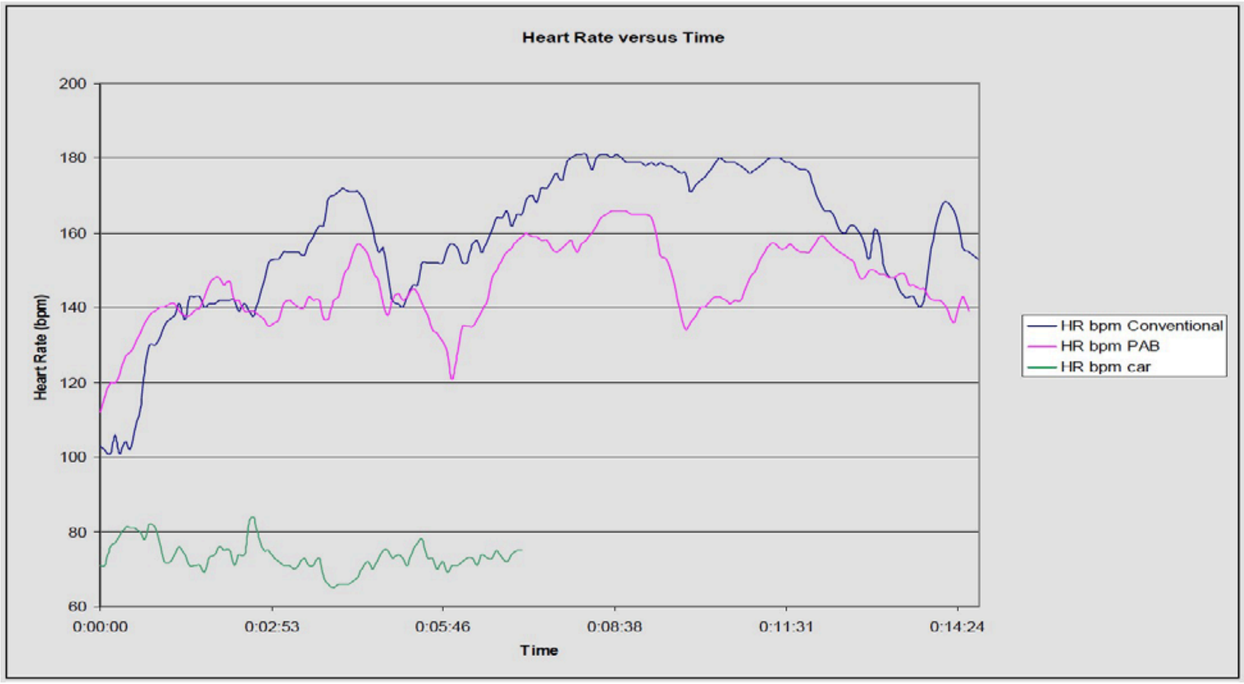
It is not within the scope of this research to dwell on the reasons individuals and governing agencies want to use and promote LPVs; however, it is useful to acknowledge some of the benefits.

1.3.1 Health

In their comprehensive review of a decade of research on e-bikes, Fishman and Cherry (2016, p82) found 'the clear theme emerging from research on e-bikes and physical activity is that they provide a lower level of physical activity than traditional bikes, but still achieve a level necessary for health enhancement'. Rose and Cock (2005) confirmed e-cyclists on power-assisted bicycles[1] have a lower heart rate than unpowered cyclists, but not markedly so (figure 1.1). The blue line represents the heart rate profile for unpowered cyclists and the pink line represents the heart rate profile for power-assisted cyclists.

[1] The authors differentiate between powered bikes and power-assisted bikes (PABs). Their graph and discussion indicates the study participants used PABs, which may be equivalent to pedelecs that require pedalling to activate the motor.

Figure 1.1 Heart rate comparison between unpowered and power- assisted cyclists (Rose and Cock 2005)



Other Dutch research shows that even when e-cyclists are using the highest levels of electrical assistance on electrically assisted bicycles (ie pedelecs)[2], they are able to meet World Health Organisation guidelines for moderate physical activity (Simons et al 2009; Gojanovic et al 2011; de Geus and Hendriksen 2015). This is because even though riding requires less effort, overall the number and length of cycling trips people make increase when they have an e-bike compared with a regular bicycle. Other overseas research has shown that because e-bikes reduce 'perceived exertion' while maintaining health-enhancing levels of physical activity, they are particularly useful for encouraging physical activity amongst people who are sedentary, older or disabled and those recovering from injury (Blumenstein et al 2014; Johnson and Rose 2015a). Quite simply, e-bikes get people moving, and keep people moving. However, there is a lack of evidence regarding the health benefits of e-bikes with open throttles[3], ie where users are not required to pedal.

1.3.2 Environment

In terms of environmental effects, Fishman and Cherry (2016, p83) summarised 'the emissions of e-bikes are inconsequential and likely better than the set of alternative modes, even in large numbers and if the power sector is dominated by coal (eg China)'. In New Zealand, approximately 80% of electricity comes from renewable sources, hence the country's environmental effects would be much better than in places where electricity is more readily produced from non-renewable sources.

E-bikes have the potential to make an important contribution to enabling New Zealand to meet carbon-reduction targets. Overseas research on mode-shift shows e-bikes tend to replace a combination of

[2] As pedelecs require pedalling to engage the motor, the highest level of assistance means the user selects a more powerful power assistance setting via a control console

[3] An 'open' throttle is one that permits engagement of the motor up to the maximum motor-assisted speed level defined by the manufacturer or the maximum speed the motor can attain (if the motor is 'ungoverned'), rather than a 'closed' throttle that is programmed by the manufacturer to only engage the motor up to a certain speed

bicycle use and car use. Summarising the research on mode shift, Roetynck (2010) concludes e-bike use contributes to a small but significant reduction in car use. They estimate each e-bike on the road results in 900 km fewer car kilometres per year; with a corresponding reduction of 108 kg of CO2 per year (ibid). Research in the USA that fitted e-bikes with GPS tracking devices showed e-cyclists were making more 'car-like' trips compared with traditional cyclists, ie longer with multiple stops (Langford 2013). E-bikes increase the distance people can cycle, enabling more people to take advantage of the health and environmental benefits of cycling (Fyhri and Fearnley 2015).

1.3.3 Mode shift

As e-bikes help more people who would not otherwise cycle take up cycling, there are potential congestion reduction and urban land form benefits. According to Mason et al (2015, p24), 'in the long run, a shift in travel modes toward more cycling has broader dynamics – supporting denser cities with transportation systems more oriented to walking, cycling and public transport, as opposed to sprawling car-dominated cities'. Getting more people cycling would also have a 'safety in numbers' benefit as more people riding improves the conspicuity of cyclists to drivers (Jacobsen et al 2015).

1.3.4 Social inclusion

In summarising the literature, Thoreau (2015b, p208) states 'studies of a range of assistive mobility devices for mobility found that users felt their device enabled them to participate in more activities, gave them greater independence and increased their sense of security'. Without these devices, many users would feel housebound (ibid).

1.4 The Safe System approach

New Zealand's *Safer journeys strategy* (MoT 2010) strategy sets out four principles of a Safe System:

- **Safe speeds** are a key issue for e-bikes and LPVs, especially in terms of sharing space with pedestrians. Higher speeds are generally associated with increased likelihood and injury severity of crashes. Throughout this report, two main approaches to mitigating speed are discussed – controlling the speed capability of LPVs and encouraging or requiring users to travel at a speed appropriate to the conditions.
- **Safe vehicles**: the features of LPVs affecting safety are discussed in chapter 7 of this report. Examples include the ability of self-balancing devices to travel at very low speeds without wobbling, disc brakes and daytime running lights.
- **Safe road use** in the context of LPVs is addressed through the existing road user rules discussed in chapter 9 and the educational messages discussed in section 10.1, Education.
- **Safe roads and roadsides** is covered at a high level in section 10.3, Engineering with a focus on geometric design, although inadequate footpath width and/or surface smoothness are longstanding issues beyond the scope of this research.

1.5 Objectives

The purpose of this research was to inform any potential changes to the vehicle classification and road user rules for electric bicycles and other LPVs and devices. In addition, the research was to determine non-regulatory alternatives for improving safety outcomes. For the purposes of this research, an initial upper limit for LPVs (including mopeds) was set at 2,000 W, which included mobility scooters with a 1,500

W (maximum) motor. More explanation on this power threshold is provided in section 2.1, and devices not included in the research are listed in section 2.12.

The main questions this research project sought to answer, and the locations within this report where they are addressed are:

1. What constitutes a LPV (existing or future devices) that should be considered in this research?
   - Chapter 2 defines and categorises LPVs covered (and omitted) with this research.
2. Is low-speed a more appropriate measure for device classification and access, and is there a need to differentiate speeds depending on where such vehicles are used? The speeds of LPVs ranges from 6 km/h for lower powered wheelchairs through to 45 km/h or higher for the most powerful e-bikes.
   - More on speed is provided in chapter 7.
3. How many LPVs should we expect on New Zealand roads in 5, 10 and 20 years' time? And what effect will this have on network planning and development?
   - Chapter 4 provides a market analysis.
4. Do LPVs, such as scooters, motorised skateboards, powered unicycles and electric bicycles, pose a safety risk to operators or others (compared with non-powered riders and pedestrians)?
   - Chapter 5 is a safety analysis of LPVs.
5. At what typical age do children develop the cognitive and motor skills necessary to handle LPVs safely within public roadways and paths? Is there a difference between LPVs and devices, and purely human power in relation to age? To what extent do these skills degrade for older age persons?
   - Chapter 6 considers the safety implications of LPVs and different age groups.
6. Do the features of EU standards relating to LPVs make them substantially safer or contribute to improved health than those typically available in New Zealand? In particular, this is focused on motor cut-out speed, throttle operation, and provision of separate categories for 25 and 40 km/h variants.
   - Chapter 7 describes these features and chapter 8 includes a review of regulations used in the EU, the UK, Australia, the USA and other countries.
7. In addition to EU standards and the assessment of appropriate age (if applicable), are there other regulatory criteria used overseas that should be considered to improve safety while supporting mode choice, innovation and sustainability objectives?
   - An evaluation of the range of regulatory options to achieve the desired outcomes is provided in chapter 9.
   - Chapter 10 discusses non-regulatory measures that can be used to complement the regulatory measures.
8. How feasible is it to enforce the main regulatory options in New Zealand?
   - Enforcement considerations are factored into the assessment of options in chapter 9.

1.6 Relevant standards and regulations

The following selected relevant text from Standards New Zealand (2016) is a useful aid in understanding the distinction between standards and regulations (emphasis added):

Standards are used by a diverse range of organisations to enhance their products and services, improve safety and quality, meet industry best practice, and support trade...By referencing standards in legislation, regulators draw on existing best practice developed by expert committees using a consensus-based and transparent process. Incorporating standards also allows regulators to provide detailed requirements without encumbering the regulation or guidance with technical detail. Standards can be:

a) referenced in Acts or regulations as legally mandatory

b) referenced in Acts or regulations as 'acceptable solutions' or 'means of compliance' – this ensures compliance with legislation but does not prevent the use of an alternative method, provided it meets the specified legislative criteria…

c) incorporated into non-regulatory material as examples of best practice or guidance…

d) employed as a means of compliance with industry regulation, for example, specifying requirements for audit certification…

***A standard is not, of itself, mandatory or legally required.** A standard has to be incorporated by reference in an Act or delegated legislation in order to be mandatory. Once referenced, it becomes part of the technical regulation framework.*

For illustration, table 1.1 presents some of the standards and regulations quoted in this research.

Table 1.1 Standards and regulations relating to e- bikes and other low- powered vehicles

Location	Standards	Regulations
AU/NZ	AS/NZS 1927:1998 Pedal bicycles – safety requirements AS/NZS 60335.1:2011 Household and similar electrical appliances – safety AS/NZS 2063:2008 Bicycle helmets AS 5732:2015 Electric vehicle operations – maintenance and repair AS/NZS 3695.2:2013 Wheelchairs –requirements and test methods for electrically powered wheelchairs (including mobility scooters)	Land Transport Act 1998 Land Transport (Road User) Rule 2004 (RUR) Land Transport Rules – various: Land Transport Rule: Vehicle Dimensions and Mass 2016 Transport (Vehicle and driver registration and licensing) Act 1986
EU	EN 15194:2009+A1:2011 Cycles – electrically power assisted cycles (EPAC) EN 50604-1:2016 Secondary lithium batteries for light EV (electric vehicle) applications. CEN TC 354 Non-type approved light motorized vehicles for the transportation of persons and goods and related facilities (draft). NTA 8776:2016 EN Standard for S-EPAC helmets	Directive 2002/24/EC Relating to the type-approval of two or three-wheel motor vehicles Regulation (EU) No 168/2013 of the European Parliament: on the approval and market surveillance of two- or three-wheel vehicles and quadricycles
UK	BS EN ISO 4210-2:2014(a) Safety requirements for bicycles. Requirements for city and trekking, young adult, mountain and racing bicycles.	Vehicle Excise and Registration Act 1994 Pedal Cycles (Construction and Use) (Amendment) Regulations 2015
USA	ANSI/CAN/UL (2016) 2272 Standard for electrical systems for personal E-mobility devices	Americans with Disabilities Act (ADA) Code of Federal Regulations (CFR) AB-604 Electrically motorized boards (California)
Inter-national	ISO 4210 Safety requirements for bicycles.	

2 Types of LPVs

This section presents broad definitions of a number of LPV categories. A selection of example vehicles is included to illustrate the multitude of products available today and on the drawing boards, blogs, and crowdfunding website pages of the world's designers. There is no practical way to cover all LPVs; instead this section is intended to inform the subsequent sections on technological features (chapter 7), existing and potential regulatory regimes (chapters 8 and 9).

2.1 Definition of low-power used in this research

This research focuses on LPVs with electric power sources. For the purposes of this research, only LPVs with a power rating no more than 2,000 W have been considered. This is because the intention was to include mobility scooters (which have a 1,500 W limit) and 2,000 W is the maximum allowable power rating currently imposed on mopeds. The standard motor vehicle rules apply to mopeds, and (at least theoretically) to e-bikes and wheeled recreational devices (WRDs) with more than 300 W of power.

The researchers did not identify any non-electric LPVs that are commonly used or have potential to develop a strong uptake; note that the internal combustion engines generally fitted to bicycles produce far more than 300 W of power (NZ Transport Agency 2013). Vehicles that are not covered in this research, such as bicycles fitted with a petrol motor, are described in section 2.12. Otherwise, for the purposes of this research, the term LPV refers to an electric-powered vehicle.

2.2 Power ratings and measurement methods

2.2.1 Measuring power

While it is common to describe and regulate LPVs according to the power rating of their motor (measured in watts and denoted as W), there are many inconsistencies associated with this system. First, it is necessary to distinguish between peak power and continuous power, and how the power will be measured. Power is measured in one of four general ways (although there are many methods):

1. **Peak** (or instantaneous) input power used by a motor is equal to the battery voltage multiplied by the current (measured in amps) supplied to the motor by the controller (Toll 2016). For example, a 36 V battery feeding power through a 15 A controller will supply a motor with peak power of 540 W. Peak power is the maximum power achievable, typically only required for short, intermittent periods such as travelling up short hills and is usually included with a time rating, eg P_{max} = 540W (1min). Therefore, peak motor power (W) ratings are dependent on components other than the motor, ie the battery and the controller[4]. While the legislation could refer to system power rating, on many systems without sophisticated software controls, all it would take to change the power is to swap in a higher voltage battery, provided the motor is capable of receiving a higher voltage without overheating.
2. **Power input less efficiency losses** of the motor. A range of various methods complicate this measurement approach.
3. **Continuous power output of the drive system.** It has been argued that this is problematic due to variances in test methods (Benjamin 2010). While standardised testing similar to an automobile

[4] Note that peak power is limited by the motor controller in response to motor temperature

dynamometer is feasible (Konecny et al 2013), the variety of LPV designs would complicate this approach.

4 **Continuous power output of the motor only**. This is the commonly used metric, and represents the power (number of watts) that the motor can safely ***output*** for an indefinite time without damage or overheating. This power rating is set with an ambient temperature and needs to be de-rated for higher temperatures in warmer climates. There is often a tolerance where manufacturers push the threshold of mechanical, thermal and electrical design to obtain a manufacturing cost advantage. The result is that two 250 W motors may not necessarily be equivalent unless they have been independently tested with a standardised test. In the EU, the EN 15194:2009 standard prescribes the method for measurement of motor power (European Committee for Standardization 2009). In other countries, such as New Zealand and the USA, motor power is generally accepted to be whatever the manufacturer says, with no testing method described or required (Benjamin 2010).

The industry often simplifies these terms: continuous power output is termed 'rated power' and peak power is termed 'maximum power'. Therefore, it can be confusing if legislation refers to 'maximum power output'. It is recommended the legislation is changed to refer to 'no more than (level to be determined) watts of rated continuous power output of the motor'. In the rest of this report (unless otherwise stated), a power rating refers to continuous motor output.

Ventilation is an important factor as it affects the motor's ability to cool down and reach and maintain peak power. Thus, the power level achieved in real use may be different from that measured in a laboratory test.

2.2.2 Power, voltage, torque and current

Power is only one important parameter and there is a complex electromechanical relationship between the battery pack, controller, motor and the human rider (control and power) of a LPV. Brushless direct current motors (BDCMs) have become the most commonly used motors in LPVs due to their higher efficiency (increased range) and lower maintenance. Other important concepts regarding LPVs with BDCMs are:

- Motor or human pedal power (watts, W) is defined as (power = torque x angular speed (cadence)). More power means the user can accelerate faster and potentially reach and maintain a higher top speed, unless the controller is speed limited. Having a higher power is useful for carrying heavy loads, hill climbing etc. The downside is that increased power comes with increased weight and it reduces the operational range for a fixed capacity battery.
- Motor or human pedal torque (Newton-metres, Nm) is proportional to power. Torque causes the LPV to accelerate to an equilibrium speed where the motor winding matches this torque (force) level. Increased torque will cause a faster acceleration and a higher equilibrium speed unless speed is limited by the controller or the rider.
- Battery current (amperes, A) is directly proportional to motor torque.
- Battery voltage (volts, V) also influences torque but by a secondary factor. Increasing the battery voltage also increases the current and therefore the resultant torque. For BDCMs, increasing the voltage does not increase the vehicle speed, as this is determined by the switching frequency of the controller. For example, if the controller has a set speed position of 25 km/h and the battery voltage is increased, the e-bike should maintain 25 km/h. This is equivalent to cruise control on a car and is independent of how much power is available. A penalty of increasing the voltage is that the battery drains faster, depending on the sophistication of the controller.

- The primary function of the controller is to regulate the torque and speed of a BDCM, with the various parameters and thresholds being defined in software. On many e-bikes, end-users can adjust parameters such as maximum motor-assisted speed in the software or by tricking the controller via sensor modifications.

Torque is only directly referenced in the Japanese regulations for e-bikes (refer section 8.3.7) although Bike Europe has advocated for a torque limit to be adopted (Bike Europe 2016a).

2.2.3 Electric motors versus internal combustion engines

Combustion engines are generally gauged according to engine capacity, measured in cubic centimetres (cc) with power ratings given in ‘horsepower’ (hp) or kilowatts (kW). It is difficult to directly compare electric powered vehicles and combustion powered vehicles.

As an example, New Zealand moped regulations up to 2011 referred to power output of less than 2 kW, but currently state that the engine capacity is not to exceed 50 cc. If the moped is not petrol powered, then there is no power limit (but a speed limit could apply).

There are many factors other than engine capacity that affect the actual power output and therefore there is no direct relationship between capacity and horsepower. For example, Walker (2015) tested a wide range of combustion engines belonging to various types of vehicle, boat and machine, to identify the ratios of capacity to horsepower (a non-metric measure of power). He found there was no direct relationship between capacity and power, with great ranges existing even within specific subsets of vehicle. Therefore, not all 50 cc mopeds will have the same power output, which makes it difficult to compare the current moped restriction with any power rating that may be proposed for e-bikes.

As mentioned earlier, the internal combustion engines generally fitted to bicycles produce far more than 300 W power, the current upper limit for power-assisted cycles to be declared ‘not motor vehicles’ (NZ Transport Agency 2013).

2.3 Motor assistance cut-out speed

An alternative to the term ‘low-powered vehicles’ is ‘low-speed vehicles’, as speed has a more direct correlation with safety outcomes. The USA sets a precedent in defining a category of vehicles not capable of speeds above 25 mph (40 km/h) as ‘low-speed vehicles’ (US Office of the Federal Register 2000).

To meet commonplace international regulations (summarised in chapter 8), many LPVs have a motor power assistance speed limit. For example, European Union electric bicycle regulations include a definition of a pedal electric bicycle ‘where the output of the motor is cut off when the cyclist stops pedalling and is otherwise progressively reduced and finally cut off before the vehicle speed reaches 25 km/h’ (Bike Europe 2016a, p6). In this report, the phrase ‘motor cut-out speed’ is used to describe the situation where an LPV is designed with an assistance speed limit.

Motor assistance cut-out speed is determined by the controller, which will reduce torque as the defined speed threshold is approached. Note that this is not necessarily the top speed at which the LPV can be operated, as any combination of human power, tailwinds, or downhill gradients can result in the cut-out speed limit being exceeded. More information on the technological features relating to motor cut-out speed is presented in section 7.1.

2.4 Overview of LPV categories

A large range of devices are available under the banner of LPV. Key configuration differences include:

- means of motor control: automatic activation via torque and/or motion sensors versus manual activation via hand-held or handlebar mounted throttle[5]
- propulsion: primarily human power via pedals or kick motion versus electric power only
- braking systems: electric and/or motor braking (may be regenerative, ie recharges battery), hydraulic or mechanical wheel brake(s), or foot-braked
- physical/geometric characteristics: presence / absence of pedals, usability of pedals if present, handlebars, seats, number of wheels, size, shape, weight.

Table 2.1 outlines the main types of LPVs considered in this research; the following sections give more detail on each of these types. Note this review does not include every possible LPV/device that has ever been developed or is currently on the market. However, it does provide a broad overview of the main attributes typically associated with them.

A full assessment of current New Zealand legislation is provided in chapter 8. With respect to the brief assessments of current legislative status for each vehicle in table 1.1, the Transport Agency web page on LPVs states (in part):

> *The following are examples of vehicles that meet the definition of motor vehicle but have difficulties meeting the safety standards and other requirements. This means they cannot be operated on the road.*
>
> - *Motorised skate boards, scooters, and roller skates*
> - *Segways and similar*
> - *Powered self-balancing unicycles* (NZ Transport Agency 2016a).

Some of these vehicles may be considered wheeled recreational devices as defined in the Road User Rule section 1.6 on interpretation:

> *Wheeled recreational device –*
>
> - *means a vehicle that is a wheeled conveyance (other than a cycle that has a wheel diameter exceeding 355 mm) and that is propelled by human power or gravity; and*
> - *includes a conveyance to which are attached 1 or more auxiliary propulsion motors that have a combined maximum power output not exceeding 300 W* (NZ Government 2004).

The Transport Agency may declare a device not to be a motor vehicle if the power output is less than 600 W. Chapter 8 of this report explores these issues in more detail.

[5] On an electric vehicle, the *throttle* is more accurately termed a *potentiometer*. However, *throttle* is a more widely understood term and will be used throughout this report.

Table 2.1 Low-powered vehicle categories, typical features and top speeds

Type	E-bikes			Mobility scooters and powered wheelchairs
	Bicycle style e-bike (BSEB)	**E-velomobiles and e-recumbents**	**Scooter style e-bike (SSEB)**	
Defining features	Designed to be primarily propelled by muscular energy. Two general types: • Pedelec: pedal assist (no throttle) • Throttle e-bike: does not require any pedalling to engage the motor	Pedal equipped Most are single seat As with BSEBs, these are designed to be propelled primarily by muscular energy of the rider	Pedals are vestigial; designed to be primarily propelled by the motor. More like a moped in size, shape, weight. May or may not have body fairings.	Up to 1,500 W; no human power permitted in New Zealand Seat and handlebars Electric and/or motor braking
Top motor-assisted speed	25 km/h (EU regulated) 32 km/h (N America regulated) 45 km/h (S-pedelec – EU or California regulated)	25 km/h (EU) 32 km/h (N America bicycle)	20 km/h (China) 25 km/h (Europe) 32 km/h (N America)	6 km/h (UK class 2) – footpath (UK) 12 km/h (UK class 3) – road legal, must be registered (UK) 16 km/h typical highest speed sold in New Zealand, but some models can reach 30 km/h
Typical continuous power	250 W (EU) 350–500 W (N America) 300 W (New Zealand)	250/500 W (pedelec recumbent, EU/USA) 750 W (ELF, N America) 300 W (New Zealand)	250 W (China) 500 W (N America)	230 W (Invacare Auriga) 1,300 W (EV Rider Royale) 1,500 W (New Zealand)
Image	**Figure 2.1 BSEB** 	**Figure 2.2 Organic Transit ELF** 	**Figure 2.3 SSEB** 	**Figure 2.4 Mobility scooter** 
Status in current New Zealand legislation	Class AB (power-assisted pedal cycle)	Class AB (power-assisted pedal cycle)	Not designed to be primarily propelled by muscular energy and therefore not a class AB cycle	Declared not to be a motor vehicle (no vehicle class). Legal for use on footpaths or roads.

Type	Seated scooters without human propulsion	Self- balancing devices	Electric skate boards	Electric push / kick scooters and trikes
Defining features	Two or three wheels Seat but no pedals No human propulsion	One or two wheels Powered self-balancing unicycles Hoverboards/glideboards No pedals, generally no seat, may have a handle No human propulsion	Four wheels Long board length for stability Motor activation can be handheld remote or weight sensors in the board Rider can contribute human power (kicking against the ground)	Two or three wheels Some have folding chassis for public transport convenience Seat optional on some models Rider can contribute human power (kicking against the ground)
Top motor-assisted speed	23 km/h (Yike Bike) 45 km/h (Boxx e)	20 km/h (Segway PT) 18 km/h (Fotowelt X30 unicycle) 10–20 km/h (typical hoverboard)	20 to 40 km/h	25 km/h
Typical continuous power	200 W (Yike Bike) 600 W (Boxx e)	750 W per wheel (Segway) 350 W (Fotowelt X30 unicycle) 250 W (typical hoverboard)	200–2000 W	250 W (Inokim)
Image	**Figure 2.5 Yike Bike**  **Figure 2.6 Boxx E** 	**Figure 2.7 Segway**  **Figure 2.8 Ogo** 	**Figure 2.9 e- skateboard** 	**Figure 2.10 e- kick scooter** 
Status in current New Zealand legislation	Yike Bike declared not to be a motor vehicle, Gazette notice 213. LPV not requiring registration or driver licence. Subject to specific rules regarding cycle helmets and road/path use. No declaration on Boxx e as yet.	Segway: The High Court has ruled a Segway PT is a mobility device. Ogo is similar to a powered wheelchair, so may be a mobility device. Hoverboards and e-unicycles are wheeled recreational devices if ≤300 W, with conditions up to 600 W	Wheeled recreational device with no conditions if under 300 W, with conditions up to 600 W	Wheeled recreational device with no conditions if under 300 W, with conditions up to 600 W

The Transport Agency has the ability under the Land Transport Act to declare certain vehicles of maximum power output greater than 300 W but not exceeding 600 W, as 'not a motor vehicle' by issuing an official gazette (MoT 1998, section 168A 3). Certain vehicles with power output up to 1500 W can also be declared a 'mobility device'. The Act outlines certain criteria for the vehicles eligible for this declaration, based on maximum power output. As indicated in table 1.1, power-assisted cycles, mobility scooters and Yike bikes have all been officially declared not to be motor vehicles. The Transport Agency could also undergo the same process to declare other LPVs as 'not a motor vehicle' to eliminate the ambiguity of having devices that 'meet the definition of motor vehicle... but have difficulties meeting the safety standards and other requirements'.

2.5 Bicycle style e-bikes

2.5.1 Terminology

Table 2.1 shows that the term 'e-bike' can cover a wide range of possibilities. MacArthur and Kobel (2014) coined the terms bicycle style e-bike (BSEB, figure 2.1) and scooter style e-bike (SSEB, refer section 2.8). Although most e-bikes look like a traditional bike, electric assistance is also available on various styles of cargo bikes, cargo trikes, recumbents, and velomobiles (refer section 2.6).

As detailed further in section 8.3, BSEBs are known by many terms (German Insurance Association 2014; Department for Transport 2015; Bike Europe 2016a; PeopleForBikes 2017b), but they generally fall into three main variants as follows.

2.5.1.1 Pedelec

- The EU 'pedelec' is a portmanteau of 'pedal' and 'electric' describing an electric power assisted cycle (EPAC) where a motor of up to 250 W only engages if the cyclist pedals, and progressively reduces assistance before ceasing at 25 km/h. Classified as a pedal cycle in all member states.
- The Australian equivalent is a 'pedalec', and reference is made to the European standards.
- The USA equivalent is a 'class 1 pedal-assisted electric bicycle', the same as a pedelec but the motor is limited to 20 mph (32 km/h).

2.5.1.2 Throttle e-bike

- The UK popular term is a 'twist and go' e-bike, which does not require pedalling to engage the motor.
- The EU term is generally a 'power on demand pedal cycle' or simply 'e-bike', with the latter term reserved exclusively for this type. Until 1 January 2017 this class was limited to 500 W and 20 km/h in most member states; now this class is limited to 1,000 W and 25 km/h.
- Australia allows throttle e-bikes, but at a lower (200 W) power output.
- The USA equivalent is a 'class 2 throttle-assisted electric bicycle'.

2.5.1.3 S-pedelec or speed-pedelec

- The EU 's-pedelec' is an EPAC where a motor of up to 4,000 W only engages if the cyclist pedals, and progressively reduces assistance before ceasing at 45 km/h. Classified as a moped in most states.
- The USA equivalent is a 'class 3 speed pedal-assisted electric bicycle'.

In Australia and New Zealand, a 'power-assisted cycle' (PAB) is a class AB pedal cycle having an auxiliary propulsion motor, encompassing potentially all the e-bikes defined by the prior terms depending on rated power output. In New Zealand, Class AB pedal cycles have no motor cut-out speed and are limited to

300 W. Europe and the USA have separate classes and rules for all three main variants. Australia has a single class but separate definitions and rules for the first two main variants.

2.5.2 BSEB components

The required components of a BSEB are the battery, motor, motor controller and a pedal assist sensor (PAS). Components that may be found on an e-bike include a throttle and a handlebar mounted console with power level controls, lighting on/off switch and other instrumentation.

Motors may be located in the front hub, rear hub or ‘mid-drive’ (at the pedal crank). Batteries may be located on or in one of the three main frame tubes (top tube, seat tube or downtube). Motor controllers are often integrated into other components, so a separate controller unit may not be visible.

2.5.3 Pedal assist sensors

The amount of power provided by the motor can be determined by a PAS and/or a throttle control. Most BSEBs have a PAS. There are two types of PAS: magnetic and torque.

Magnetic motion sensors detect pedal crank motion (cadence) or wheel rotation, irrespective of the amount of human effort. While they are inexpensive, a major disadvantage is that when motion is detected, the motor will activate up to the maximum motor torque or vehicle speed parameters set by the user via the console and limited by controller software settings. This can result in an unintended level of acceleration or speed, and a common complaint is the power transmission feels ‘jerky’ or ‘non-linear’. This characteristic can cause loss of control, especially for front wheel drives and when used off-road, and therefore riders tend to prefer throttle operation, as discussed in section 2.5.4. By definition, less human effort is required to accelerate or maintain a given speed with a magnetic sensor than with a torque sensor.

Torque sensors detect human power input and the motor torque is applied proportionally. This provides a seamless and smooth power delivery, in proportion to the amount of human effort (EU regulations limit this to 4:1 motor to human power). Users typically describe the feeling of riding a torque sensor equipped bike as just like an unpowered bike, but the rider feels ‘bionic’. Torque sensors are standard on costlier European models, but the price differential has been reducing lately (N Pollet, 28 August 2016, pers comm). Torque sensors used in mid-drive systems are integrated into the motor and crank mechanism; however, aftermarket torque sensor equipped bottom brackets are available starting at NZ$210 (ebikes.ca 2016). This compares to about $35 for a magnetic PAS (ibid).

In summary, a magnetic sensor detects how *fast* the user is pedalling (or that there is pedalling motion), while a torque sensor detects how *hard* the user is pedalling. Some high-end e-bikes have both sensor types, enabling the user to select motion-sensing mode for on-road use and torque sensing mode for off-road use using buttons on the handlebar console.

2.5.4 Throttle controls

This section introduces the topic of throttle controls. Please refer to section 9.2.3 for further assessment of throttles.

E-bikes without a throttle rely solely on pedal assistance to control the motor power output, these e-bikes are often termed ‘pedal-assist’ or ‘pedelec’, even though most e-bikes with a throttle also have pedal assistance. Most European pedelecs, and almost all mid-drive e-bikes powered by motors such as Shimano STEPs, Bosch and Yamaha, do not have throttles (in order to comply with common regulations overseas). Currently, most such e-bikes are EU standard and therefore cannot provide assistance at speeds above 25 km/h. However, the researcher tested several pedelecs with the Shimano STEPs system in the USA and found a motor cut-out speed of 20 mph (32 km/h). Most new models, and all mid-drive equipped models, use torque sensors.

E-bikes with a throttle (also known as an ‘auxiliary’ or ‘over-ride’ throttle) can provide motor assistance when the user pedals or when the throttle is operated. Therefore, the user does not need to pedal at all. Throttles can be in the form of a button or ‘twist and go’ grip, the latter in particular are common in New Zealand because of perceived or actual advantages for people with disabilities, hills, and/or higher speeds than afforded by EU standard pedelecs.

Lower priced e-bikes usually have a twist grip throttle and a magnetic motion PAS. As noted previously, there are concerns with the performance characteristics of such systems. Users interviewed or surveyed through this research have reported that e-bikes with a throttle control plus magnetic motion sensor can have jerky or unpredictable acceleration characteristics. One workshop participant involved in a cycle hire business does not allow children to use twist and go e-bikes for this reason and because he reports that the added complexity of a throttle control (in addition to brake and gearshift levers) is too much for novices to deal with while simultaneously maintaining balance and negotiating with other road or path users. Retailers surveyed for this research also indicate that throttles are preferred by customers, but it is not clear if this is simply due to retailer influence or the relative lack of higher quality (and price) torque assist models to try out. One e-bike shop owner interviewed for this research indicated that a major New Zealand distributor that has specified a torque PAS and no throttle on one high-end model is now being forced to retrofit that model with throttles due to customer demand (Kirsty Wild, pers comm). Several survey respondents reported that using the throttle without pedalling permits ‘finer’ control of acceleration and speed, especially during low-speed manoeuvring.

There are a few e-bikes (generally regular bikes retrofitted with a kit or a replacement all-in-one wheel) that ONLY have a throttle to activate the motor. This is also the case with ‘scooter style electric bicycles’ (SSEBs) that look like a motor scooter but have pedals (section 2.8).

Throttle equipped e-bikes have been dominant in New Zealand, but this may be changing as discussed further in section 4.1.

2.5.5 Sub-categories of BSEBs

It is important to understand the different BSEB types and their potential usage, as regulation may need to distinguish or consider the associated design features and needs. The principal types are:

- cargo and child carrying bikes and trikes, often used for commuting and urban errands
- comfort and recreation bikes, including ‘cruiser’ style bikes with wide tyres
- commuter bikes with upright seating position, integrated lights, locks, mudguards and cargo rack
- sport and hybrid road bikes for long (and fast) commuting
- recumbents with two or three wheels, and the related ‘velomobile’ with body fairings
- sport mountain bikes.

Production BSEBs (as opposed to ‘kit’ e-bikes discussed in section 2.5.7) are observed to be the most common type of e-bike in New Zealand.

2.5.6 Typical BSEBs in New Zealand

For BSEBs, power ratings are typically between 250 W for the European market and up to 500 W for the North American market (the majority of USA market e-bikes have 350 W motors). Based on survey responses (refer section 3.2.2) and interviews, New Zealand retailers overwhelmingly state that higher power and speed than available from traditional EU standard 250 W hub motors is required for the New Zealand topography and traffic conditions (although a 250 W mid-drive motor is generally adequate, as the power is multiplied through the bicycle's gear system). Accordingly, many New Zealand importers have custom specified bikes from China or sell North American brands that have 350 W motors, and either claim compliance with New Zealand's 300 W limit or simply do not mention the continuous power rating at all (refer section 8.3.2). With new EU regulations that lift the power limit for e-cargo bikes, subject to type regulation and additional requirements (refer section 8.3.4), it is likely that a niche market will develop for higher power production e-bikes – although the manufacturers will continue to electronically limit the motor cut-out speed to meet EU/USA regulations.

Prices start at about NZ$1,900 and range up to $10,000 or more. In the UK, the key price point is between GBP1,749 and 2,500 (NZ$3,115 and $4,450) (Peace 2016) in line with the typical prices advertised by specialist retailers in New Zealand.

2.5.7 E-bike kits

Kits are available to convert regular bikes to e-bikes. The major advantage of kits is the buyer's initial cost is reduced, having already purchased the bicycle to which the kit will be fitted. There are three basic kit formats: complete kits, separate components (build your own) and all-in-one wheels.

Complete kits are available, generally with the battery sold separately. These may be fitted by specialist retailers or purchased online and fitted by the consumer. A popular example in New Zealand is a NZ$999 kit made by Bafang and marketed under the 8Fun label. Commercially available kits generally have all the required components. Most kits have a throttle control and usually have a pedal or crank sensor. Only the highest priced kits such as the Canadian BionX (starting at NZ$2,500) have a torque sensor and an optional throttle (not available in markets that have adopted the EU standard).

To install a kit, buyers must either have fairly advanced skills or purchase the kit through a specialist e-bike store offering installation services. Staff in these stores have acquired technical knowledge of e-bike systems through experience, as there are no known e-bike modules in New Zealand training courses offered by major providers like the University of Otago or Sheppards Industries. In the UK, e-bike training has only been offered by the major industry trainer since 2016 (Cytech 2016).

Separate components can be purchased for a 'garage' built e-bike. This is likely to be limited to a relatively small group of consumers, based upon difficulties inherent in matching components (Harwood 2016). Although the majority of builds using common components are likely to be similar to e-bikes built using complete kits, high power motors are available and dedicated enthusiasts have built single or multi-motor e-bikes with peak power levels exceeding 10 KW[6] that reach speeds over 130 km/h (Hicks 2013). For a savvy enthusiast, the cost of building an e-bike from separate components can be significantly less than a production e-bike or adding a complete kit to a donor bike. Another benefit prized by enthusiasts is the ability to easily upgrade or replace worn or outdated components (especially batteries). Production e-bikes generally have proprietary components, and there are as yet few businesses offering battery repacking services.

All-in-one e-bike wheels are a relatively recent development, where the motor, battery, controller and sensors are all housed in the hub or wheel. By simply replacing a 26" (traditional mountain bike) or

[6] This is not a misprint; the cited article describes a modified Giant DH with a 100 V battery and 150 A controller, equivalent to 15,000 peak watts

28”/700C (road or hybrid bike) wheel, these kits provide a relatively easy way for the consumer to convert a standard bike into an e-bike. These wheels are a rare sight in New Zealand, perhaps due to the difficulty and cost of shipping lithium ion batteries internationally. Examples[7] include:

- FlyKly’s NZ$1,575 Smart Wheel is a rear wheel replacement with a 250 W motor and motion/torque sensor activated power up to 25 km/h; this is the smallest, most ‘normal’ looking wheel on the market. Settings are controlled via a Bluetooth connected smartphone.
- Evelo’s NZ$1,375 Omni Wheel – a front wheel replacement with a 350 W motor and throttle activated power up 27 km/h; available in a range of battery capacities.
- Electron’s NZ$1,100 wheel – a front wheel replacement with a 250 W motor and wireless pedal sensor activated power up to 32 km/h (USA) or 25 km/h (EU).
- Other models still in crowdfunding or development stage include the Copenhagen wheel and the GeoOrbital wheel.

2.6 E-velomobiles and e-recumbents

Recumbent bikes and trikes are increasingly available with electric assistance. While most e-recumbents are standard unpowered recumbents with an e-assist kit added, some are designed to be electric from the ground up. For example, the Outrider recumbent e-trike (figure 2.11) has a rated continuous power of 750 W, a rated peak power of 4.2 KW, and a maximum motor-assisted speed of 56 km/h. If such recumbent trikes were to be made legal in New Zealand (through changes to or removal of the power limit), then they may need to be classed as a moped or included in a new S-pedelec class.

Figure 2.11 Outrider recumbent e- trike

Source: outriderusa.com

Velomobiles are enclosed for weather protection like a car, but they have ergonomic pedals like a recumbent bicycle. They also provide some physical protection to the rider in the event of a crash. Some velomobiles may be designed as pedicabs for transporting passengers (figure 2.12). The NZ$11,000 Organic Transit ELF (figure 2.13) is a recumbent trike with a motor that stops providing assistance above 20 mph (32 km/h) to meet USA bicycle standards. The ELF is designed to be primarily propelled by pedals, and has optional features such as a rear passenger seat, half doors, lockable boot and a solar panel roof.

[7] The listed specifications and prices are as stated on each manufacturer or authorised retailer website and currency conversion rates as of September 2016, excluding shipping, GST and import duties.

Under EU regulations, velomobiles and recumbents having a saddle height below 54 cm are exempt from vehicle type regulations and are effectively treated the same as a bicycle (Bike Europe 2016a).

Figure 2.12 Velomobile taxi in Zürich, Switzerland

Source: Richard zh, Wikimedia Commons

Figure 2.13 Organic Transit ELF in Wellington

Source: John Lieswyn

2.7 High power, high speed electric bicycles

Some production high-powered, high-speed e-bikes are available overseas. In the electricbike.com review (2017) *10 fastest production ebikes*, only one had a power rating of less than 2 kW. Examples of production (albeit low volume, niche brand) e-bikes that could fall into a grey area are listed in table 2.1. From this list, only the Vintage Tracker is currently known to be available in New Zealand at NZ$8,650. For the other models, shipping, import duties and GST would substantially increase the final consumer cost. Except for the Nyx (figure 2.14), these e-bikes are all below 2 kW in 'base' configuration. If the Transport Agency were to increase the motor power limit to 750 W (as in the USA) or higher, then some of these models might become legal (at least in 'base' configuration) – unless a motor cut-out speed criterion is implemented.

Because most of these are esoteric in price and/or subject to moped or motorcycle rules in most jurisdictions (including New Zealand), the market for these e-bikes is expected to be very small.

Table 2.1 Sample of high power and/or speed e- bikes

E- bike	Rated continuous power (W)	Motor cut- out speed (km/h)	Base price NZ$	Motor activation	Notes
Vintage Tracker	750/3,000 (USA) 300/3,000 (NZ)	32/58 (USA) 32/50 (NZ)	$8,650	Throttle	USA cruiser bike with 'race' key for non-public road use
M1 Spitzing	250/500/800	24/47/70	$12,000	Pedelec	German mountain bike
HPC Supermondo	750	32/64	$7,000	Throttle	USA cargo bike
Cutler Fusion	1,000	51	$1,300	Throttle	USA low-end mountain bike
Marrs M-2	1,000	48	$5,000	Throttle	USA single speed low rider
Nyx X-series	3,000	50/95	$9,000+	'Half' throttle	French mountain bike

Figure 2.14 Nyx X14 e- mountain bike

Source: www.nyxbikes.com

Figure 2.15 Vintage Tracker e- bike

Source: www.vintageelectricbikes.com

There are a few options for consumers in the e-bike kit market for motors between 500 W and 1,000 W, and some enthusiasts can modify a motor by improving cooling and/or rewinding to attain a higher continuous power capability. Some enthusiasts may choose to build up a bike with multiple motors. These have already been briefly described in section 2.5.7 on e-bike kits.

2.8 Scooter style e-bikes

Scooter style e-bikes (SSEBs) often have body fairings (figure 2.3) and are closer in design to a motor scooter (moped) than to a bicycle (Jamerson and Benjamin 2016). Commonly speaking, the difference between a moped and a motor scooter is that the latter has no pedals. Although vestigial pedals are provided (presumably to meet legal requirements), these are located too far apart and behind the rider's knees to be useful.

Accordingly, the pedals are often removed at the point of sale or quickly bent[8] and SSEBs are generally operated by throttle only. SSEBs are the most common e-bike type in China (Aia 2013). In many other jurisdictions including California, a SSEB is classified as a moped or as a motorised scooter and must be registered and insured if they are to be operated on a public roadway (MacArthur and Kobel 2014).

In New Zealand, Gazette Notice 2013-au4618 states:

> *For the avoidance of doubt readers are advised that the District Court has held that low powered electric scooters are NOT power-assisted cycles, but are motor vehicles (of a type known as mopeds).*

Unfortunately, this text omits reference to pedals, but case law (NZ Police v Bridgman, Blenheim 2010) provides more detail. The defendant in this case believed that what he was riding was not a motor vehicle, but a 300 W vehicle marketed as an 'electric bicycle'. However, the vehicle did not have its detachable pedals fitted at the time and, irrespective of that, they were not considered the primary means of propulsion. The judge deemed it a 'pedal-assisted power cycle' rather than a 'power-assisted pedal cycle'

[8] Due to the scooter-like chassis of an SSEB, the pedal crank arms must be located more than twice as far apart compared with a normal bicycle, which affects ergonomic usability and makes it difficult to efficiently operate the pedals. Furthermore, the weight of an SSEB (typically around 50 kg) increases the likelihood of it being dropped which often results in damage to the pedals, rendering them unusable.

– the distinction is crucial – and only the latter was considered exempt from motor vehicle classification. The Land Transport Rule 2004 states that a cycle is defined as '…designed primarily to be propelled by the muscular energy of the rider'. Because SSEBs are designed *primarily* to be propelled by a motor, they are not currently legal to be used on the road without full registration and licensing.

SSEBs are rarely seen on New Zealand roads. The NZ$4,200 Newage Hybrid SSEB (figure 2.16) has a 350 W electric motor and a petrol generator to charge the battery and extend the range. The NZ$3,200 Newage SSEB (figure 2.17) omits the petrol generator.

Figure 2.16 Newage Hybrid SSEB

Source: mynv.nz

Figure 2.17 Newage SSEB

Source: mynv.nz

2.9 Mopeds and motor scooters

According to the Land Transport Act 1998, a class LA (2-wheel) or class LB (3-wheel) moped means a motor vehicle (other than a power-assisted pedal cycle) with two wheels; a maximum speed not exceeding 50 km/h; and either an engine capacity not exceeding 50 cc; or a power source other than a piston engine. According to the Transport (Vehicle and Driver Registration and Licensing) Act 1986, moped means a motor vehicle running on two or three wheels that is fitted with a motor having a power output not exceeding 2,000 W[9] and is designed to be ridden at a speed not exceeding 50 kilometres per hour under normal conditions of use.

A moped driver must have a driver licence, wear an approved motorcycle helmet and register the moped. (NZ Transport Agency 2011). It must also have an import entry certification or be certified at a testing station.

Traditionally, petrol powered mopeds had vestigial pedals like the modern day SSEBs. Such mopeds are no longer prevalent on New Zealand roads and the research did not reveal any current suppliers. Several 50 cc scooters governed to 50 km/h (meeting the New Zealand definition of moped) are currently marketed at around the NZ$2,400 price point, including the Sunny 50 (figure 2.18), Suzuki UZ50, Honda Giorno and Peugeot Kisbee 50. The original motor scooter, the Vespa, is sold in two 50 cc variants in New Zealand: the NZ$5,500 Primavera 50 and the NZ$6,000 Sprint 50.

The NZ$8,000 Ubco (figure 2.19) is a New Zealand designed off-road electric vehicle with two 1 kW motors (2 kW total) and a top speed of 45 km/h. Currently marketed to farmers for off-road use only, the

[9] According to the NZ Transport Agency factsheet, the 2,000 W limit only applies to older mopeds. The Road User Rule only references the Land Transport Act definition.

company is working on a street-legal version. The Ubco is on the boundary of the scope of this research. It has no pedals, so would not be a powered pedal cycle. In its current design, it does not look like a modern motor scooter. However, with 2 kW of power and a 45 km/h top speed, it would probably be covered by existing moped rules just like a motor scooter.

Figure 2.18 A typical 50 cc petrol motor scooter

Source: Hongyumotor.com

Figure 2.19 Ubco 2 kW 45 km/h electric motor scooter

Source: Ubco

2.10 Powered mobility devices

Mobility devices can include manual wheelchairs propelled by the occupant or by an assistant, electric power wheelchairs or mobility scooters. The focus of this research is on the latter as they have a higher speed capability; they are referred to as 'powered mobility devices' in this report.

Mobility scooters are most commonly single occupant vehicles designed and constructed for people needing help with mobility because of physical or neurological impairment. They have between three and five wheels and are powered solely by an electric motor of up to 1,500 W, in line with the New Zealand regulations. Most mobility scooters have top speeds of up to 6 or 15 km/h, depending on price and feature sets (refer appendix B), and this is the speed to which the current New Zealand standard applies (Standards New Zealand 2013). As they are generally not permitted in buildings, they are 'designed for and used by individuals who are able to walk and manipulate themselves on and off a seated object' (Thoreau 2015b).

The most common type of mobility scooter is illustrated in figure 2.20. The Newage B4 enclosed mobility scooter (figure 2.21) is a NZ$10,000 model with two-speed gearbox (7 km/h footpath speed and 15 km/h road speed) in contrast with the electronically set dual speed modes of most scooters. The B4 can be re-programmed to travel up to 30 km/h. The NV X2 (figure 2.22) is a NZ$9,500 enclosed scooter that is 5 cm wider and has larger braked wheels than most scooters. The X2 has a standard steering wheel, a two-speed gearbox, rack and pinion steering, and independent suspension. The X2 has a motor rated less than 1,500 W and comes standard with a 15 km/h limit, but can be re-programmed to travel up to 30 km/h (G Stanley, pers comm.) At present, the B4 and X2 in low-speed form would appear to meet the legal requirements to be classed as a mobility device. In higher speed form, they would exceed the 15 km/h definition used in the New Zealand standard, but would still appear to be legally classed as a mobility device. Arguably the feature set and speed capability of the X2 has more in common with a motor vehicle such as the low-speed electric vehicles (LSEVs) discussed in section 2.12.2.

Figure 2.20 Standard mobility scooter

Source: NZ Transport Agency

Figure 2.21 Newage B4 cabin scooter

Source: mynv.nz

Figure 2.22 NV X2 mobility scooter

Source: mynv.nz

For any person with a disability or older adults with difficulty maintaining their previous levels of mobility, a mobility scooter allows them to participate in activities they previously could not access, participate in activities without discomfort or extend the duration of participation (Thoreau 2015b). A scooter can be driven forwards and backwards using tillers located on the handle bars. Speed is controlled via a pushbutton, switch or dial on the dashboard (figure 2.23). In the UK, different scooters can be ridden either on the footway or the road, depending on speed capability (refer section 8.4.4).

Figure 2.23 Typical dash of a mobility scooter

Source: Thoreau 2015a

A mobility scooter user is considered a pedestrian in New Zealand. The Road User Rule definition of a pedestrian 'includes a person in or on a contrivance equipped with wheels or revolving runners that is not a vehicle' (NZ Government 2004). The New Zealand *Pedestrian planning and design guide* defines a pedestrian as 'Any person on foot or who is using a powered wheelchair or mobility scooter or a wheeled means of conveyance propelled by human power, other than a cycle' (Land Transport NZ 2007).

2.11 Other LPVs

2.11.1 Yike Bike

The Yike Bike is a New Zealand invention with a folding chassis, a large front wheel and one or two smaller rear wheels, a seat and a handlebar. It is propelled solely by an electric motor rated by the manufacturer at

230 W[10], at speeds up to 23 km/h, without any possibility of human propulsion. Safety features of the Yike Bike include 'anti-lock' regenerative braking and permanent and inbuilt LED lighting for visibility. The removable third wheel accessory on the 13.5 kg Yike Bike Model V (figure 2.24) adds extra stability for new users. Yike Bikes are a premium product priced at over NZ$5,700 and are thus rare.

Figure 2.24 Yike Bike Model V with 3rd wheel

Source: Yike Bike

Figure 2.25 Yike Bike riding position

Source: Yike Bike

2.11.2 Self-balancing vehicles

The EU regulation 168/2013 defines a self-balancing vehicle as '...a vehicle concept that is based on an inherent unstable equilibrium and that needs an auxiliary control system to maintain its balance, and which includes powered one-wheel vehicles or powered two-wheel, two-track vehicles' (European Parliament and Council of the European Union 2013).

2.11.2.1 Segway type two- wheel vehicles

The most commonly known self-balancing device in New Zealand is the Segway PT, originally introduced in 2001. With a top speed of 20.1 km/h and the ability to climb kerbs and small stairs, the Segway PT (figure 2.26) is marketed for people with balance or mobility issues, law enforcement and other emergency services personnel, and tour operators (Segway 2016). It has twin motors rated at 750 W continuous power each. Segway is also marketing a range of other similar products including the Ninebot MiniPro with a seat and top speed of 16 km/h (figure 2.27).

The Airwheel A3 (figure 2.28) is equipped with a seat and handlebar. It has a 1,000 W motor and a top speed (electronically limited) of 18 km/h. The user leans forward to accelerate and side to side to turn. It has electronic braking, built in lights and automatic turn signals. A remote control allows the user to customise operational features but is not needed during motion. Figures 2.26, 2.27 and 2.28 show self-balancing scooters with a handlebar and no seat; with a seat and no handlebar; and with both a seat and a handlebar.

[10] Independent testing revealed a higher motor power (T Hughes, pers comm)

Figure 2.26 Segway i2

Source: Segway

Figure 2.27 Ninebot

Source: Segway

Figure 2.28 Airwheel A3

Source: Airwheel

The Ogo (figure 2. 29) is a New Zealand invention currently in the product development phase. It is based on Segway mechanical systems and is characterised by an ‘active moving seat control’, meaning the user simply leans in the direction of desired travel to operate it.

Figure 2.29 Ogo self- balancing personal mobility device

Source: Ogotechnology.com

2.11.2.2 Self- balancing unicycles and hoverboards

With gyroscopes, accelerometers, controllers such as used in the Segway coming down in price, a plethora of other self-balancing devices have come to market in the past few years. In a category best known for battery fires during recharging, the remaining manufacturers have emphasised their battery safety and quality control (The Electric Rider 2016a). E-unicycles are sold under brand names such as IPS (figure 2.31), Ninebot (now part of Segway) and Airwheel. They have a single wheel or two wheels side-by side, footpegs to stand on, and some can climb gradients up to 20 degrees, but are more difficult to learn how to use for new operators than other self-balancing devices (ibid). Amongst members of the Electric Unicycle Forum (http://forum.electricunicycle.org/), these devices are known as EUCs.

Hoverboards such as the Phunkeeduck (figure 2.32) have two wheels, on each end of a deck to stand on, and can travel up to 20 km/h. According to the Phunkeeduck manufacturer, the devices are FCC, CE and RoHS certified and recharged with UL listed chargers. Hoverboard wheels range from 15–25 cm (6-10 inches) but are typically 18 cm (7 inches), which means they are more susceptible to surface imperfections than e-unicycles, which have wheels ranging from 30–45 cm (12 to 18 inches). Accordingly, e-unicycles are much more likely to be used for transportation than hoverboards.

Figure 2.30 Three LPVs in Singapore

Source: Singapore Land Transport Authority

Figure 2.31 e- unicycle: IPS FBA

Source: Mini Segway Center

Figure 2.32 Phunkeeduck

Source: phunkeeduck.com

The Airwheel self-balancing unicycle has a MSRP of NZ$995 to $1,380, while the Ninebot unicycle is listed at NZ$1,995. Hoverboards have a MSRP of $1,095 to $1,399. However, online prices are typically 40–50% lower than list price (ie NZ$500 to $1,000).

Note that a large proportion of the power usage of self-balancing vehicles is directed into the self-balancing mechanism, rather than propulsion. Thus, the overall peak and/or continuous power requirement for a self-balancing LPV will be higher than that of other LPVs to achieve the same forward momentum. This should be taken into consideration in determining regulation of self-balancing LPVs. Furthermore, most self-balancing LPV manufacturers do not list the continuous rated power of their device.

2.11.3 Electric kick scooters

An electric scooter is in the style of a traditional push/kick scooter with an electric motor. The user stands on the platform and pushes against the ground to move and/or twists a throttle to activate the motor. While the name is similar, this should not be confused with a motor scooter (or moped), a completely different device with a heavy frame on which the user sits and is therefore more akin to a motorcycle (see section 2.9).

The Inokim Quick 2 Hero folding e-kick scooter (figure 2.33) weighs 15 kg with 10 inch (25 cm) wheels, a 250 W motor that will propel the scooter up to 27 km/h and retails for NZ$2,000. The digital console has three torque and speed settings (9, 18 and 27 km/h) to assist users during the learning to ride phase as well as help control speed on footpaths. The throttle is a thumb lever. With a lithium-ion battery, pneumatic tyres, light alloy folding frame, and a rider weight capacity of 120 kg, scooters such as this are aimed at the adult commuter market. An optional seat is available, which makes the scooter a lightweight alternative to a mobility scooter. The majority of sales are to Auckland residents looking for a first/last leg public transport solution (H Tan, Scoozzi, 30 August 2016, pers comm).

The NZ$1,799 Emicro One is relatively light at 7.5 kg and is also aimed at adults, with a recommended minimum age of 18. It is claimed to be the world's first motion activated e-kick scooter. The motor begins to assist only after reaching a certain speed under human 'kick' power. It has a 25 km/h top speed and the manufacturer lists a 500 W motor (although this is assumed to be a peak power rating). Like the Inokim, there are three selectable torque and speed settings.

E-kick scooters such as the NZ$200 Razor E90 (figure 2.34) are marketed as a toy for children. The E90 has a low-cost sealed lead acid battery, 16 km/h top speed, and low maintenance but hard riding urethane wheels. As hard urethane wheels have less traction than rubber tyres, they are more crash-prone.

Figure 2.33 Inokim folding e- scooter

Source: H Tan

Figure 2.34 Razor child's electric scooter

Source: razor.com/nz

2.11.4 Electric skateboards

Electric skateboards generally involve a remote control to allow the user to control the motor input. The user can generally assist the propulsion by pushing, and steering is controlled in the same way as a regular skateboard by shifting one's weight (The Electric Rider 2016b). Virtually all models incorporate motor braking and/or regenerative braking that can be effective at slowing the board (ibid). An example product is the Yuneec E-Go weighing 6.3 kg with a 150 W motor that propels the rider up to 20 km/h for up to 20 km range. The E-Go is available in New Zealand for NZ$1,299. The Australian Evolve Carbon (AU$2,100) has a 350 W motor capable of up to 38 km/h and anti-lock braking.

Figure 2.35 Evolve Carbon e- skateboard

Source: evolveskateboards.com

Figure 2.36 Evolve hand- held remote

Source: evolveskateboards.com

2.12 Vehicles not covered in this research

There do exist 'higher powered' devices that are similar in style to some of the LPVs considered here but have significantly higher continuous power ratings (ie over 2,000 W). These include some scooter-style electric bikes, kit e-bikes with high-power motors, golf carts, and three or four-wheel vehicles (such as the NZ Post Paxster). Such vehicles are outside the scope of this research and may need to be considered in subsequent research, or else be subject to the same rules as general motor vehicles. Some of these vehicles are briefly described in this section.

This study also does not consider solely human-powered vehicles and devices, including cycles, kick-scooters, roller-blades and skateboards. Generally, these are already classified under New Zealand legislation, either as 'cycles' or 'wheeled recreational devices'. However, it is acknowledged that some of the safety issues regarding their use on roads and paths are similar to those being investigated here.

2.12.1 Cycles fitted with a petrol engine

Bicycles fitted with small petrol motors such as the $199 CyclePro 50cc kit could be considered LPVs but these would need to be registered as a moped, and are unlikely to be granted registration without meeting moped vehicle lighting and braking standards and having a mirror fitted. Furthermore, such kits are not legal (NZ Transport Agency 2013) and their popularity is expected to decrease even more as electric LPV technology presents more attractive options.

2.12.2 Four-wheeled electric vehicles larger than mobility scooters

In the USA, four wheeled vehicles that can travel at least 20 mph (32 km/h) but not more than 25 mph (40 km/h) can meet the definition of a low-speed vehicle (LSV)[11] set out in the Federal Motor Vehicle Safety Standards (NHTSA 1998). These differ from electric buggies or 'golf carts' in that they are permitted to be driven in mixed traffic lanes of roadways with speed limits of up to 35 mph (60 km/h) (ibid). These vehicles are also known as LSEVs, or Neighborhood Electric Vehicles (NEVs) in the USA. A popular brand is the Polaris GEM (figure 2.37). LSVs have many fewer parts than traditional motor vehicles and hence lower initial and ongoing maintenance costs.

Such LSVs may help achieve New Zealand government objectives such as addressing climate change and improving safety (because the lower mass of these vehicles means they are less likely to harm others in the event of a collision). Other benefits of LSVs relative to traditional motor vehicles are space savings (up to four will fit in one standard car parking space), initial and maintenance cost savings, enhanced manoeuvrability and the 'fun factor'. Benefits relative to other LPVs (including mobility scooters) include partial or full weather protection, ability to keep up with traffic on most urban streets and load capacity.

Figure 2.37 GEM LSEV/NEV

Four or six passenger and cargo versions are used for tourism, commercial, security and enforcement purposes. Although these vehicles meet the definition of 'low-speed' used in North America, they typically have motors of 5 kW or more and are therefore out of the scope of this research. It is recommended future research and policy making consider the economic (lower cost), air quality and energy saving benefits that such vehicles may present.

[11] Speed and power are only loosely related. The use of the term *low speed* in the USA enables classification of vehicles based on the speed limit of roads where they are permitted by default.

3 Survey summary

3.1 Survey overview

A survey of interested stakeholders was undertaken to better understand the current climate of LPVs in New Zealand. Purposive sampling was used to identify and include important stakeholders, from groups including:

- e-bike, mobility scooter and other LPV manufacturers, importers and retailers
- transport researchers
- elderly advocacy groups (including Age Concern and Grey Power)
- Disabled Persons Assembly (DPA)
- pedestrian and cycling advocacy groups (Living Streets Aotearoa and Cycling Action Network)
- government agency staff
- transport writers for blogs and traditional media outlets.

The survey comprised a total of 76 questions, with detailed survey logic designed to ensure each participant was asked only questions that applied to them (refer appendix E). The survey was openly available online and was advertised through a variety of means, including purposive sampling (invitations to deliberately selected key stakeholders). It was understood this method would not provide a statistically significant representation of the entire population; rather the intent of the survey was to supplement the desktop research and serve as a forum for people to share their opinions and help guide the focus of workshops.

The survey ran for 10 weeks during which 1,356 responses were received, including from:

- 1,067 people who indicated they cycle at least once a month
- 273 people who already own an e-bike and 234 who indicated they are interested in one
- 117 people who indicated they either own a mobility device or someone in their family does
- 99 people who own ‘other’ types of LPV, ie Segway, e-unicycle, e-kick scooter.

Appendix E presents more detail about the survey structure and questions.

3.2 Survey findings

3.2.1 E-bike market estimates

The industry questions were answered by 94 persons, with 15 of these manufacturing, importing or retailing LPVs other than e-bikes, although only two of these did not deal in e-bikes as well. An indication of the number of e-bikes sold over the last 12 months and anticipated to be sold in the next 12 months has been calculated using the central value of each bin (volume category) in the response list (note, though, that the ‘500+’ bin has been counted as 500 units only, which is a conservative assumption).

This method cannot be used to estimate total sales in New Zealand due to the survey sampling and the fact that there is likely to be multiple counting of the same e-bike (if the importer is not also a retailer). It does help indicate the proportion of e-bikes being sold by type (kit only, retrofitted e-bike, or production e-bike) and show the degree of anticipated sales growth (or contraction). It appears that even with fewer responses for the forecast 12 months, production e-bike sales are expected to grow rapidly while kit sales and retrofitting of unpowered bikes are both static (table 3.1).

Table 3.1 Estimated e- bike sales by respondents

E- bike type	Last 12 months	Forecast next 12 months
Production e-bike	4,589	8,136
Retrofitted e-bike	456	626
E-bike kit	1,421	1,495
Total	6,465	10,256
Number of retailers selling at least one e-bike type	67	63

The low number of responses for other LPVs is considered to preclude an approximation of sales.

3.2.2 Is power an appropriate measure?

Although the researchers have not found any evidence of an independently certified 300 W motor being available in the international market, 49% of e-bike owners (n=198) answered that their e-bike has a 300 W motor. Twenty-five percent of owners have a 250 W motor, and the balance of respondents either did not know or had another power rating. Only 7.2% indicated a power rating above 300 W. It is acknowledged that some respondents with motors rated above the current 300 W legal limit may not have answered this question truthfully.

Asked about the 300 W power limit, 55% of e-bike users felt it is about right, 20% felt it is too low, and 16% supported the statement that motor power is not a good regulatory criterion. Only about half (55%) of the respondents indicated that their e-bike always has enough power assistance for hills, and 35% indicated that battery level affects hill climbing ability. 5.1% indicated that even in the best conditions (full battery charge, agreeable ambient temperature, and absence of cargo weight) their e-bike fails to provide enough assistance on hills. Survey respondents and workshop participants indicated that 250 W may not be sufficient for hills, although higher-end mid-drive retailers and users are dismissive of this concern.

Typical open ended answers included:

- *…if there has to be a choice between 250 or 350 watts, I vote for 350 – this would make the very sophisticated BionX motor legal for NZ*
- *one horsepower should be the maximum wattage*
- *300 W is about right for a "normal" bike, but potentially limiting for cargo e-bikes, and also in areas of steep hills*
- *…for me, the greater speed makes my commute viable, and I wouldn't want to see the power limit lowered. It (is) weird being between the EU and USA standards when shopping for new bikes…*
- *speed limits might be a better option on public roads*
- *there should be a maximum speed limit for e-bikes, not a power limit, and regardless of whether the rider is using a throttle or pedal assist. This would allow a high-powered motor solution for cargo/utility bikes where speed is not the priority.*

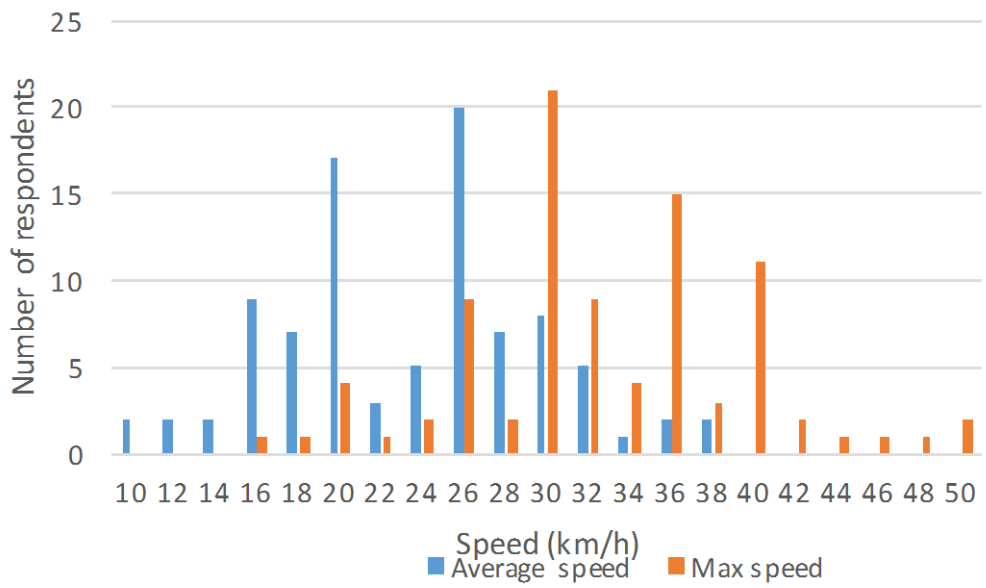
- *...there is an easy way to measure the power output of an e-bike. Many of the more intelligent controllers provide full power (~700 W) up to ~30 km/h, then as the bike (speed increases) it reduces power...above 37 km/h the assistance is zero...this is not hard for the controller to achieve, and provides a huge assistance on hills, and yet maintains a sensible speed on the flat.*

3.2.3 What speed is considered most appropriate for an e-bike?

When asked at what speed their motor cuts out, 22% said 25 km/h (the EU limit, thus roughly in-line with the 25% who said they have a EU standard 250 W motor), 26% said 32 km/h (the North American limit), and 12% has a user-adjustable cut-out speed. The16% who answered 'no cut-out speed' may have bikes where the top motor assistance speed is limited only by the system power output and conditions (gradient, wind). 23% were unsure and could therefore belong to any of the other categories.

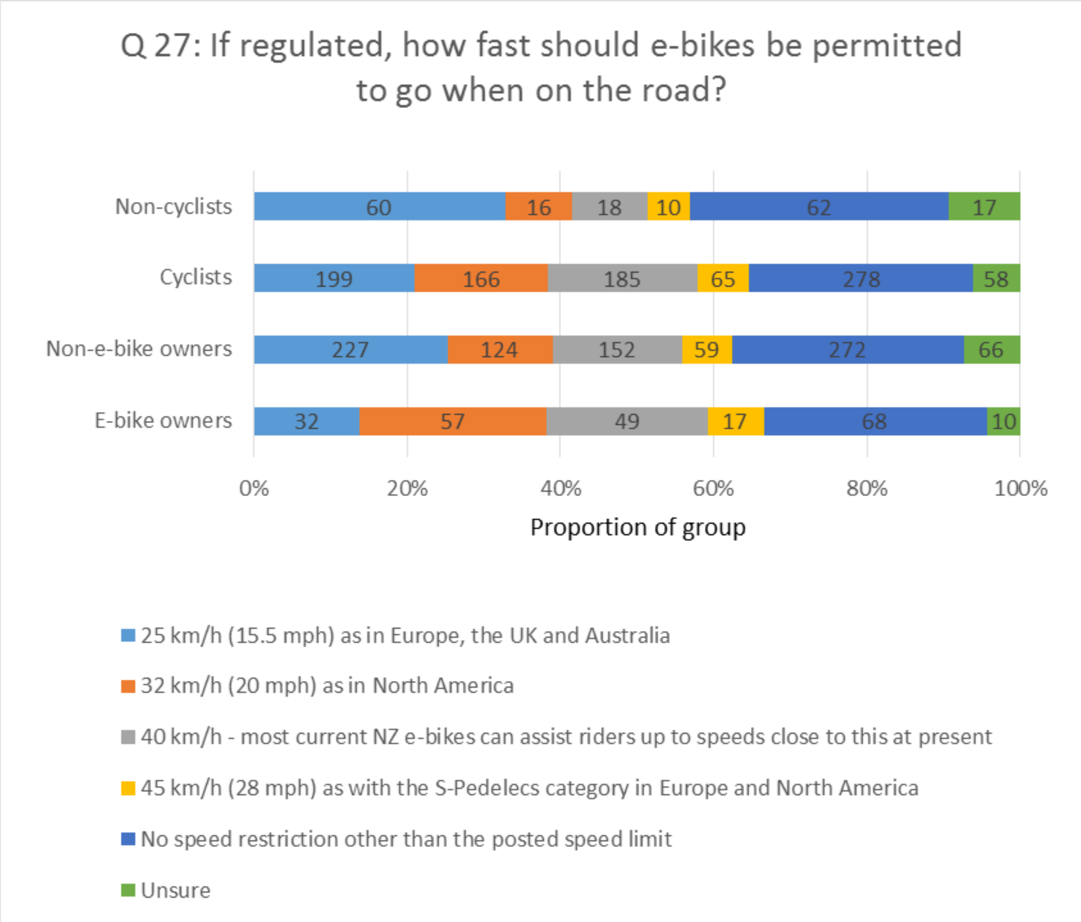
A free-form comment field was provided to answer the question on the average and maximum speed (figure 3.1) e-bike owners attain on level ground (n=92). The average values for these speeds is 23 and 33 km/h, respectively. Inspection of the individual answers indicates a few respondents are elderly and/or mobility impaired, operating their e-bikes at about 10 km/h. Conversely, a few respondents indicated 50 km/h for a top speed, suggesting they either have high-powered e-bikes and/or misread the 'level ground' part of the question. Given the large number of responses, these outliers do not have a major impact on the findings.

Figure 3.1 Frequency distribution of e- bike owner reported average and maximum speed (level ground)



When asked about how fast e-bikes should be permitted to travel on the road, if speed were to be regulated (figure 3.2), the most frequent response by non-e-bike owners was 'no speed restriction', closely followed by '25 km/h'. The 25 km/h EU, 32 km/h USA and 40 km/h typical ungoverned speed capability all received similar support. This question was open to all respondents, not just e-bike owners or cyclists. The most frequent response by e-bike owners was 'no speed restriction', closely followed by '32 km/h'. 35 km/h was not a selection, but evolved as a potential regulatory option later in this research.

Figure 3.2 Responses on e- bike speed regulation (n=1133)



There were 282 comments on this topic, typically:

- *why separate e-bikers? Regular cyclists can bike very fast anyway!*
- *it seems unreasonable to restrict e-bikes' top speed if normal bikes breach them legally*
- *I am often passed by un-assist bikes when I drive at 25km*
- *25 km/h is too slow and therefore people will work around this…32 km/h is sensible*
- *…a cut off speed of 25 km/h…preserves the concept of a bicycle*
- *I disagree that 'most' current e-bikes can do 40 km/h. I tried several types, and 35 km/h was typical maximum*
- *if you want to make cycling commuting attractive, the last thing you want to do is slowing them down arbitrarily*
- *40 km/h is a safe speed on a highway. A rider should ride at a safe speed on a busy city road or cyclepath*
- *On shared paths, they should be limited to walking pace*
- *32 km/h is similar in speed to a typical road-bike user. The European limit only makes sense in high-density city-type environments*

- *A good cyclist can ride a regular bike at speeds up to 40 km/h, e-bikes should not be limited to speeds below that*
- *I feel the speed should be controlled by the user of the vehicle…we don't regulate automobiles, trucks or motorbikes…*
- *turn off assist on footpaths/high pedestrian areas*
- *e-bikes should be able to keep up with city traffic*
- *if classified under the same rules as a bike, speed should be in comparison. Making it a speed limit rather than a power limit has implications for off-road use. Bikes travelling uphill tracks at 30 km/h will cause issues*
- *25 km/h in 50 km/h areas and 32 km/h in other areas*
- *As a competent cyclist I often travel at approx. 30-40 km/h. The stopping distance from 40 km/h on a bike is huge. If you add another 5-10kg (typical e-bike weight addition) the stopping distance from 40 km/h would be dangerously long in my opinion. I would therefore suggest 25-32 km/h as acceptable*
- *make it the same as the posted speed limit. If they want to make it 30 km/h, reduce all traffic to that limit.*

A higher proportion of non-cyclists than cyclists advocated the lowest speed threshold (25 km/h) but, conversely, non-cyclists were also the group with the highest proportion to consider that no speed restriction other than the posted speed limit should be required for e-bikes.

Pedestrian advocates generally do not want to see e-bikes used on shared paths. Another comment raises the point that higher speeds may be safe and appropriate in rural areas or for intercity travel. Commenters who drew parallels with motor vehicles not being governed may not appreciate the differential regulatory regimes applying to people who cycle and motorists. Suggestions for differential limits may be difficult to enforce, but are similar to the idea behind adjustable speed limits on e-kick scooters and mobility scooters. However, the industry is not currently producing e-bike consoles with such a feature. Many respondents appeared to misunderstand the differences between motor cut-out speed enforced via point-of-sale restrictions and the maximum possible speed the e-bike can travel under human power, which is regulated on the road by posted speed limits and must be enforced by police officers (or speed cameras, if the technology can be extended to LPVs, which would require some sort of visible identification feature similar to a vehicle's number plate).

3.2.4 E-bike owners' views on throttles

When e-bike owners asked what type of motor activation their primary e-bike has, 74% indicated they have a pedal assist with a throttle (n=189). This indicates the majority of existing e-bikes are not EU standards compliant and likely to be New Zealand brands sourced direct from China, USA brands such as Pedego, or kit built.

When asked for views on throttles, 80% indicated across-the-board support for the feature, while 14% agreed with a possible restriction where twist and go bikes are only allowed on shared paths if the rider is pedalling (as in the UK, refer section 8.2.4). Only 5.2% of respondents indicated support for a prohibition on throttles.

This question garnered a substantial number of open-ended comments (85), typically:

- *Hand throttle is essential for people like me with a heart condition*

- *Without the throttle I would not be able to ride a bike, this allows me the opportunity to still get out and about*
- *I have never experienced any difficulty in negotiating shared paths. I use a bell. I'm a human being; I can adjust my speed to the circumstances*
- *I need the throttle to get started initially then use pedal assist for cycling. It is especially handy on my cargo bike…starting off on hills or slopes. I would have no objection to speed being limited to about 10kph as that is about all you need to get moving [ed.: this is provided for within the EU rules]*
- *I normally use the pedal assist mode at a low level (1 or 2 out of 5) and reserve my throttle to get me out of tight situations quickly. I find this combination provides maximum safety.*
- *Bike Forza is heavy, almost impossible to start, especially uphill, without short use of throttle. Excessive use runs battery down fast, so (I) only use sparingly*

Respondents frequently noted they felt a throttle was important to get started on hills and a safety feature for accelerating quickly in 'tight spots' or to avoid conflicts with motorists. No respondents reported any difficulty with learning how to use the throttle or concerns about any added cognitive load. In reading all the comments, it is clear most people (in line with the 74% who answered they have a throttle feature) have not had the opportunity to ride a modern mid-drive e-bike with a torque sensor. This is probably because such e-bikes typically start at NZ$3,200 to $3,600, while the twist and go 'Chinese' e-bikes with a throttle start at NZ$2,000 to $2,400 and therefore are more accessible to a larger market.

3.3 Key points from survey

Industry respondents expect to sell almost double the number of production e-bikes in the next 12 months (compared with the previous 12 months), up to over 8,000 units. Meanwhile, sales growth for e-bike kits and retrofitted e-bikes is expected to be flat.

The existing 300 W power limit was not supported by 51% of the respondents, many of whom suggested regulating speed instead.

The average speed travelled by owners on flat ground was reported to be 23 km/h, with a 32 km/h typical maximum speed. However, 40 (out of 185 respondents) indicated a typical top speed of up to 40 km/h, indicative of the fact that the New Zealand market has a number of e-bikes designed for markets other than the EU or the USA where the legal limits are 25 and 32 km/h respectively.

The issue of motor cut-out speed received more comments than any other topic. Many respondents did not feel a motor cut-out speed was necessary, suggesting e-bike riders adjust their speed to the conditions. There was also support for not allowing power assistance or throttle-only operation on shared paths, although the former would be impossible to enforce.

Throttle activated motors were overwhelming supported, although this may be due to the current dearth of quality torque sensor equipped pedelecs. This in turn may be due to the relatively low number of EU style pedelecs available in New Zealand with the American motor speed cut-out, the clear preference of Kiwis for power assistance at speeds above the EU's 25 km/h threshold, and a price differential of about NZ$1,000.

4 Market analysis

4.1 E-bikes

4.1.1 International trends

Electric bikes ('e-bikes') are the most widely used form of electric transportation in the world (Mason et al 2015). China is the world's largest e-bike market, as sales of lead-acid battery scooter style e-bikes have been driven by environmental policies restricting petrol powered two-wheelers (ibid). Lithium-ion battery bicycle-style e-bikes are the mainstay of current sales in western countries. With rapid advances in battery technology and manufacturing economies of scale, weight and prices are dropping while range is increasing. These factors are helping propel sales growth. The comparison between the car-oriented USA and Western European countries may be useful in establishing New Zealand's position with respect to e-bikes. Data from the Confederation of the European Bicycle Industry (CONEBI) show between 2011 and 2014 e-bike sales increased 71% in the USA and 59% in Europe (Benjamin 2015a; CONEBI 2016). Market adoption figures suggest e-bikes are more popular in Western Europe than in the USA, as shown in table 4.1. This is also intuitive, as all types of bicycle are likely to be more popular in places where cycling is more normalised.

Table 4.1 2014 e- bike sales comparison between top three EU e- bike countries and USA

Location	E- bike sales, 2014 (1,000s)[(a)]	Population, 2016 (1,000s)[(b)]	E- bikes sold/1,000 population
Germany	480	80,682	5.9
The Netherlands	223	16,980	13.1
Belgium	130	11,372	11.4
Top 3 EU consumers	832	109,034	7.6
USA	193	321,369	0.6

Notes: [(a)] EU data: CONEBI (CONEBI 2016) USA data: EBWR (Benjamin 2015a)

[(b)] Population source: www.worldometers.info

Figure 4.1 shows the trends in e-bikes sold per capita for the main western European countries that have adopted e-bikes and figure 4.2 shows the overall sales for these countries combined. Of particular note in figure 4.1 is the steep rise in sales per capita experienced in Belgium between 2012 and 2014. ECF (2016) suggested this is due to strong advocacy targeted at reducing Belgium's car use (which is high by European standards) and the influence from the Netherlands, which is exhibited by particularly strong sales in the Flanders region (ie the part of Belgium neighbouring the Netherlands).

Figure 4.1 E- bike sales in 11 western European countries

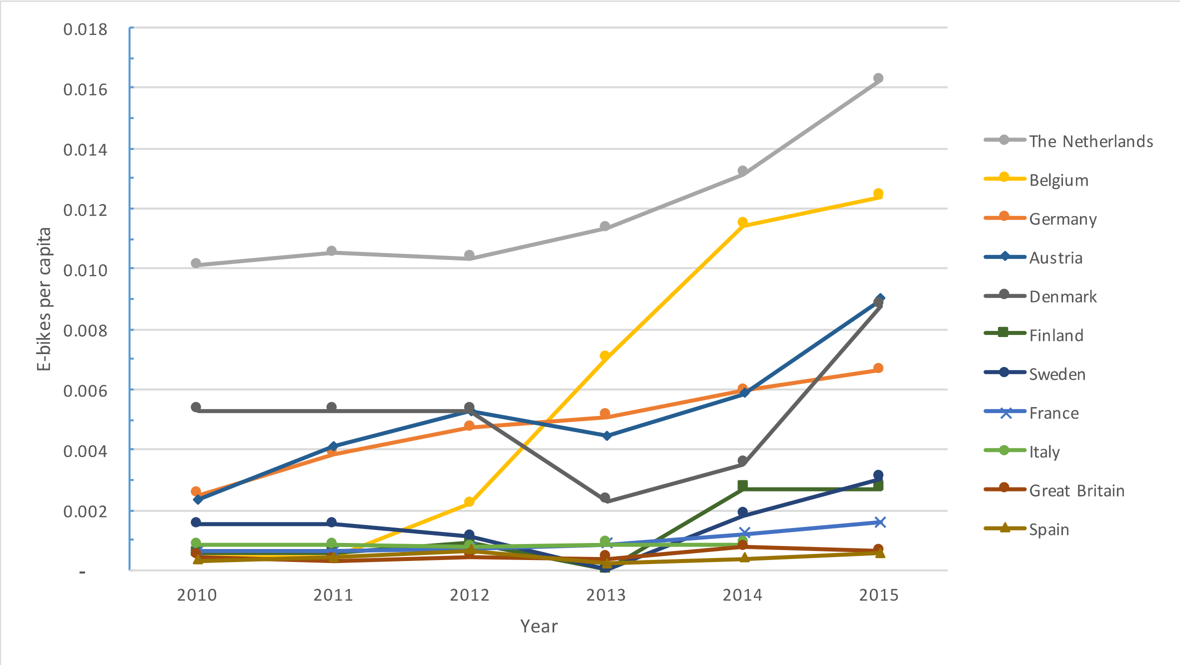
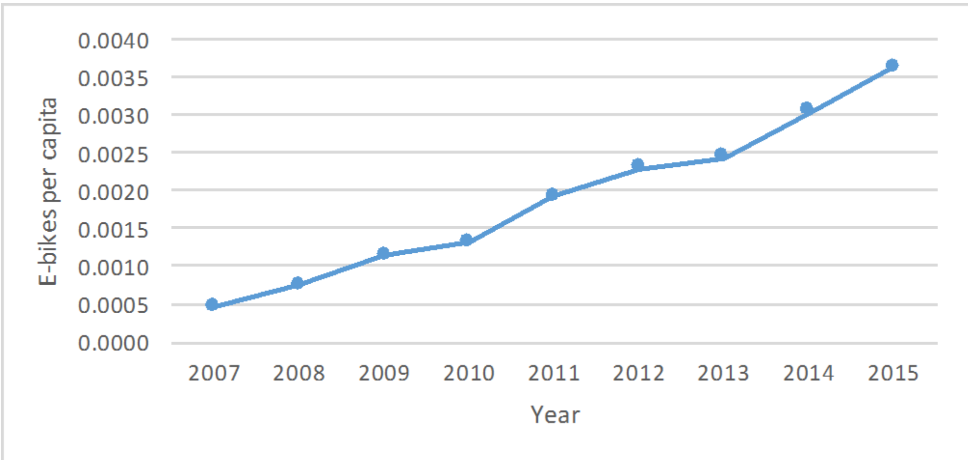


Figure 4.2 E- bike sales for 11 western European countries combined



Major e-bike OEM system manufacturer Bosch anticipates continued growth in the sector (Sutton 2016a):

- Between 30 and 40% of bikes are expected to carry some form of electric assistance in the future.
- Some markets are currently growing up to 30–40% annually.
- Bosch's European business has been growing 25% year-on-year.
- E-bike sales figures from regions with a harsh climate have shown e-bike sales might be less weather dependent

According to research by Navigant, the global e-bike market value is expected to reach US$24.3 billion (NZ$33 billion) by 2025, a rise of 37% from the US$15.7 billion market value in 2016 (Sutton 2016b). This is equivalent to an average annual growth rate of over 5% across all countries, but it is unclear whether this estimate includes the large SSEB sector in China.

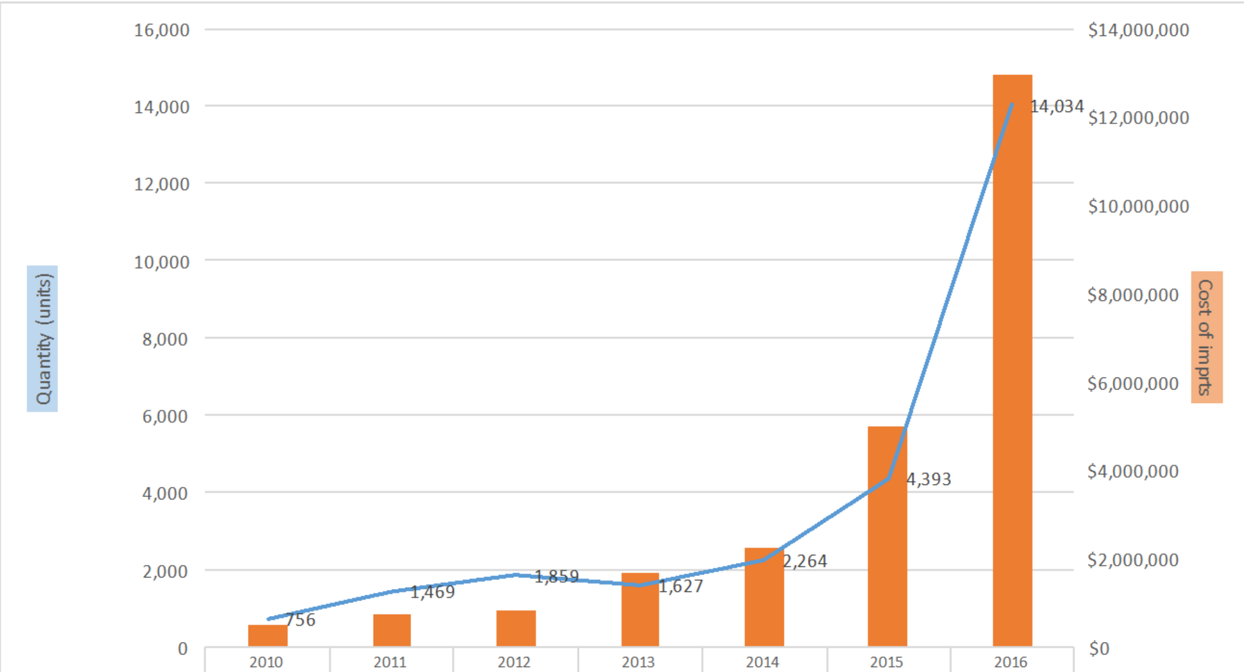
The e-bike market is maturing faster in Europe than in the USA due to the general cultural attitudes towards cycling. In Europe, e-bikes are seen as an enabler of utility cycling[12], so retailers already used to catering for the utility market had no problem selling them (Citron and Gartner 2014). In English-speaking countries, cycling is more commonly associated with sport. Electric assistance is anecdotally seen as 'cheating' by staff working in traditional bicycle shops, and so there have been limited opportunities to see or purchase e-bikes.

This is now changing, as New Zealand-based e-bike specialist retailers are setting up physical and online stores. For example, two physical e-bike specialist stores have recently opened in Christchurch. Plus, in the time this research has been conducted, the researchers have noticed a shift where most traditional cycle shops in Christchurch are now selling e-bikes.

4.1.2 New Zealand import data for e-bikes

The NZ Customs Working Tariff Document provides a breakdown of relevant import categories (NZ Customs nd). Category 8711.90.00 is defined as 'Motorcycles (including mopeds) and cycles fitted with an auxiliary motor, with or without side-cars; side-cars: other', where all other categories relating to cycles with motors specify petrol motors. In other words, the vehicles in category 8711.90.00 are fitted with an electric motor. Therefore, the category would include all electric motorcycles, SSEBs and e-bikes. No further disaggregation of the category is available, although it is reasonable to assume the majority of vehicles in the category are e-bikes, given anecdotal experience that electric motorcycles and scooters are rare in New Zealand. The actual data is available using NZ Statistics Infoshare.[13]

Figure 4.3 New Zealand imports of electric motorcycles, mopeds and cycles (November 2010 – November 2016)



	2010	2011	2012	2013	2014	2015	2016
Cost of imports	512,968	746,669	868,273	1,696,366	2,251,144	5,023,958	12,968,982
Quantity	756	1,469	1,859	1,627	2,264	4,393	14,034

[12] Including the Copenhagen bike share scheme 'Bycyklen', which since 2014 utilises e-bikes.

[13] Refer to table reference TIM001C: www.stats.govt.nz/infoshare/

The data enables a computation of the value per unit, which ranges from a low of NZ$355 in 2012 to a high of $1,276 in 2015 before falling back to $826 in 2016. This may be due to the relatively small size of the New Zealand market and the consequent impact of a few importation decisions.

4.1.3 New Zealand sales indications from surveys

The survey undertaken for this research included industry participant questions on sales. A summary of this report's survey data is provided in chapter 3. With respect to the e-bike market, the key points are:

- Of the 1,356 survey respondents, 67 indicated they were involved in manufacturing, importing and/or retail of powered bicycles; nine for powered recumbents and five for velomobiles (Question 65). An individual respondent might be involved in more than one of these cycle types.
- Of all retailers (ie including other devices) participating in the survey, the majority sold both powered and unpowered bicycles (Question 65).
- Most businesses dealing in both powered and unpowered bicycles were focused primarily on unpowered bicycles (Question 67).

Approximate sales figures for the last 12 months and anticipated for the next 12 months are shown in figures 4.4 and 4.5 respectively.

Figure 4.4 Survey respondents' estimate of units sold in last 12 months

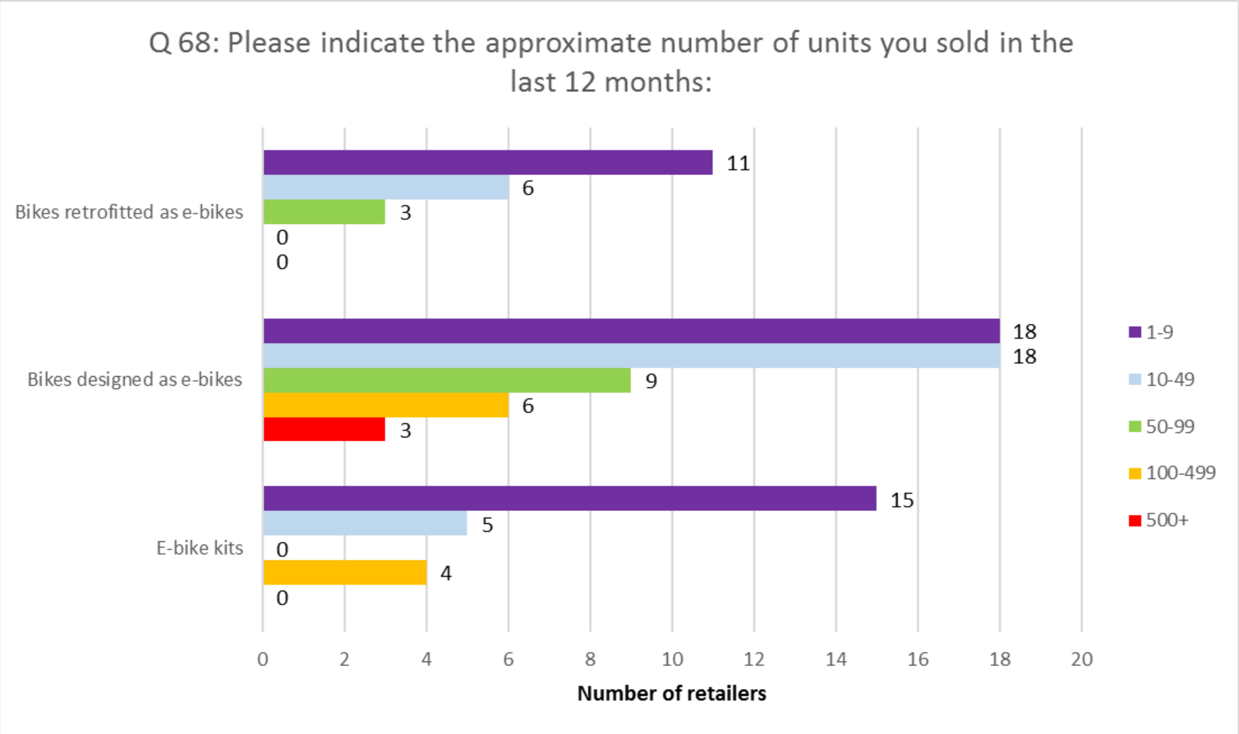
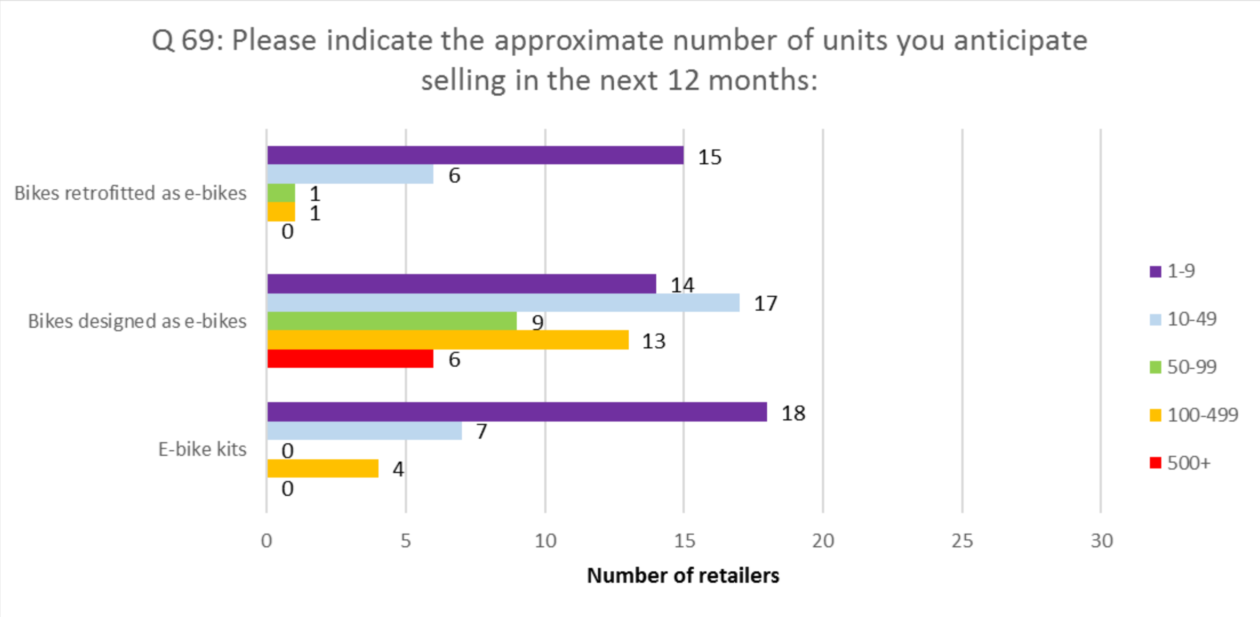


Figure 4.5 Survey respondents estimate of units anticipated to be sold in next 12 months



The survey cannot be used to directly forecast e-bike sales, as the sales categories used in the survey were broad ranges, and the respondents' proportion of the market share is unknown. What the survey does reveal is that respondents expect a marked increase in e-bike sales in the coming year compared with the previous year (eg 19 respondents indicated a sales expectation of 100 units or more versus nine respondents indicating having sold 100 units or more in the past year). A rough estimate of the change in sales by e-bike type is given in the survey summary (table 3.1).

According to a recent Colmar Brunton poll, 'more than 40 per cent of Kiwis would consider purchasing an e-bike and they cited health benefits/getting active (28 per cent), cost savings (21 per cent) and reducing commuting times (20 per cent) as key reasons for the choice' (Mercury 2016a).

4.1.4 Types of e-bikes in New Zealand

Notwithstanding the benefits some stakeholders have identified (section 9.2.3) twist throttles are common in New Zealand primarily because they cost less than torque sensor activated e-bikes. However, the price differential is decreasing with increasing Chinese production of torque sensor systems for European and Australian markets.

A scan of 2016/17 models in Christchurch stores shows throttle/magnetic PAS/rear drive e-bikes range from NZ$2,000 to $4,000. Non-throttle/torque PAS/mid-drive pedelecs range in price from NZ$3,200 to $8,000, with most models around NZ$4,000 to $4,500.

As noted previously, the variety and availability of all e-bikes has increased substantially in the last year. Major brands are adding e-bikes to their model ranges, almost exclusively specifying mid-drive models without throttles. It is assumed this is in order to appeal to the widest number of markets, but may also be due to performance and reliability advantages (versus hub drive systems).

4.1.5 E-bike sales forecast

Like all forecasting exercises, predicting future sales of e-bikes in New Zealand involves some speculation, but some information is available to help inform this. Industry reports from the Eurobike 2016 expo indicate interest in e-bikes is attracting attention from outside the bicycle sector, and forecast a market of some 6 million e-bikes sold per year in Europe by 2020 (Oortwijn 2016a). According to 2015 statistics, published recently by the Confederation of the European Bicycle Industry (CONEBI), e-bikes accounted for 6.5% of all bikes sold in the 28 EU member countries; in 2010 (the first-year e-bike sales were included in the CONEBI report), e-bikes accounted for 3.0% of total bicycle sales. CONEBI reported total e-bike sales rose by 19% to 1.357 million from 2014 to 2015.

Claus Fleischer, head of the division of Bosch that manufactures e-bike motors in Germany, predicts an annual growth rate of 15% in Europe (McClellan 2016).

Transportation-oriented e-bikes are expected to dominate sales in urban areas with recent major investments in cycleways, such as London, Birmingham and Leeds (Peace 2016). Key price points for e-bikes in the UK are between NZ$3,200 and $4,500, with average sale prices climbing every year (ibid). Clearly, e-bikes are not being considered by buyers as substitutes for recreational bicycles but as substitutes for other transportation modes such as driving or public transport.

Several factors will contribute to the uptake of e-biking and therefore e-bike sales trends; those predicted to be the most influential are presented in table 4.2.

Table 4.2 Influences on future market

Factor	Conditions that could result in accelerating e- bike sales	Conditions that could result in declining e- bike sales
Technology	Improvement in battery capacity and/or life, reduction in component weight, enhanced safety features, smoothness of motor assistance from torque control etc will better suit/appeal to more people.	Improvements in technologies for other transport modes – e-bikes become less attractive relative to other modes.
Regulatory environment	Wide range of possibilities permitted – will better suit/appeal to more people.	Heavy restrictions on power, speed and use that increase e-bike cost or total generalised cost of travel – fewer people likely to want to use e-bikes, higher cost of implementing/ enforcing the regulations.
Urban speed limits	Moves to area-wide lower urban speed limits would see a reduction in speed differential between cars and bikes (electric or conventional), making biking much more attractive.	Not applicable, as presumably, urban speed limits will not increase area-wide.
Attractiveness of alternative modes	Rise in petrol prices – more people seek to use alternative modes. Increased congestion – more people seek to use alternative modes.	Decrease in petrol prices – less disincentive to drive a private motor vehicle. Decreased congestion – less disincentive to drive a private motor vehicle.
Demographics	Aging population – older people are more likely to be able to use e-bikes than unpowered bikes.	E-bikes being portrayed as more dangerous to older people than other travel modes.

Factor	Conditions that could result in accelerating e- bike sales	Conditions that could result in declining e- bike sales
Parallel goals and promotions	Increased promotion of cycling in general – more people cycling more often, with some choosing to use e-bikes. Increased focus on health – more people likely to choose e-bikes over non-active transport due to removal of commonly cited barriers such as lack of fitness, distance or hills.	Cycling being portrayed as inherently dangerous.
Cycling infrastructure	Improved infrastructure for cycling, such as 'cycle highways' (eg Auckland's North Western Cycleway) with appropriate geometric design, intersection priority, lighting etc. Permission for e-bikes to use more facility types and an expanded cycling network.	Declining condition of cycling facilities. Restriction on e-bikes for certain facility types and a stagnation in the development of the cycling network.
Incentives and promotions	Tax breaks and promotions such as the Mercury discount coupons and test rides offered in 2016 promote adoption	No incentives or promotions offered.

The e-bike sales in a given year will depend on the combination of all these various factors.

The CONEBI data for e-bike sales from 2010 to 2015 (shown in figure 4.1) illustrate different growth patterns and rates. These can be used to establish scenarios for how the e-bike market in New Zealand might develop over time, starting from the base of existing sales figures.

Four growth scenarios have been considered:

1 Low growth rates

   a an initial growth of 0.0002 e-bikes per capita per year, similar to what was experienced in France during 2010–2015

   b an eventual decline in the growth rate (to 0.0001 e-bikes per capita per year after 10 years) tending towards stabilisation of sales.

2 Medium growth rates

   a based on current trend of 0.0004 e-bikes per capita per year as per the average across all the main European countries adopting e-bikes (ie those countries shown in figure 4.1) during 2010–2015.

   b assumes a continued linear increase at this moderate rate, ie does not tend towards a stable rate of sales per capita in the next 20 years.

3 High growth rates

   a initial growth rate of 0.0012 e-bikes per capita per year, similar to what was experienced in the Netherlands during 2010–2015

   b reducing to a growth rate of 0.0008 e-bikes per capita per year after five years, similar to what was experienced in Germany during 2010–2015.

   c reducing further (ie tending towards stabilisation) to a growth rate of 0.0004 e-bikes per capita per year after five years, as per the average across all the main European countries adopting e-bikes (ie those countries shown in figure 4.1) during 2010–2015.

4 Extreme growth rates

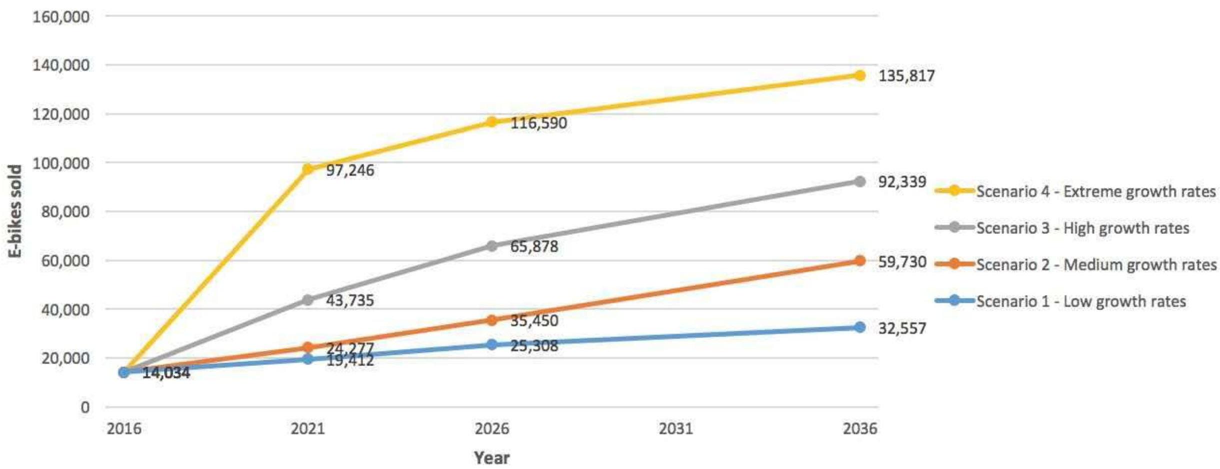
a initial growth rate of 0.0034 e-bikes per capita per year, similar to what was experienced in Belgium during 2012–2015

b reducing to a growth rate of 0.0006 e-bikes per capita per year after five years, similar to what was experienced in Germany during 2012–2015

c reducing further (ie tending towards stabilisation) to a growth rate of 0.0002 e-bikes per capita per year after five years.

The profiles of these four growth scenarios, in terms of the forecasted numbers of e-bikes sold each year over the next 20 years, are shown in figure 4.6. Note this represents predicted sales, not the total e-bike fleet on New Zealand roads during any given year.

Figure 4.6 Forecasted e- bike sales for different growth scenarios (as per scenarios detailed above)



4.1.5.1 Market outlook for kits

E-bike kits were popular in New Zealand up until a few years ago (N Pollett, E-Motion Bikes, 28 August 2016, pers comm). It is likely that e-bikes built from kits will represent a declining proportion of all e-bikes due to the following factors:

- Initial cost differentials are reducing to nearly zero as the price of production e-bikes declines, while the labour cost of installing a kit (for consumers without the capability of DIY installation) remains a large part of the cost.
- Whole-of-life cost advantages for production e-bikes will become more apparent to consumers, as the reliability of a kit-built e-bike is generally lower (donor unpowered bicycles are not designed for the extra load and stresses of electrification, and consequently have a higher maintenance cost on average).
- Selection, availability and performance of production e-bikes continues to improve relative to kits.

According to retailers responding to the survey conducted for this research, sales of kits are expected to grow, but not nearly as fast as for production e-bikes (refer section 4.1.3).

4.1.6 S-pedelec market survey

An S-pedelec or speed pedelec has a maximum 45 km/h motor cut-out speed, and generally does not have an open throttle (to comply with EU standards, refer section 8.3.4). In the USA, the national standard of 20 mph (32 km/h) has limited production and demand for S-pedelecs (faster e-bikes generally must be registered as mopeds). The main market offering has been the Specialized Turbo S[14]:

In 2015, California passed new legislation establishing three classes of e-bikes including a 28 mph (45 km/h) class (refer section 8.3.6). Utah and Tennessee followed suit in 2016 and more are expected (PeopleForBikes 2017a).

Although no sales data relating to S-pedelecs specifically was found, a web search was conducted on retailers in Europe and New Zealand to determine product availability (a proxy for demand). S-pedelecs appear to be a small (relative to other e-bikes) but growing market segment. The major brands in Germany all have one or more speed pedelec models in their range. For example, the €4,999, 350 W Kalkhoff Integrale I11 Speed is one of many 'trekking' e-bikes available in a speed version[15]:

In New Zealand, four S-pedelecs were found advertised at the time of writing:

- Impulse Evo: http://prv.co.nz/electric-e-bikes/
- Trek XM700+: www.trekbikes.com/nz/en_NZ/bikes/city-bikes/urban-commuter-bikes/xm-series/c/B448/
- SmartMotion Pacer: www.burkescycles.co.nz/products/smartmotion-pacer
- Specialized Turbo: www.specialized.com/nz/en-au/bikes/turbo.

4.2 Powered mobility devices

4.2.1 Current usage and sales

The actual number of mobility scooters currently in use in New Zealand is not known, but information is available for Australia, which can be assumed to be reasonably similar in this aspect. An Australian study has identified that 13 out of every 1,000 Australians over the age of 18 use a mobility scooter (ACCC et al 2012).

The 2015 Survey of Disability, Ageing and Carers estimated 18.3% of the Australian population had a disability defined as a limitation, restriction or impairment, which has lasted, or is likely to last, for at least six months and restricts everyday activities (Australian Bureau of Statistics 2016).

Using the same definition, the 2013 NZ Disability Survey found 24% of New Zealanders have a disability (Statistics NZ 2014). Fourteen percent of the New Zealand population is estimated to have a physical impairment limiting their everyday activities; the corresponding statistic for Australia is not known. Whereas the New Zealand classification system broadly identifies the type of disability (hearing, sight, mobility, intellectual etc), the Australian classification system is based on the part of the body affected (eg nervous system, circulatory system, muscular-skeletal) and the severity of consequences[16]. Overall,

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[14] www.specialized.com/us/en/bikes/turbo/urban/turbo-s-ce/106434

[15] www.kalkhoff-bikes.com/de/bikes/2017/e-bike/e-trekking/kalkhoff-integrale-i11-speed.html

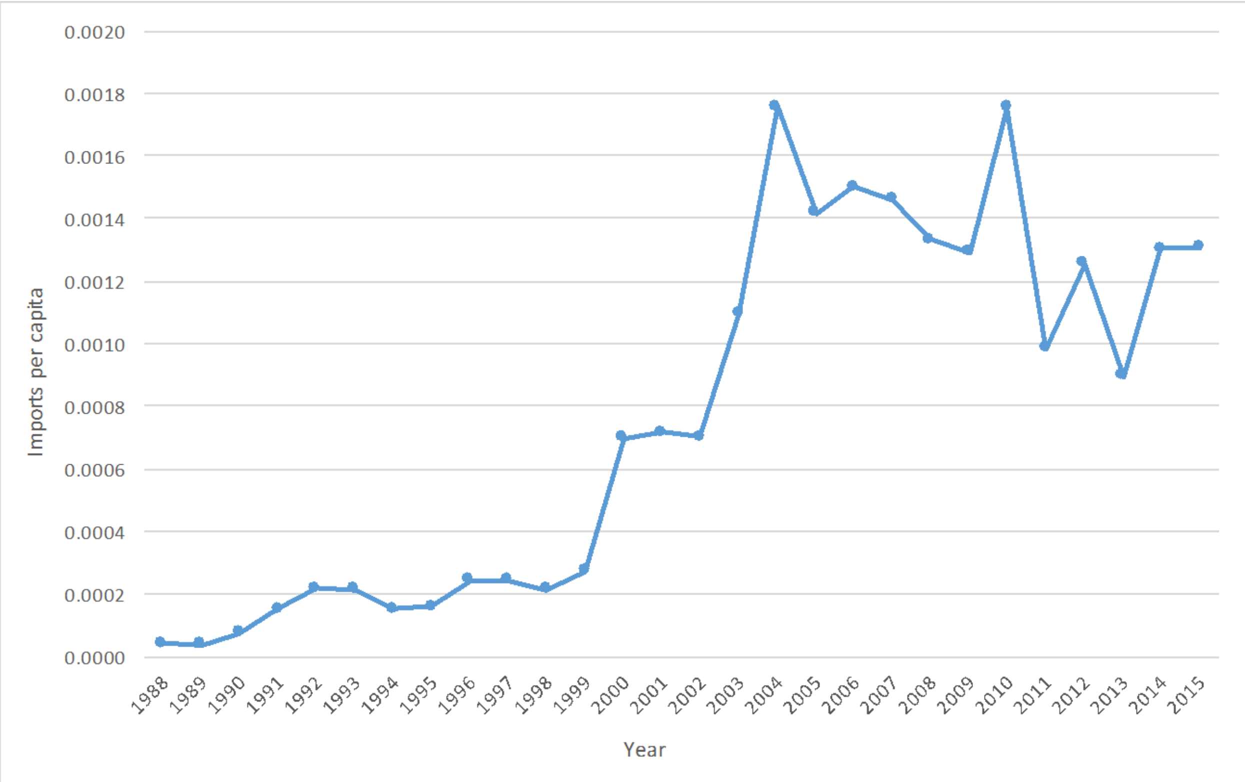
[16] It is therefore recommended the NZ Disability Survey be adapted in future to obtain information regarding the number of users of mobility scooters, electric wheelchairs or other similar devices.

though, it seems the rate of disability is higher in New Zealand than in Australia. A conservative estimate is therefore to apply the Australian proportion of 1.3% of the population using a mobility scooter; ie 60,970 people in 2016 based on the June 2016 estimated resident population.

Figure 4.7 shows the number of mobility scooters (code 8713.90.00 in the harmonised trade category system) per capita imported into New Zealand since 1988. It can be seen a steep jump occurred between 1999 and 2003; it is assumed that during this period the technology improved and public awareness of the devices increased. After 2003, import rates have fluctuated around the level of 0.0014 devices per person per year (roughly a total number of 6,000 devices per year). This means New Zealand is significantly different from the UK, where sales of mobility scooters have been steadily increasing at 5–10% per annum (RICA 2014).

Note the entire population has been used as the adjustment factor, not simply the elderly population. RICA (2014) showed that 53% of mobility scooter users in the UK are aged under 65 and the New Zealand disability survey shows 30% of those with a mobility impairment are aged under 65. Therefore, the general population estimates will be used.

Figure 4.7 Mobility scooter imports per capita from 1988 to 2015



4.2.2 New Zealand sales indications from survey

A summary of the full survey is given in chapter 3. With respect to the mobility scooter market, the key point is only four of the 1,356 survey respondents indicated they are involved in manufacturing, importation and/or retail of mobility scooters (Question 68).

Approximate sales figures for the last 12 months and anticipated for the next 12 months are shown in figures 4.8 and 4.9.

Figure 4.8 Mobility scooter sales by general quantity category according to New Zealand retailers

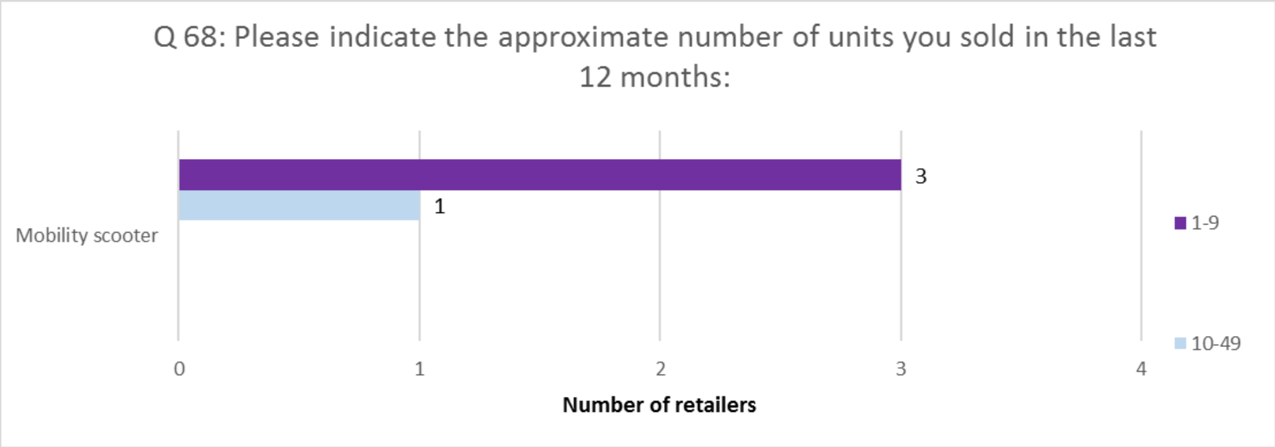
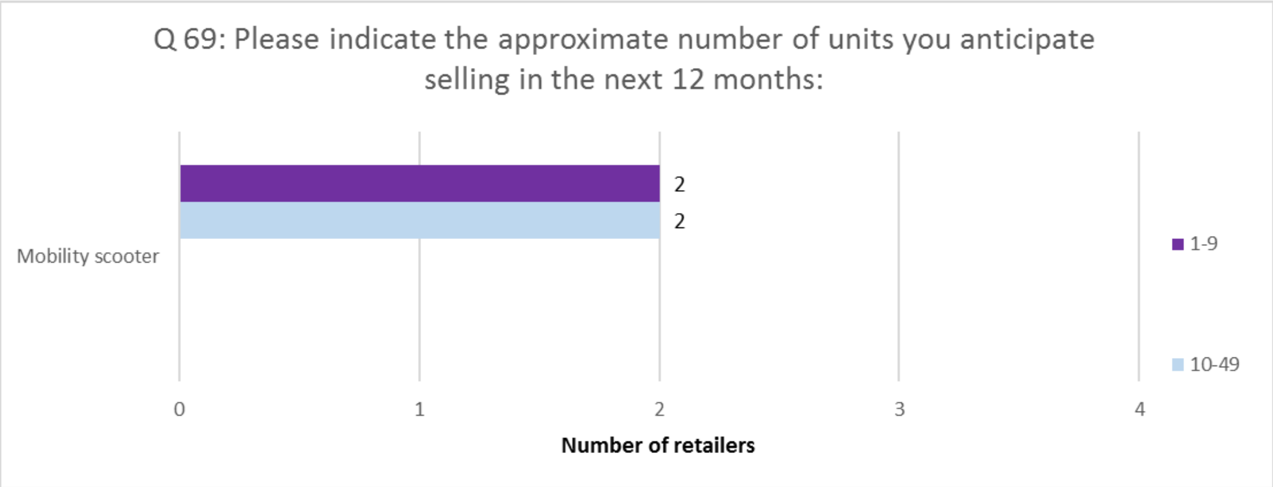


Figure 4.9 Mobility scooter sales forecast by general quantity category according to New Zealand retailers



Since only a small number of mobility scooter retailers participated in the survey, the statistics available regarding use of mobility scooters and sales, and comparisons with other countries, will be more useful in understanding the current market and predicting future growth.

4.2.3 Mobility scooter sales forecasting

Mobility scooters are now well known to consumers, with an established legislative framework supporting their use. It seems reasonable, therefore, to assume there will not be a significant step change in their ownership levels in the near future, as occurred in mobility scooter sales around the year 2000 and as might be expected for many of the other LPVs discussed in the research which are newer technologies.

Factors that might affect the sales rates of mobility scooters are given in table 4.3.

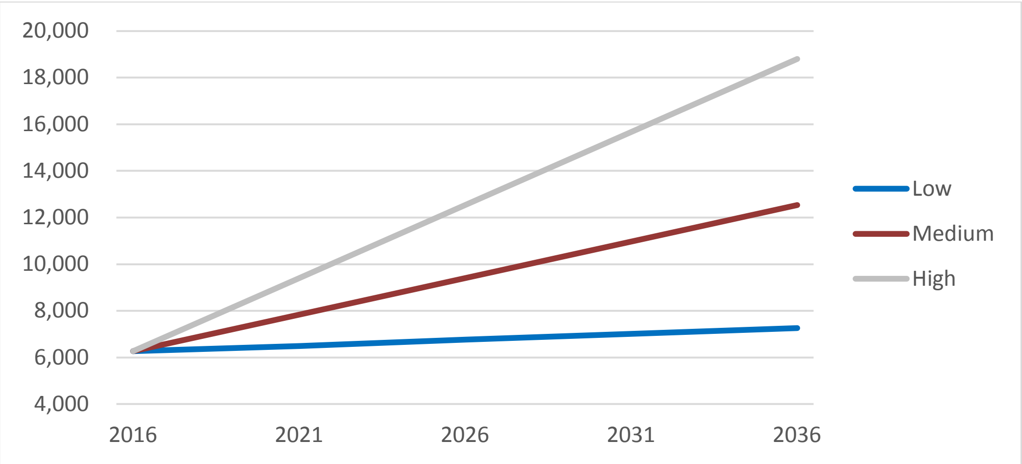
Table 4.3 Factors affecting sales of mobility scooters

Factor	Conditions that could result in growth in mobility scooter sales	Conditions that could result in a decline in mobility scooter sales
Technology	Improvement in battery capacity and/or life, reduction in component weight and enhanced safety features will better suit/ appeal to more people.	Technological improvements in alternative transport modes.
Regulatory environment	Wide range of possibilities permitted will better suit/appeal to more people.	Restrictions on power, speed and use – fewer people use mobility scooters.
Social/political context	Ageing population – while not all mobility scooter users are elderly, older people are more likely to use them than younger people.	More people choosing to live in rest-homes or seek in-home care, rather than live autonomously – less need to travel longer distances independently.
Public transport services	Decreased public transport services – more people have difficulty getting around by themselves and more likely to consider mobility scooters.	Enhanced public transport services including demand responsive approaches may reduce the incentive to consider mobility scooters.
Built environment	Compact land use patterns and/or high quality pathways will improve the feasibility of mobility scooters.	Sprawling land use patterns and/or degraded, disconnected pathways will reduce the feasibility of using mobility scooters.

Figure 4.10 shows three possible growth scenarios for mobility scooters in the coming years:

- low growth – assuming the sales per capita remains constant at the 2015 rate
- medium growth – according to the lower limit (5% per annum) predicted by RICA (2014) for the UK.[17]
- high growth – according to the upper limit (10% per annum) predicted by RICA (2014) for the UK.

Figure 4.10 Possible sales of mobility scooters in next 20 years



Therefore, by 2036, it is expected anywhere between 7,300 and 19,000 mobility scooters will be sold in a year.

[17] Note the UK has an ageing population much like New Zealand.

4.3 Other LPVs

4.3.1 New Zealand sales indications from survey

Only seven survey participants were involved in manufacturing, importing or retailing LPVs other than e-bikes or mobility scooters (Questions 65 and 66). These respondents reported low sales numbers and predicted a small decrease in hoverboard sales, small increase in e-skateboard sales and a significant increase in e-scooter sales in the coming year.

Figure 4.11 Other LPV product mix according to New Zealand retailers

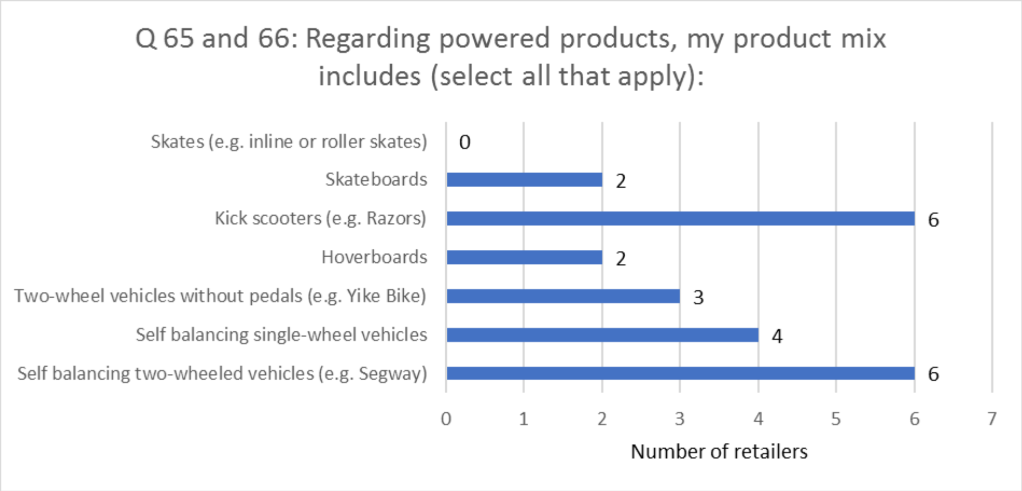


Figure 4.12 Other LPV sales by general quantity category according to New Zealand retailers

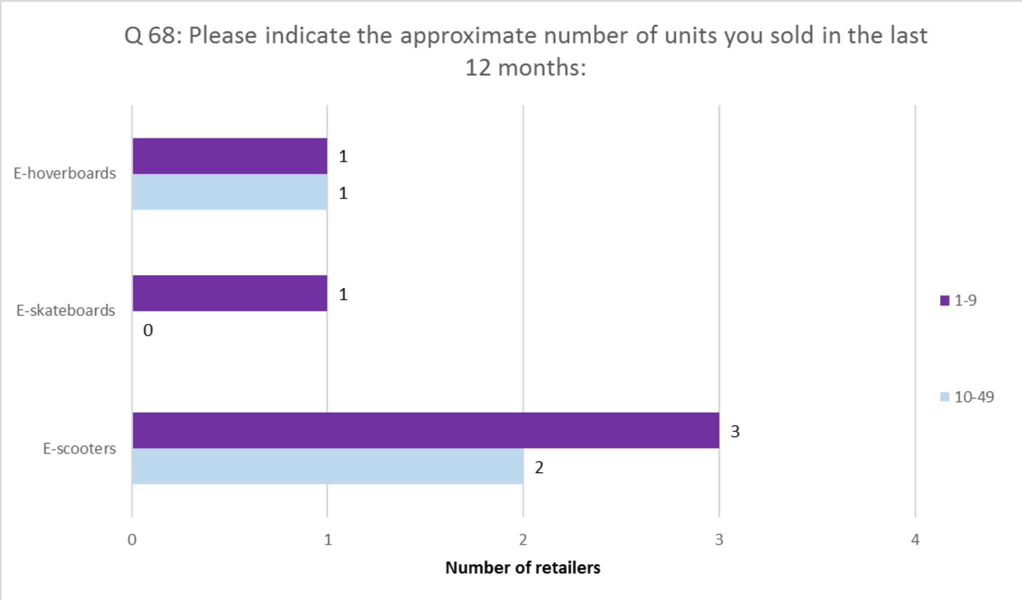
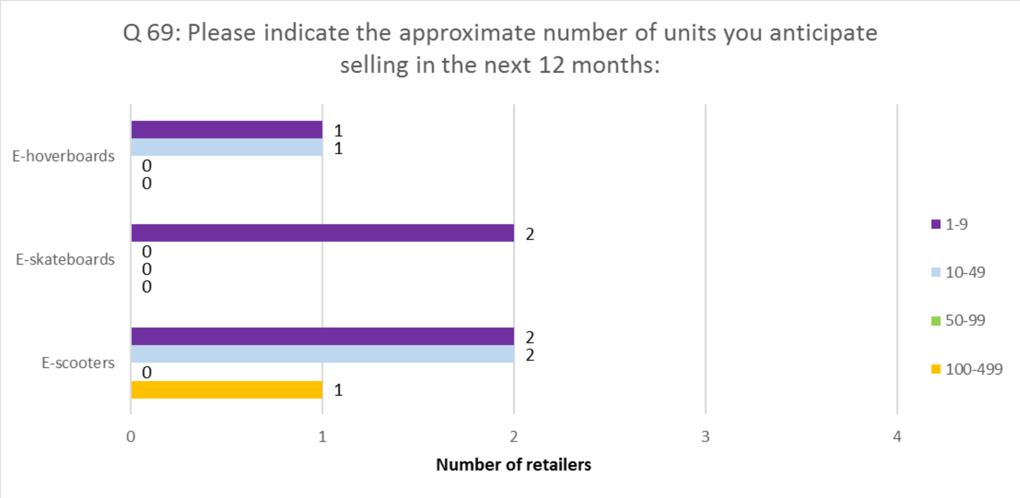


Figure 4.13 Other LPV sales forecast by general quantity category according to New Zealand retailers



4.3.2 Other LPV sales forecasting

Very little information is available to indicate the current levels of ownership/sales of the other LPVs (ie excluding e-bikes and mobility scooters) or estimate future sales. A search for customs statistics or research report data from other countries that have legalised these devices (for example e-kick scooters in Israel, e-skateboards in Australia and California, and Segways in various USA states) has been undertaken, but nothing of use has been identified. Based on the responses from the survey and anecdotal evidence, it is expected these other LPVs will be much less common than e-bikes and mobility scooters, and it is not expected a change in legislation will result in a significant increase (or decrease) in their sales rates. If more data regarding the prevalence and uptake of these devices is required, the following could be considered:

- conducting mode share surveys at specific locations across the country
- instigating counting programmes for specific modes, at specific locations across the country
- requesting general (and separate) categories for bikes, e-bikes, and other LPVs be included in the travel to work question in the New Zealand census.

5 Safety analysis

A key consideration in regulating the characteristics and/or use of e-bikes and other low-powered devices is whether performance characteristics affect road safety. As e-bikes are relatively new and fast evolving, there is relatively little in the way of relevant published research on the topic. China, with a longer history of e-bike use has some more longitudinal data; other places are only just starting to consider the issue. Mobility scooters have seen a relatively high number of deaths and injuries, and thus there are also a reasonable number of studies worldwide. Other low-powered devices are much more limited in what has been investigated to date.

5.1 E-bike safety

The safety effects of e-bikes (particularly relative to ordinary unassisted bikes) are largely influenced by the relative differences in both the bicycles and the riders. A typical e-bike is about 4 to 8 kg heavier, able to accelerate more easily, and travel 3 to 8 km/h faster (refer table 5.1) than its unassisted counterpart, thus potentially increasing the risk of crashes associated with vehicle momentum or speed. As discussed further in chapter 6, many e-bike users are also older or less physically fit than an ordinary bicycle rider, thus potentially increasing their risk of difficulties with bike handling and sensory perception/reaction.

5.1.1 Perceptions and behaviour

Fishman and Cherry (2016) in a review of e-bike literature, noted conflicting views about the perceptions of safety by e-bike owners and users. Some studies cited owners feeling safer riding an e-bike, and even stating they had assisted in avoiding crashes or clearing intersections more quickly. Conversely some users had reservations about the higher speed of e-bikes, especially in mixed-use cycle lanes. In a recent Australian study of e-bike users, one in five elderly riders reported their e-bike had enabled them to avoid a crash due to increased stability or additional speed across intersections (Johnson and Rose 2015a). Participants in this study also reported increased cognition due to reduced tiredness, and better visibility due to the use of a more upright cycling position as additional safety benefits associated with using their e-bike (ibid).

Yao and Wu (2012) surveyed 603 Chinese e-bike riders to investigate e-bike user behaviour in relation to crash history. They found riders who have been involved in at-fault crashes generally have lower safety attitudes and risk perception. This makes them more likely to engage in ‘aberrant’ behaviour, including making errors, impulsive and aggressive actions, and violating traffic rules. In a study of 5,646 Chinese riders, Guo et al (2014)) also found users of e-bikes and e-scooters were significantly more likely to run red lights than riders of conventional bicycles, and young riders were the most likely to run red lights and older riders the least likely.

In a survey of 718 self-identified American bicyclists, McLeod (2015) showed eight types of e-bikes and asked whether these bikes were bicycles. The results showed lower motor speed cut-out tends to make people more likely to see e-bikes as bicycles; the shape of the e-bike matters; and throttle controlled e-bikes are less accepted. The author suggests unless these characteristics are included in national legislation, then communities will regulate their use based on public perceptions. Additional commentary on pedestrian perceptions of safety is found in section 5.5.

5.1.2 Speed

The potential speed of e-bikes is frequently identified as a concern. Dozza et al (2013) suggested:

riding faster increases cyclists' attention demand as interaction with other road users, such as overtaking manoeuvres, becomes more frequent. Further, electrical bicycles are not always clearly distinguishable from traditional ones. As a consequence, it may not be obvious for other road users, (e.g. a driver at an intersection), to estimate their speed (e.g. when deciding to cross the bicycle path)

The incidence of overtaking was studied by Sander and Marker (2015) in a naturalistic study of 52 riders on a 7.5 km route in central Berlin using a pedelec with and without the motor assistance turned on. Riders were classified as 'fast' or 'slow' based upon whether they were above or below the measured average unpowered riding speed of 19.8 km/h. The rate of overtaking other road users (usually, other cyclists) with motor assist increased by 9% and 113% for fast and slow riders, respectively. The number of overtaking manoeuvres over the course is relatively high in Berlin compared with most New Zealand cities – for motor-assisted riders this was up to 160 events on average.

With respect to speed, some of the concern may be more an issue of 'public perception' than actual speed differentials with unassisted cyclists (Roetynck 2010; Schleinitz et al 2016). Table 5.1 presents a summary of studies comparing the speed of e-bikes with unpowered cycles. Statistical tests or grading of the study methods have not been undertaken, so the data should be considered merely indicative. The column headings for 'e-bike' include a number referring to the maximum motor-assisted speed (in km/h) applicable in the country where the study was conducted or as defined by the study author. The studies included:

- Dozza et al (2016) collected data from 12 riders using pedelecs over two weeks in Gothenburg, Sweden. Eleven of the riders had no prior experience with e-bikes. The average speed of these riders was 16.9 km/h, about 3 km/h faster than unassisted riders in a similar earlier study.
- The German Insurance Association (2014) gathered 2,300 hours of data from 90 riders in Chemnitz using GPS and video cameras. The results indicated pedelec and S-pedelec riders average 2.1 km/h and 7.9 km/h faster than unpowered riders, respectively.
- Schleinitz et al (2015) found e-bike speeds are lower on shared paths. Their study of German e-bike users showed while they travelled on average 2.9 km/h faster than conventional cyclists, they maintained the same speed as conventional cyclists when not cycling on cycleways. S-pedelec riders travelled an average of 8.8 km/h faster than conventional cyclists on cycleways.
- Sander and Marker (2015) conducted research in Berlin as previously noted; their speed differential finding reported here is the average speed for the entire 7.5 km course. A potential limitation is that an e-bike with the motor switched off can be quite heavy and sluggish compared with a standard unpowered cycle.
- Sperlich et al (2012) examined eight female cyclists on a 9.5 km course riding an e-bike with and without the assistance activated to examine the biomechanical, cardiorespiratory, metabolic and perceived responses to electrically-assisted cycling. They found a 2.1 km/h difference in speeds with and without electric assistance.
- Parkin and Rotheram (2010) issued GPS devices to 16 volunteer unpowered riders in Leeds, UK. Their finding of 21.6 km/h on the flat is another data point for comparison.
- Vlakveld et al (2014) gathered data from 58 Dutch elderly (65+) riders and middle adult (30–45) riders over a 3.5 km route with simple and complex traffic conditions. They found riders on pedelecs travelled about 2 to 3 km/h faster than on unassisted bikes.

- Langford et al (2015) studied data from bike share users in Knoxville, Tennessee and found that riders using e-bikes with a maximum motor-assisted speed of 20 mph (32 km/h) travel slightly faster than unpowered riders on-road but slightly slower on shared use paths. Both groups exhibit nearly identical safety behaviour and have high rates of violations. However, bike share system users may not be representative of the wider cohort of people riding e-bikes.
- Gojanovic et al (2011) examined 18 sedentary participants travelling an uphill route by walking, biking and e-biking (on both standard and high-powered settings) and found a 6.2 km/h difference in speeds. Only 16 participants completed all four tests. The authors concluded that riding e-bikes can help sedentary people meet physical activity guidelines.
- The lead author of this report used a radar gun with a +/- 1 km/h accuracy to measure the spot speed of 572 morning commuter cyclists at four high-use cycle lane, shared bus-bike lane and shared path locations in Christchurch. The measurements were ‘free speed’, taken of unimpeded riders not within view of a controlled intersection. The average speed of unpowered and e-bike riders was found to be 23.6 and 30 km/h, respectively. The statistical precision of these averages is within 0.3 km/h and 2.0 km/h at the 95% confidence level, respectively. Therefore, it is likely Christchurch commuting e-bike riders travel about 6.4 km/h faster than unpowered riders (although the difference may actually range between 4.1 and 8.7 km/h).

Torres et al (2017) showed the average speed of a group of racing cyclists riding on rural two-laned roads in Spain was 32 km/h on flat sections, and was affected by gradient. As this study was narrowly focused upon rural sports cycling, the data has not been included in table 5.1.

Three studies in China cited by Fishman and Cherry (2016) found e-bike cruising speeds were 40–50% faster than ordinary cycles, even in shared facilities. However, these studies compared scooter style e-bikes with traditional (heavy) unpowered utility bikes; in New Zealand, the typical unpowered bike is sportier and faster than in China. Therefore, the Chinese data has been omitted from table 5.1.

Table 5.1 Comparison of e- bike and unpowered bike average speeds

Mean speed (km/h)					Study details		
Unpowered	**E- bike 25**	**E- bike 32**	**E- bike 45**	**Diff.**	**Study**	**Sample size**	**Method/env.**
-	16.9	-	-	3.3	Dozza et al (2016)	12	Sweden: 50/50 gender split, median age 38, 8 riders had no prior experience with e-bikes; 1,474 km over 86 hours
13.6	-	-	-		Dozza et al (2013)	20	Sweden: 1,549 km over 114 hours
15.3	17.4			2.1	German Insurance Association (2014)	87	Germany: instrumented bikes; over four weeks of observation the average distance travelled was 192.5 km
			23.2	7.9			
16.1	-	-	-	-	Schleinitz et al (2015)	28	Germany: free flow speed of riders on their own bikes; difference between e-bike riders and 28 unpowered riders
	19.0	-	-	2.9		48	
	-	-	24.9	8.8		9	
19.8	22.5			2.7	Sander and Marker (2015)	52	Germany: 45 hours of data from 7.5 km urban route on same e-bike with and without motor turned on

Mean speed (km/h)					Study details		
Unpowered	**E- bike 25**	**E- bike 32**	**E- bike 45**	**Diff.**	**Study**	**Sample size**	**Method/env.**
13.7	15.8			2.1	Sperlich et al (2012)	8	Germany: 8 female participants cycling 9.5 km on a course of varying elevation, with and without electrical assistance.
21.6	-	-	-	-	Parkin and Rotheram (2010)	518	Leeds, UK: GPS speed data of everyday cyclists on their journeys
17.7	19.3			2.6	Vlakveld (2014)	29	Netherlands: middle adult (30-45) complex traffic parts of 3.5 km route
14.9	16.6			1.7		29	Netherlands: elderly adult (65+) complex traffic parts of 3.5 km route
10.5		13.3	-	2.9	Langford et al (2015)	240	Tennessee, USA: e-bike share system user comparison (top row: road, bottom row: path)
12.6		11		-1.6		57	
10.3	16.5			6.2	Gojanovic et al (2011a)	16	Switzerland: uphill route undertaken by sedentary participants in need of active transport options.
23.6		30		6.4	Lieswyn (unpublished)	572	Christchurch, NZ: radar spot speed measurements of commuting cyclists at cycle lane, shared bus/bike lane and shared path locations.

Most of the values presented in table 5.1 are based on research conducted using EU standard e-bikes with a 25 km/h motor cut out. The survey undertaken for this research (chapter 3) suggests most New Zealand e-bikes are not limited to 25 km/h. However, New Zealand urban cyclists in general rider faster than European riders (ViaStrada 2009). In the New Zealand context, the average on-road speed of e-bike riders is probably about 6 km/h faster than unpowered cyclists.

The injury risk for cyclists involved in motor vehicle collisions at various impact speeds can be approximated by considering pedestrian injury risk curves (Cycling Safety Panel 2014). A meta-analysis of published research by Scott and Mackie (2014) yielded the curves for fatality and severe injury risk shown in figures 5.1 and 5.2 respectively. The coloured bands represent the range of data points in the individual studies.

Figure 5.1 Pedestrian fatal injury risk (green line and shaded area, figure 6 in Scott and Mackie 2014)

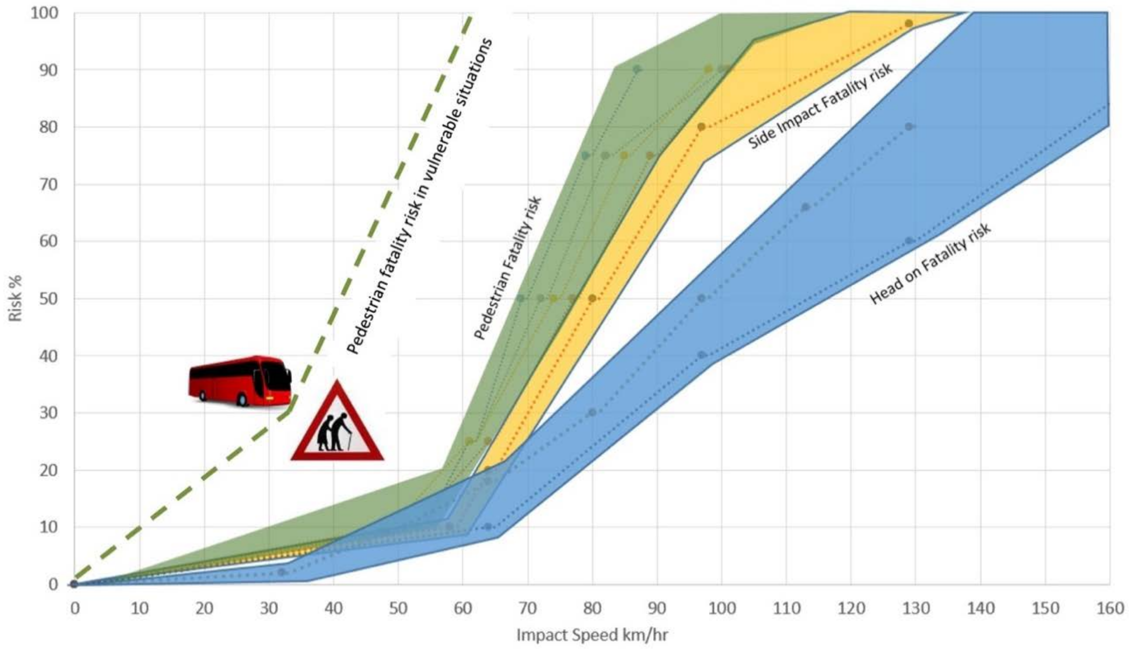
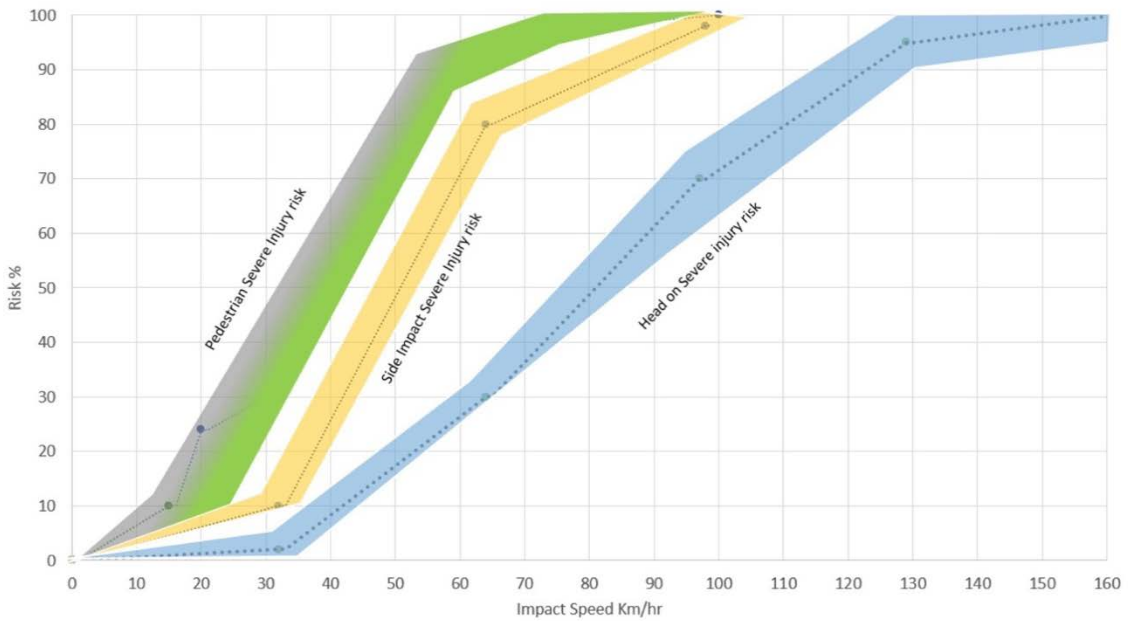


Figure 5.2 Pedestrian severe injury risk (grey/green shaded area, figure 7 in Scott and Mackie 2014)



From these curves, the risk of fatality and severe injury has been estimated (table 5.2). Probability values have been approximated using the midpoint of each coloured band, excluding the heavy vehicle fatality curve.

Table 5.2 Estimated risk of fatality and severe injury at various speed of impact with a motor vehicle

Injury risk category	Probability of occurrence at pedestrian/motor vehicle impact speed						
	15 km/h	20 km/h	25 km/h	30 km/h	35 km/h	40 km/h	45 km/h
Fatal	<5%	<5%	5%	7%	8%	10%	12%
Severe	10%	15%	25%	40%	45%	55%	65%

As discussed in section 9.2.1, the two main options for limiting motor cut out speed are 25 km/h (EU) and 35 km/h (similar to the current typical top speed of ungoverned e-bikes and 32 km/h USA models). Although reliable data comparing the average speeds of unpowered cyclists and e-cyclists is sparse (refer table 5.1), a rough estimate of average speeds under the two regimes would be about 18 km/h and 23 km/h, respectively. A conservative alternative assumption is that all collisions occur at the top motor assisted speed. Based on these scenarios, the difference in fatal and severe injury risk probabilities is shown in table 5.3.

Table 5.3 Risk scenarios for average and top speed of unpowered and e- cyclists

	Probability of occurrence at pedestrian/motor vehicle impact speed					
Injury risk category	Estimated average speed (interpolated)			Top motor assisted speed		
	18 km/h	23 km/h	Difference	25 km/h	35 km/h	Difference
Fatal	<5%	<5%	Negligible	5%	8%	3%
Severe	13%	20%	7%	25%	45%	20%

The main limitation to this estimation method is that the reported crash statistics on which the curves are based probably include a higher proportion of vulnerable persons (children and frail elderly) than cyclists or e-cyclists.

5.1.3 Crash studies

Dozza et al (2016), in a follow-up naturalistic study of e-bike users, found electric bicycles conflicted more often with motorised vehicles than traditional bicycles did. Interestingly, conflicts with other vulnerable road users such as pedestrians were less, possibly suggesting e-bike riders were less inclined to use shared path facilities. The authors suggested different countermeasures may be required, therefore, to address some issues identified for e-bikes, particularly given their higher average speeds. This may be as simple as making e-bikes more distinctive and conspicuous in appearance from their unassisted counterparts (eg requiring continuous operation of lights on e-bikes), so other parties may be more likely to appreciate their potential speed.

The German Insurance Association (2014) in its naturalistic study of bikes and e-bikes found no differences in the number or type of ‘critical incidents’ recorded by each group, despite the speed differences noted. The most frequent type of critical incidents was between bikes travelling along the road and other road users turning or crossing.

Standard bicycles have been found to be involved in fewer crashes with motor vehicles than ‘cycle only’ crashes, and the same may be the case for e-bikes. Papoutsi et al (2014) investigated a number of e-bike injuries to adult riders in Switzerland, where the number of e-bikes sold grew from 1,700 in 2005 to 52,000 in 2012, while other bike sales remained fairly static. Although admittedly a small sample (23), it was notable that 14 (61%) involved some form of unknown self-accident, while another five (22%) got caught on a tram rail, and only four (17%) collided with a motor vehicle. The authors also noted a much lower proportion of head and neck injuries recorded (27% of all recorded injuries), compared with similar studies in China (46% recorded), and suggested the different helmet wearing rates (75% in Switzerland vs 9% in China) were a key factor.

5.1.4 Lighting

A positive is that e-bikes often have continuous running lights, making users more visible in traffic. This is, however, not necessarily a benefit exclusive to e-bikes, as day-time running lights for bikes have been on the market since 2010 (Fahrradtest 2010).

5.1.5 Mechanical failure

An unintended consequence of the previous 200 W Australian regulation was that one in five crashes was due to a mechanical failure, often related to self-assembly[18]. Self-assembly crashes involved bikes that were retrofitted with electric bike kits and electric bikes purchased online that required some assembly. It is anticipated the increasing availability of higher-quality models in store will reduce the frequency of this crash type (Johnson and Rose 2014). On the other hand, if many New Zealanders consider the regulations to be too restrictive, they may purchase conversion kits, which increases the possibility of crashes due to mechanical failure, either due to poor assembly or use of a bicycle that is not suited to electric power.

In June 2016, the manufacturers of Brompton unpowered bicycles issued a notice to inform that Brompton bicycles would not be sold to any dealers or distributors known to retro-fit electric drive kits to Brompton bicycles. Brompton stated such kits might compromise the integrity of the original bicycle, to the point it may no longer meet European and UK standards. Furthermore, Brompton was concerned the end-user would assume such bicycles were endorsed by Brompton and may not understand, under EU law, the company performing the retro-fit is considered the 'manufacturer' and any such additions invalidate the original Brompton warranty. Finally, Brompton has indicated they will release a range of electric bicycles in 2017 (Loftus 2016). This latter point suggests Brompton's reasons for issuing such a notice may have included the desire to curb marketplace competition.

5.2 Mobility device safety

Early mobility scooters first appeared in the 1950s and 60s (often termed 'power chairs' or similar), although designs similar to what is prevalent today have only been around for the past three decades. Recent developments have seen enclosed mobility scooters introduced into New Zealand with top speeds of 30 km/h (Maxwell 2015). Fundamentally, however, the safety features of mobility scooters have changed very little in recent times, and concerted investigation of mobility scooter crashes has only been considered seriously in the past two decades.

In the last five years in New Zealand, 12 people have died nationwide and more than 100 have been injured (19 seriously) in crashes involving mobility scooters (NZ Transport Agency 2016b). They are thus the most visible low-powered device in terms of safety issues. Crash data recording issues are discussed further in section 5.4.

Gibson et al (2011) investigated mobility scooter injuries in Australia. Over two years between 2006 and 2008 there were 442 injury hospitalisations related to falls from mobility scooters around Australia and 62 deaths in the 10 years between 2000 and 2010 (mostly as a result of collisions with motor vehicles). Although the number of injuries presented at Australian emergency departments appears to be increasing, under-estimation of the true figure is also thought to occur due to inconsistent coding of hospital data.

[18] Production 200 W e-bikes are unavailable so consumers assembled their own from kits

Jancey et al (2013) reviewed the safety of motorised mobility scooters. They noted the high prevalence of older users of mobility scooters contributed to the number and nature of related injuries, as they were more likely to suffer from poor eyesight and hearing, slower cognitive processing, reduced strength and flexibility, and loss of bone mass. All these factors affect the ability of the older user to safely judge the speed and distance of approaching traffic, and to control their scooter appropriately.

Jancey et al (2013) also note the dangers typically inherent in the street environment for mobility scooter users. These include narrow, uneven or rough footpaths, poorly angled crossing points, busy traffic and the presence of pedestrians and other path users. Initial training in the use of their mobility scooter is also often very limited and, although there are a number of targeted mobility scooter training programmes for seniors, very little has been formally evaluated.

A study of mobility scooter users in the UK (RICA 2014) found 21% had experienced crashes or incidents on their scooter, mostly on footpaths, and generally resulting in only minor consequences.

Overall, it appears a relatively high proportion of mobility scooter users (20–30% from various studies) are likely to be involved in an incident with their device at some stage, be it their scooter toppling over, a trip or fall from the scooter, or a collision with a stationary or moving object (Newman 2015).

The long-term health effects of relying on mobility scooters for transport has also been called into question by some researchers. Thoreau (2015a), for example, notes that while mobility scooters may help to improve the quality of life of many users, it also appears the sedentary nature of their usage results in a decline of physical functionality and therefore reduced capabilities. This is particularly significant given that typically 65–75% of people have taken up using a mobility scooter without any consultation with or recommendation by a medical professional.

Mobility scooters have also resulted in injuries to other pedestrians; the weight and speed of most scooters can lead to quite severe injuries, particularly to older people. No fatalities to pedestrians have been identified in New Zealand as a result of a collision with a mobility scooter, but some injury crashes have been reported. It is unclear, though, whether such crashes would routinely be recorded in the Crash Analysis System (CAS), as further discussed in section 5.4.

5.3 Other low-powered device safety

Few serious injuries or deaths using low-powered devices appear to have occurred in New Zealand to date, partly due to the relative rarity of these devices here. Hence, any notable cases have often been reported in the media, such as the deaths of motorised skateboard riders in 2008 and 2010 (Dominion Post 2008; Ensor and Howie 2010), which led to a call by the Coroner for mandatory helmet use.

5.3.1 E-scooter safety

Griffin et al (2008) compared the relative severity of injuries among children aged 2 to 12 in the USA using powered and non-powered scooters. From an analysis of approximately 200,000 injuries related to scooters, powered scooter-related injuries were over three times as likely to be ‘severe’ (eg requiring hospitalisation) than non-powered scooter injuries. Based on a review of e-kick scooters available online and the researchers’ own experience, it is noted the typical powered kick scooter in the USA is more of a toy than the adult foldable e-kick scooters used to address public transport first leg/last leg issues in Asian countries.

5.3.2 Self-balancing device safety

The Australian Capital Territories (ACT) Government (2016a) discussed the potential safety issues relating to Segways and similar personal transportation devices. At present, Segways have an exemption allowing their use for commercial operations in parts of the ACT; otherwise they would be considered a motorcycle-type vehicle (and effectively not be allowed due to not meeting all the requirements for such a vehicle). The Queensland Government defines Segways as 'pedestrians', while the Northern Territories Government considers them 'bicycles' but preclude riding on-road. In both cases, there is a minimum rider age of 16 years old, or 12 years if supervised by an adult rider. The discussion document notes their use in the ACT since 2011 has been relatively safe, as has been the case in other Australian states. The current Segway commercial operator in ACT had submitted 18 incident reports in about three years, of which only three could be considered more serious.

Miller et al (2008) investigated the behaviour of both novice and experienced Segway users in the vicinity of pedestrians. Using a controlled footpath layout with various obstacles (barriers and pedestrians), they found novice riders (with no prior experience before the day of survey) rode on average about 3–4 km/h slower than experienced riders, but there was no significant difference between average clearances to obstacles. All riders also slowed down only slightly (<2 km/h on average) when encountering obstacles or a narrower pathway; however, it is comforting that the average clearance distance when passing a pedestrian was about 0.8–1.0 m at a speed of about 8 km/h.

Xu et al (2016) kinematically modelled collisions between motor vehicles and vulnerable road user types (e-unicycles, Segways, pedestrians and cyclists). The modelling generally found the self-balancing devices resulted in lower head injury severities than the equivalent pedestrian or bicycle collisions. Pratt et al (2016, p11) concisely summarise Xu's research: 'they identified rider height as a key factor in injury severity, placing the rider at particular risk of head injuries. Figure 5.3 shows the expected repercussions of a collision with a vehicle at 10 m/s (36 km/h) with a pedestrian, Segway rider, unicycle rider and cyclist. They also found of the different groups tested, pedestrians were more likely to sustain head injuries from striking the engine bonnet (and thus receive higher levels of trauma), whereas the other devices were more likely to strike their head on the windshield due to their higher centres of gravity. Figure 5.4 shows that pedestrians also travel further when struck at any speed compared with a Segway or motorised unicycle'.

Figure 5.3 Pedestrian, Segway, e- unicycle and cycle side impact crash (figure 4 in Xu et al 2016)

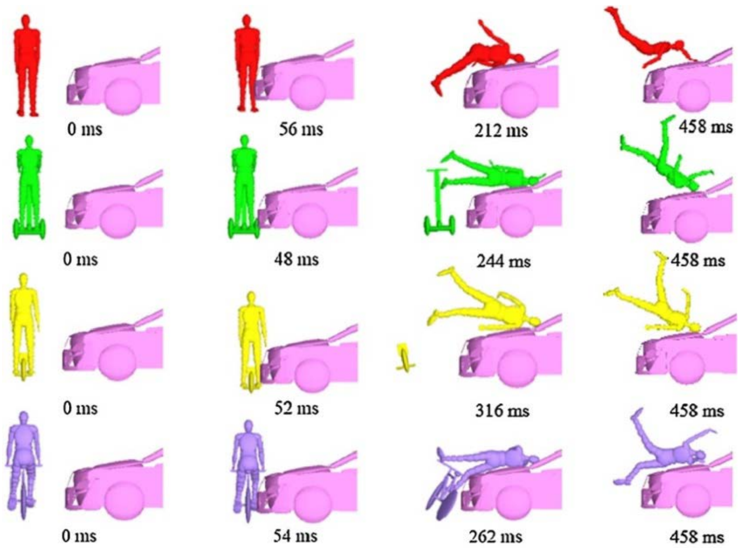
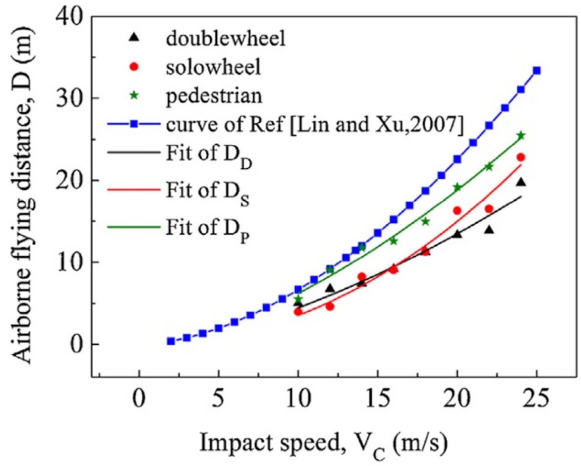


Figure 5.4 The relation of impact speed and vulnerable road user airborne flying distance for side impact cases (figure 5 in Xu et al 2016)



5.3.3 Electrical safety

Another safety issue that has come to the fore especially with hoverboards is the problem of batteries overheating and igniting (Consumer Product Safety Commission (CPSC) 2016). The problem has typically been traced back to either poor battery manufacturing standards or the use of battery chargers that are not fully compatible with the device being used. Section 8.2 discusses this issue in depth.

5.4 New Zealand crash data

CAS was interrogated to assess the scale of the crash problem with e-bikes and other low-powered devices. As well as undertaking queries in the complete CAS database, interrogation of the CAS fatal crashes database was also undertaken, as these could often be more easily linked with related media reports. In CAS there are a number of road user and vehicle type codes that may be applicable to this study:

- S = bicycle. This may include both ordinary pedal cycles and e-bikes; no distinction is provided in the coding. For example, a 2015 collision between a motor vehicle and an e-bike (Galuszka 2016) is simply recorded in CAS as a cycle crash. A 2014 fatality involving a petrol-powered bicycle (technically a moped) was also recorded using this code.
- P = moped/power-cycle. It is possible some e-bikes, especially high powered ones, could be coded as a moped. The only fatality in CAS coded as 'P' (in 2012) was actually an unregistered farm motorbike.
- K = skateboard. CAS does not identify whether the skateboard involved was powered or unpowered. It is also not clear whether this category would include new powered devices like 'hoverboards', and some crashes involving kick scooters have also been coded here. Two known fatalities involving powered skateboards (in 2008 and 2010) are not recorded in CAS, presumably because they did not involve a motor vehicle.
- H = wheeled pedestrian. Typically, this category will include mobility scooters, wheelchairs, Segways and kick-scooters (whether they are powered or not). At least one child cyclist fatality (in 2016) was also recorded using this code, presumably deeming the child's cycle to be a 'small-wheeled recreational device'.

- E = pedestrian. Although normally this category is only used for walking/running pedestrians, at least one fatality with this code was identified as travelling on a mobility scooter (in 2014).
- O = other. This category can include tractors, construction vehicles (eg diggers), motorised go-karts, and quad bikes amongst others; even hovercrafts. However, there has been at least one mobility scooter fatality recorded using this code (in 2008).

A significant drawback with the existing crash reporting system is there is no easy way to differentiate a powered device/vehicle from an unpowered one. A very useful improvement for future monitoring would be the addition of a code to record whether relevant wheeled devices (cycle, skateboard, scooter, wheelchair, etc) were powered devices. This could be either a separate CAS field or a new factor code (the latter may be easier to implement retrospectively).

The existing 'wheeled pedestrian' category is rather broad and it is not easy to distinguish between the different types of users that fall under this category without inspection of the detailed crash records. The typical crash mechanisms involved with (say) a mobility scooter are quite different to those from a kick scooter or child's bike. Self-balancing devices such as Segways and Airwheels would also seem to be a different group again. It may be appropriate to consider creating additional categories (or reassigning existing ones) to aid with monitoring, eg kick scooters (powered or otherwise) may be better off being grouped with skateboards, giving the similarities in their operations. Alternatively, additional factor codes could be used to identify the specific type of device involved.

Another challenge is, generally, crashes not involving a motor vehicle are less likely to be reported to Police, and therefore are not recorded in CAS (eg motorised skateboarder losing control and falling off). Until recently this was also a particular issue for cycle crashes, although current practice seems to be capturing more cycle-only crashes. Given e-bike crashes may be more likely to not involve a motor vehicle (Papoutsi et al 2014), this practice becomes even more important. A similar approach would be desirable for recording (at least serious and fatal) crashes involving other wheeled devices, even where the crash does not involve a motor vehicle.

CAS factor codes are another possible way to identify possible crashes related to low-powered devices. At present, only two factor codes have been identified that may indicate low-powered devices: code 204 'driving or riding in pedestrian space', and code 705 'wheeled pedestrian inconsiderate/dangerous on footpath'. Code 204 is commonly used when a motor vehicle or cycle illegally drives on a footpath, but could possibly highlight when other powered devices have been using a footpath too (especially if their legal status is unclear). Code 705 could identify users of higher-speed devices behaving inappropriately, although it is acknowledged that someone on an unpowered device could also behave poorly. From 2011 to 2015, only one crash reported code 204 for a non-motor vehicle (a mobility scooter), while only 16 crashes reported code 705 attributed to a 'wheeled pedestrian' or "skateboard" (including six mobility scooters and one Segway). This suggests either there is not a big crash problem with these low-powered devices or these codes are not being sufficiently used to record suitable cases.

Hospital data (from the NZ Injury Query System) or injury claims data (from the Accident Compensation Corporation ((ACC)) Injury Statistics database) is not considered to be easily available at the level of disaggregation required to assess the safety of e-bikes and low-power vehicles separate from equivalent vehicles propelled by human power alone. Online ACC data, for example, can easily report about 12,000–13,000 new claims are received each year for scooter and skateboard-related injuries. The research team is not aware whether the data on how many involved motorised devices is recorded.

As a result of the above-mentioned problems, it is not easy to get a clear idea of the scale of injuries involving e-bikes and other low-powered devices in New Zealand. CAS typically records an average of about 800 pedal cycle, 20–25 skateboard, and 35–40 wheeled pedestrian injury crashes a year, but it is not at all clear what proportion might involve vehicles and devices relevant to this study.

With fatality data, more certainty can be determined, due to the availability of corresponding media reporting. Mobility scooters in particular have been involved with a number of fatalities (at least 20 in 2004–15). Meanwhile, two fatalities since 2008 have involved motorised skateboards, while there is no record of any in the past decade involving either motorised scooters, Segway scooters, or legal e-bikes (there have been fatalities involving illegally modified powered cycles).

Selective inspection of the CAS data also suggests some relevant crashes may end up being coded under non-standard categories identified above. The introduction of additional categories or factor codes, together with clearer guidance to CAS staff on how to code different vehicles and devices, would help to provide some consistency in monitoring the safety situation in New Zealand in the future.

5.5 Impacts on the perceived safety of pedestrians

The survey and stakeholder interviews conducted for this research suggest that some pedestrians perceive these devices to be a threat to their safety. Increased speed was the main cause of concern, and the silence of electric motors was also noted by some people who were concerned about being caught unawares and frightened by devices approaching from behind.

It is important to understand the difference between *perceived* safety, ie the subjective level of comfort people feel based on their interpretation of the situation, and *actual* safety, ie the objective extent to which conflict occurs; these two measures may not necessarily align.

From the literature reviewed in this chapter, it is not clear that an increase in e-bike use will result in a decrease in pedestrian safety; in fact, the opposite may even be true. Dozza et al (2016) found electric bicycles conflicted less often than traditional bicycles with other vulnerable road users such as pedestrians, possibly suggesting that e-bike riders were less inclined to used shared path facilities. Jacobsen et al (2015) suggest that e-bike use could actually improve the safety for pedestrians, if this results in a reduction in motor vehicle volumes.

Of all the devices considered, mobility scooters are most easily identifiable within the current CAS coding convention and therefore this is the only category with useful crash data. Pedestrians have been injured by crashes with mobility scooters, but no fatalities have occurred.

In terms of other LPVs, the investigation by Miller et al (2008) of both novice and experienced Segway user behaviour in the vicinity of pedestrians found the average clearance distance when passing a pedestrian was about 0.8–1.0 m at a speed of about 8 km/h. Although the study conditions were simulated on a test track, the speed differential and clearance would probably be found comfortable for most people. Xu et al (2016) modelled collisions between motor vehicles and people on self-balancing devices, pedestrians and cyclists. The modelling generally found that the devices resulted in lower head injury severities than the equivalent pedestrian and bicycle collisions. While self-balancing devices may appear to be less safe than walking or cycling, their modelling indicates otherwise.

Thus, based on the literature review and crash data, it is reasonable to expect that an increase in mobility scooter use will result in an increase in injuries to pedestrians, but this is not necessarily the case for e-bikes and other LPVs.

Peoples' perceptions of safety may be based on actual experience, but, in lieu of this, people rely on extrapolations and many jump to unfounded conclusions. At this point in time, most people are familiar with mobility scooters and many are familiar with e-bikes, but very few have actual experience of other devices such as e-unicycles and Segways. The workshops conducted for this research introduced a number of people to new LPVs they had never previously encountered. In many cases, first-hand experience with a device improved participants' perceptions, as they were more aware of the device's capabilities. For example, most people did not know that all self-balancing devices have the capability of travelling at walking pace (without wobbling as a bicycle would), which makes them more conducive to shared path use. This is a good example of how education/information can be used to improve people's perceived safety, and accord it more with the reality of actual safety.

Regardless, it is understandable that people on a footpath or shared path feel uncomfortable encountering a faster device, especially when the device approaches from behind. The researchers acknowledge this is a current concern for pedestrians with mobility or vision impairments encountering fast-moving bicycles or small-wheeled devices on shared paths. In the vast majority of cases, such encounters will not result in an actual crash, as the cyclists and LPV users are in control of their trajectory.

Thus, where education/information is not sufficient to improve perceived safety, regulation may be required to limit the devices, limit the environment and/or limit user behaviour. The approach may be to address pedestrian comfort levels, while giving LPV users credibility and acknowledging they have no desire to crash into someone else.

6 User limitations

6.1 Overview

The relative safety of powered and unpowered devices has already been discussed in chapter 5. The premise of the assessment in this section is that, given the safety implications of LPVs, it may be necessary to restrict use to certain users (be that by age, physical ability, or skills assessment).

Anyone can legally ride an unpowered bike (either on the road or on paths designated for cycling) or walk or use an unpowered small-wheeled device on a footpath, but to obtain a licence to drive a motor vehicle one must be at least 16 years old, medically fit, and pass theoretical and practical tests.

Given potential speed and/or mass, it may be necessary to distinguish other LPVs from other types of vehicles or devices. Again, currently no licence or other pre-requisite is required to operate devices such as mobility scooters or Segways, although training is often recommended for new users. While self-balancing devices are intended to prevent users from falling off them, it is still quite possible to do so and suffer injuries, as well as the potential to hit and injure others.

The age of a user is of particular importance in determining their aptitude to operate certain vehicles/ devices. Cycling can be viewed as a skill consisting of several different components, including motor elements such as pedalling, balancing, steering and braking, and cognitive elements such as concentration, attention, judgment, planning and decision making (Briem et al 2004). Operating a mobility scooter arguably requires the same tasks, apart from pedalling and balancing, to the same degree as riding a bicycle.

Kovácsová et al (2016) noted safety concerns for older e-bike riders as they have less accurate sensory abilities, slower average reaction times and declining physical strength. The importance of age is recognised in the driver licensing system, which includes a threshold age for eligibility and also more stringent testing for drivers above the age of 75, to ensure they are still capable of driving a motor vehicle safely. It has been predicted that e-bikes are likely to attract a large proportion of younger and older users, thus it is necessary to understand the effects of age on their ability to do so. Note mobility scooter users are not necessarily elderly – a study from the UK (RICA 2014) found 53% of mobility scooter users are under 65 years old; these people are likely to possess the necessary cognitive faculties to drive, but choose to use a mobility device in some situations. It might be argued mobility scooter users would be better off using an e-bike from a health benefits perspective. However, Thoreau (2015a) found most mobility scooter users would have either been housebound or in a wheelchair if not for the scooter, so at least in the New Zealand context where cycling is not as normalised as it is in Northern Europe, there may be few candidates for a switch to e-bikes.

E-bikes are promoted as 'enabling' because they can be used by people who are physically unable to ride an unpowered bike (and, in some cases people who cannot drive a motor vehicle can ride an e-bike). While e-bikes may overcome some barriers, it may be necessary to discern whether these 'enabled' users do in fact possess all the faculties required to ride without endangering themselves or other road/path users. For example, an elderly person who cannot ride an unpowered bike due to arthritis might find this is no longer a problem with an e-bike, but this does not address other issues such as their limited vision and slowed reaction times. Similarly, an elderly person who chooses to use a mobility scooter rather than drive may also have difficulty judging more difficult tasks such as crossing roads.

Much of this research focuses on e-bikes, rather than other LPVs, because of their prevalence and characteristics such as speed and size. There is already a solid framework regarding the use of mobility scooters, through the specifications in the Land Transport Act 1998 and the more user-friendly information provided by the Transport Agency.

6.2 Safety of younger users

While it is acknowledged the human brain does not reach maturity until adulthood (Simpson 2008), there is little information available about the level of cognitive ability required to operate an e-bike (or other LPVs) and the age at which this level is attained. Some notions can be inferred from studies that focused on children riding unpowered bikes.

The Organisation for Economic Cooperation and Development (OECD 2004, p64).[19] states:

> *Children's acquired intellectual skills and knowledge in terms of understanding movement in space, time and distance relationships, and physics and the law of mechanics continue developing through adolescence. Until they reach an adult level of understanding, children do not understand and react to complex traffic situations in the same way as adults.*

Briem et al (2004) studied groups of children aged 8, 10 and 12 years riding conventional bicycles. They found cycling speed increased with age, as did the number of mistakes made, but increasing the task load, by using music as a distractor, did not increase the number of mistakes made. They concluded, in addition to motor and perceptual capabilities, motivation factors also affect a cyclist's performance. The authors discuss possible risk-taking behaviour:

> *…diminished apprehension with regard to the consequences of one's actions, as well as changes in attitudes toward the social desirability of daring and spectacular actions, may lead to increased risk taking. Consequently, older children do not always perform better, even though their physical and cognitive capacity is superior to that of younger children.* (p376)

Bromell (2016) studied 293 children between the ages of 8 and 12 from four primary schools in the Otago area. The study included practical assessment of basic cycling skills (table 6.1), helmet fit and bicycle condition.

Table 6.1 Cycling practical assessment performance by age (source: Bromell 2016, table 1)

Age	8	9	10	11	12
Total no.	43	49	43	44	45
No. completing assessment safely	32	33	33	40	42
%	74.4%	67.3%	76.7%	90.9%	93.3%

The author noted children at all four schools received cycle safety and riding lessons, but it was not clear whether this applied to all the age groups surveyed.

The author concluded 'there is no specific age at which it can be said that a young child can be allowed to ride unaccompanied on public roads' and recommended cycle skills courses, while cautioning parents to not rely on these courses as sole proof of their child's competence. Nevertheless, the Transport Agency's

[19] (OECD) an international organisation which promotes the economic and social well-being of people.

official *New Zealand code for cyclists* states 'From age 11 onward, children may be able to start riding in traffic unsupervised' (NZ Transport Agency 2009, p63).

Twisk et al (2014) reviewed a number of road safety education programmes and supporting literature and concluded:

> *Lack of control especially may play a stronger role among adolescents than among adults, because of adolescents' greater impulsiveness (e.g., Gerrard et al., 2008; Gibbons et al.,2009; Gibbons et al., 2002; Reyna and Farley, 2006), their still-developing cognitive and executive skills (e.g., Blakemore et al.,2007; Blakemore and Choudhury, 2006), and their inexperience as road users (Twisk and Stacey, 2007; Vlakveld, 2011). In addition, the influence of the social context may differ between adolescents and adults, because of peer pressure that leads to adolescents taking greater risks in the presence of peers than when being on their own (e.g., Brown, 2004; Gardner and Steinberg, 2005; Sumter et al.,2009).* (p56)

While the studies mentioned above focused on unpowered bikes, the findings suggest teenagers are likely to take risks when using e-bikes or other LPVs. Unpowered cycles, scooters and skateboards are already popular with many younger people, so it would not be surprising to see the appeal of a powered version to the same audience. Given the safety information presented in chapter 5, the frequency and consequences of resulting crashes are likely to be greater for e-bikes than for unpowered bikes. Rose (2012), based on Njå and Nesvåg (2007), notes there can be a particular problem for higher-powered e-bikes, which are more similar to mopeds in terms of speed and performance, because mopeds have a poor safety record when ridden by inexperienced, adolescent riders. On the other hand, since the cost of S-pedelecs with a 45 km/h speed capability may well be outside the budget of most young people, the user demographics may reduce this safety disparity. This could change in time as the technology becomes less expensive, but for now the high-powered e-bikes available to adolescents that could result in this safety problem are more likely to be e-bikes that have been modified (potentially illegally) or kit e-bikes.

While an e-bike with a motor cut-out speed of 25 km/h might not help an adult ride much faster than normal, it could help a young child to ride much faster than on an unpowered child's bike.

6.3 Safety of older users

Section 5.2 covers issues with the safety of mobility scooters, although they are not necessarily operated by older users. In general, older mobility scooter users tend to be injured just getting on and off the vehicle, or in tipping over incidents where they fall from seat height and cannot escape being pinned to the ground by the weight of the scooter (Jancey et al 2013).

Some researchers have considered the opportunities and risks of older people riding e-bikes, but it remains 'unknown how an age-related decline in motor, sensory, and cognitive functioning is associated with rider performance' (Kovácsová et al 2016). What is known is that as speed increases, the size of the effective visual field decreases (Rogé et al 2004). This relationship suggests while eyesight degradation may mean a person is no longer fit to drive a motor vehicle, they may still be capable of operating a low speed vehicle, such as a mobility scooter, for which their visual field may be sufficient. Kovácsová et al (2016) compared middle-aged persons with older persons, riding unpowered bikes and e-bikes and assessed their cycling safety, particularly with respect to control of the bike as measured by steering and leaning. They found cyclists aged 65 and over maintained balance by additional steer and roll motions when cycling at low speeds and looking over the shoulder, but roll angles were lower for the e-bike than the unpowered bike. This suggests e-bikes help older people maintain a more normal, and therefore safer, riding style. Conversely, the researchers found e-bikes assisted older cyclists in particular to accelerate quickly to cruising speed and that participants' chosen cruising speeds were higher on the e-bike than on the unpowered bike. Increasing speed can increase the risk and consequences of crashes, and therefore this suggests e-bikes decrease the cycling safety.

Vlakveld et al (2014) studied the speed choice and mental workload of elderly people cycling in simple and complex traffic situations, comparing unpowered bikes and e-bikes. They found the 'mental workload of the elderly cyclists was somewhat higher than the mental workload of the cyclists in middle adulthood' and this, coupled with the higher speeds of e-bikes, might increase the crash risk of elderly cyclists when they rode on an e-bike. However, Vlakveld et al (2014) also believe if uptake of e-bike use amongst older cyclists continues, this trend has the potential to increase the safety of riders over all because older e-bike users tend to travel at the same speed as middle-aged conventional cyclists, thus 'homogenising' cycle speeds. They also cite the improved balance available at higher speeds as another advantage of e-bikes for older riders.

Whereas Cantin et al (2009) found elderly drivers had a disproportionately higher mental workload in complex traffic situations, the elderly cyclists Vlakveld et al (2014) studied did not have a disproportionate increase in mental workload in complex situations compared with simple situations. They were not certain why this occurred, but suggested it was possible the driving task was cognitively more demanding than the cycling task. Therefore, there may be cases of an elderly person who lacks the cognitive ability to drive a motor vehicle but can still safely ride an e-bike (or mobility scooter).

Vlakveld et al (2014) noted from other studies, it was likely the casualty risk for older people (above the age of 75) using e-bikes was higher compared with younger people[20]. They suggested three main reasons for this: 1) increased weight of e-bikes; 2) reduced physical condition of elderly riders, able to ride an e-bike but not a conventional bike; 3) increased speed. This is of concern given the availability of e-bikes is likely to encourage uptake by older users in particular, and these users are more frail and susceptible to injury. However, injury rates were the same for cyclists and e-cyclists until the age of 75. This is an issue for elderly users of all devices – generally the elderly have higher fragility rates than their younger counterparts; thus they are more likely to suffer serious or life-threatening injuries from the same type of collision or fall.

While there may be higher risks involved for older people, they also arguably have a greater potential for improving health by e-biking. MacArthur et al (2014), based on a survey of e-bike users in North America, concluded 'e-bikes allow people who would otherwise not be able to bike because of physical limitations or proximity to locations, the ability to overcome these challenges to bike with electric assist'. Johnson and Rose (2015b) interviewed cyclists who had switched to using an e-bike and found 16.3% did so due to physical limitation including injury, illness or disability whereas 11.6% cited age as the main reason.

6.4 Conclusions regarding users of LPVs

As noted previously, the research on e-bike safety is currently limited, and at times inconsistent; however, early results from the literature suggest there are some increased safety *risks*, and some increased safety *benefits* associated with e-bike use compared with the use of traditional bicycles. There may be safety concerns for faster e-bikes compared with unpowered bikes, and in particular for younger and older

[20] Note that the authors of this study also recognised the limitations of making this claim, due to data reporting and not fully understanding exposure rates and comorbidity factors such as other physical ailments that pre-dispose elderly people to crashes

users. While an e-bike with a motor cut-out speed of 25 km/h might not help an adult ride much faster than normal, it could help a young child to ride much faster than on an unpowered child's bike.

However, there is not enough information available regarding the level of cognitive ability required to operate an e-bike or other types of LPV. Furthermore, it is not clear how to test younger and older users in particular to assess whether they possess the required level.

This discussion must be seen in conjunction with the consideration of specifications for e-bikes and LPVs, as factors such as operational speed, device weight and places where the device can be used, all affect the level of cognitive ability required to operate them safely in the given environment.

Furthermore, the regulatory framework for LPVs must be consistent with other regulatory changes being considered. In particular, New Zealand is currently exploring the possibility of allowing children to cycle on the footpath until they reach a certain age at which it is deemed they can ride safely on the road. If it were to be determined that e-bikes should not be ridden on the footpath, then it might logically follow that child cyclists would only be allowed to use e-bikes once they were old enough to be denied access to footpaths.

7 Features of LPVs affecting safety and health

This section describes the features of LPVs that can affect safety and health and therefore should be the motivating factors in regulation. Chapter 8 adds to this by detailing how these factors are addressed through the current regulatory approaches in New Zealand and internationally. Based on this discussion and information, chapter 9 presents possible criteria that could be adopted to improve New Zealand's regulatory framework for LPVs.

7.1 Speed restrictions

7.1.1 Rationale for speed restriction

As speed increases, so too do the likelihood and severities of crashes. Increasing speed differentials between users creates conflict and decreases comfort. Speed, or more accurately motor cut-out speed, is used in numerous countries to regulate e-bikes. Of all the countries reviewed, only the New Zealand regulations do not mention motor cut-out speed. As noted in table 8.3, the range of limits is from 20 km/h to 45 km/h, with lower values common in Asia and the highest values accorded only to a limited and more regulated class of e-bikes.

There are competing objectives when setting the cut-out speed. Lower speed thresholds may be more appropriate for shared paths, cycle lanes or narrow pathways (if overtaking is difficult). Higher speed thresholds can be advantageous where e-bike riders want to travel to destinations more quickly or want to achieve more equitable speeds with motorists in mixed traffic conditions, eg roundabouts that are designed for free-flow rather than safety. As with high-standard motorways, higher speeds can be accommodated through high-quality geometric design and the absence of conflict points such as driveways and side roads (eg portions of the Northwestern Cycleway in Auckland or the Christchurch Southern Motorway path).

As described in section 3.2.3, some survey respondents and researchers (Langford 2013; MacArthur et al 2014; Popovich et al 2014) note safety is improved when the user is able to keep up with traffic rather than being constantly overtaken. A faster bicycle helps riders 'claim the lane' in roundabouts and wherever there is insufficient lane width for sharing with a motor vehicle. E-bikes help people who would otherwise not have the fitness to maintain equitable speeds.

There are very few commercially available e-bikes that can provide motor assistance beyond 45 km/h (the EU limit for an S-pedelec and the California limit for a class 3 e-bike). Production models are in the same price bracket as mid-range motorcycles (refer section 2.7). Users who wish to go faster than 45 km/h can avail themselves of numerous do-it-yourself resources on the internet to build their own bike (refer to section 2.5.7 for a discussion of kits). According to Hicks (2012b), there are many limitations to fast e-bikes that can go faster than an S-pedelec (more than 45 km/h), including:

- *Expensive to buy, especially for production models*
- *Illegal*
- *Inefficient, and therefore require a large and heavy battery*
- *Heavy, due to the extra strength of components required to cope with higher speeds*
- *Due to chain noise and bulk of the components, they don't fit in with regular bicycles*
- *Bulky and inelegant due to the DIY nature of kit builds; not stealthy*

- *Poor reliability (at this time) with consequent higher cost of upkeep and potential dangerous breakdowns*
- *Risky for the e-bike movement – for example bicycle messengers in New York City turned public opinion against all e-bikes by riding 'hot-rodded' electric bikes in a reckless manner.*

It could be argued the disadvantages noted by Hicks may be overcome with technological advancement. For example, lighter batteries and components may be developed that are suitable for high speeds. However, given the primary limitations of cost and regulation (also noted in section 2.7), it is unlikely fast (> 45 km/h) e-bikes will ever account for more than a tiny proportion of all e-bikes. The safety implications of fast e-bikes will likely need to be addressed through enforcement (which is far easier as long as these bikes remain 'not stealthy' in appearance).

Unlike e-bikes, self-balancing devices do not have the possibility of being propelled by human input; the propulsion is completely governed by the motor. Above any top speed programmed into the device software (eg on a downhill), the motor remains active for balancing and braking.

7.1.2 Tampering with speed restriction

When made for markets where speed is regulated, e-bikes generally limit speed by use of sensors that detect wheel speed. Speed is set in software for BCDM motors; however, manufacturers often have mini-switches or jumpers on the control board where it is possible to change the speed limit. This allows them to make one configuration of the control board and then easily set it for different speeds and markets. There are also software parameters that can be set from the handlebar mounted controller and/or system diagnostics interface. These parameters may be accessible to end users with or without a password, or may only be accessible to authorised dealers, service technicians, or the manufacturer. It is difficult to determine the potential for tampering with parameters without getting detailed specifications from each manufacturer.

Post-sale, technical users with the ability to modify controller power limits can drill out the motor casing to obtain higher power (Hicks 2012a). Some users can tamper with the system to 'fool' the sensors, or a 'dongle' can be installed to increase or eliminate the motor cut-out speed. Dongles are popular in the UK market, where the EU standard pedelec cut-out speed of 25 km/h is considered by some to be slightly below the desired commuter operating speed (Brown 2013). Dongles are software-based, encased in a device that plugs into the speed sensor port on the motor with an audio jack, and result in the handlebar display indicating a speed half that of the actual speed (ibid). While some niche brands permit customer 'tinkering', no information is available on whether mainstream, high-volume manufacturers are working to eliminate the potential for tampering. In California, tampering is explicitly prohibited (State of California 2015).

It is likely the incentive for tampering reduces as the motor cut-out speed threshold increases. This is supported by the survey and workshop findings, which show most of the current owners of e-bikes in New Zealand consider 25 km/h too slow given the capabilities of unpowered cyclists, yet would be satisfied with a top motor assistance speed of between 30 and 35 km/h.

7.1.3 Footpath mode or automatic speed controls

Many LPVs have a footpath mode (often illustrated on the console or smartphone interface as a 'turtle' icon) that reduces the top speed to about 6 km/h. This removes the onus from the rider to manage the throttle (or tiller, on mobility scooters) in order to maintain a lower speed on footpaths or busy shared paths. A potential feature is a prominent indicator light that could help the rider and other users (or enforcement officers) confirm footpath mode is engaged.

Some mobility scooters such as the Invacare Comet have an automatic speed reduction device that operates in curves[21]. A system for automatic deceleration (from 6 km/h to 2 km/h) using a laser scanner to detect pedestrians and obstacles in the path of travel has been developed for mobility scooters (Inoi et al 2013).

According to Airwheel, their x6 e-unicycle has active speed warning built in: 'to prevent injuries caused by speeding, Airwheel sets a maximum speed. When the speed exceeds 12km/h, the front end of the pedal will rise gradually and when the speed exceeds 16km/h, the pedal will pose a 10º angle to the levelling surface, which stops you from inclining further to accelerate.'[22]

As the price of sensors and automated controls continues to decline (PwC 2016), it is considered likely manufacturers will offer autonomous speed, braking, or deceleration features.

7.1.4 Speedometers

Pedal cycles, power-assisted cycles, other LPVs, mopeds and any other motor vehicles not capable of travelling faster than 50 km/h are currently exempt from the requirement to have a working speedometer (Land Transport Vehicle Equipment Rule 2004). However, this does not exempt them from the requirement to travel no faster than the posted speed limit.

In California, only their class 3 e-bike (similar to a European S-pedelec) must have a speedometer while classes 1 and 2 are excluded from this requirement. According to the Calbike Executive Director (a key party to the legislative development effort), since all known e-bikes available in California come equipped with a speedometer, this requirement should not be difficult to comply with (D Snyder, 11 January 2016, pers comm).

At present, some New Zealand importers are moving away from consoles equipped with digital displays (and speedometers) in order to reduce the warranty costs of a component with a higher potential for failure than a console without a digital display (A Malek, 30 October 2016, pers comm). If a speedometer were required, importers might specify the higher cost digital display consoles or augment a basic console with a low-cost aftermarket speedometer. Low-cost speedometers have thin wires and therefore are more susceptible to failure – but the importers may still find the cost of replacing a $25 speedometer preferable to a $200 digital display console. What is likely to happen is that a portion of e-bikes sold will end up with non-functional speedometers and users will need to be accountable if stopped for a speeding violation.

7.2 Power restrictions

7.2.1 Safety benefit of regulating power

Despite the difficulty in measuring power (refer section 2.2), most jurisdictions limit continuous power in order to help differentiate vehicle types for regulatory purposes. As noted by Benjamin (2010):

> *One of the key issues in defining an electric assisted bicycle as a "bicycle" is the power of the motor. The general idea is that if the bike has a motor that is "too powerful" then it is really a moped or motorcycle. So most laws that create and define the category of electric bicycle*

[21] www.mobilitytherapycentre.com.au/wp-content/uploads/2015/04/heavy_duty_mobility_scooter_controls.jpg

[22] www.airwheel.net/home/product/x6

> *worldwide have a limitation on the power of the motor – with the idea that the e-bike should have similar speed and performance to a normal bike.*

Regulating power limits the rate at which LPVs can accelerate and the ultimate speed they can reach, and is therefore an alternative to approaches that seek to mitigate severity, eg allowing faster devices but requiring their users to wear a motorcycle helmet.

While the maximum continuous power output is simple to mandate, it is not as easy to measure, especially after the point of sale. Therefore, regulators rely on manufacturer's stated ratings.

It may be argued that limiting power reduces the incentive for users to tamper with their e-bike to obtain higher speeds (because a low-power motor would burn out). However, this may be true only for regulation of relatively high power motors. For example, the same Bosch motor is used for 250 W/25 km/h pedelecs and 350 W/45 km/h pedelecs (Brown 2014), although Bosch has a different part number for each specification (C Burke, 24 March 2017, pers comm).

7.2.2 Power requirements for e-bikes

Selection of the appropriate motor should help achieve an optimum balance between performance, weight, and operational range. The amount of power required depends on the load and the speed required. It appears from manufacturers' specifications that a BDCM motor power range between 250–1,500 W is the industry optimum depending on the LPV weight and configuration. For e-bikes, it has been suggested:

- 250 W systems are satisfactory for pedelecs where the rider is pedalling
- 350 to 500 W systems are better for throttle controlled systems where the rider is not pedalling
- 750 W requires a large battery, where the combination of weight and cost is not that attractive. (Benjamin 2010)

However, Benjamin's rule of thumb obscures topographical and technological variables. Notwithstanding cost implications, a 250 W hub motor does not provide the same hill-climbing ability as a 250 W mid-drive motor that delivers assistance through the gearing system (Prebus 2015). Advancements in battery technology may render the constraint of battery size less of an issue for higher power motors.

The researchers have found that a 500 W motor on a fully laden cargo e-bike[23] provides sufficient assistance to climb steep gradients of the Christchurch Port Hills at about 10 km/h (with moderate human effort).

7.2.3 Progressive motor power reduction

A nuance of the EU and Japanese standards (refer section 8.3.4) is that the motor must provide progressively less assistance as the rider nears the cut-out speed. If the controller cuts motor assistance abruptly it could cause a handling issue. The reverse is true also in that if the vehicle is travelling at a speed greater than the defined motor assistance cut-out speed but slows down and the motor cuts back in with full power, handling could again be compromised. This feature is not necessarily limited to e-bikes equipped with a torque PAS and is detectable on some 'twist and go' throttle e-bikes sold in New Zealand (C Randall, 21 December 2016, pers comm).

[23] A Larry vs Harry Bullitt (2013 model) cargo e-bike with aftermarket Bion-X D500 rear hub motor (2016 model); 40 kg load; 6% grade; maximum assist (300%) setting on console selected; 45x25 gear selected.

7.3 Lighting

E-bikes and many other LPVs often make use of the on-board power to provide continuous running lights, making users more visible in traffic. This is, however, not necessarily a benefit exclusive to e-bikes, as day-time running lights for bikes have been on the market since 2010 (Fahrradtest 2010). When provided as a factory installed feature for e-bikes, the lights are integral rather than available as an accessory as with unpowered bicycles; thus the use of continuous lighting by e-bike users is potentially far greater than with unpowered cyclists.

7.4 Connected vehicle systems

The battery of e-bikes and other LPVs provides a power supply not only for motor propulsion, but also to run on-board electronic systems that can serve other uses. An example of this is the COBI system – a smartphone mount that provides a display of trip information, navigation, weather, automatic lighting (daytime running, low and high beam front light, turn signals, and a planned collision avoidance rear light), alarm system, and an electronic bell (COBI 2017). COBI replaces the original console on five different e-bike motor systems and is standard equipment on certain models of six different bicycle manufacturers (ibid).

Beginning with the General Motors 'OnStar' system, vehicles have long had the ability to contact a centralised response centre in the event the vehicle sensors detect a fault, collision, or user initiated emergency (Litman 2017). With on-board power, electronics and the disbenefit of added weight for communications equipment more or less neutralised by electric assistance, automatic alert systems could become more widely available in the LPV market.

Some bike share systems already have internet connected bicycles that can alert the system operators (Cuddy et al 2014). A possible market led innovation could alert system operators and/or emergency services in the event of vehicle malfunction, loss or theft, or user injury. For example, an elderly person who falls down while trying to stand up from a mobility scooter could speak a command to a voice recognition system on the scooter to alert emergency services, or the scooter could detect an impact with an object and also trigger the alert.

7.5 Electric vehicle warning sounds

Since the advent of electric cars, pedestrian advocates (especially vision-impaired pedestrians) have noted they cannot depend on the sound of an internal combustion motor to detect an approaching vehicle (Sandberg et al 2010). Regulators and vehicle manufacturers have been looking into electronic warning sounds to help avoid this issue, although there are no known implementations of this (ibid). Several survey respondents noted e-bikes and other LPVs can startle them as the electric motors are nearly silent. However, human-powered versions of these vehicles also are nearly silent, so any requirement for an LPV to make a constant sound would also need to be considered for unpowered vehicles.

A warning sound initiated by the user (eg bell or horn) is required by some overseas jurisdictions (refer chapter 8). A warning sound initiated by automatic sensors on the device (eg electronic beep) could be a feature offered by manufacturers.

7.6 Braking

Braking requirements are generally established in the applicable Australian/New Zealand (AS/NZS) or international (ISO) standards. The manufacturer or importer must declare conformity to those standards.

7.6.1 E-bike braking systems

7.6.1.1 Land Transport Rule

At present, the Land Transport Rule: Light-vehicle Brakes 2002 states a '…vehicle of class AA or class AB manufactured before 1 January 1988 must have at least one service brake acting on the rear wheel' (NZ Transport Agency 2002). Single brakes are generally only found on lower-speed children's cycles, 'cruisers' and single-speed track cycles.

7.6.1.2 Safety standard

Brake requirements are defined in AS/NZS 1927:1998 *Pedal bicycles – safety requirements*: 'All bicycles shall be equipped with not less than two brakes, one acting on the front wheel and one on the rear wheel. On a children's bicycle one brake shall be a back-pedal brake' (Standards New Zealand 1998). While the standard includes mention of a 0.2 kW motor option in the definition of a pedal cycle, the braking performance specification does not mention any need for electrically assisted cycles to have a more powerful braking system than an unpowered cycle.

7.6.1.3 Braking systems for production e- bikes

Production e-bikes must be declared to comply with applicable safety standards and therefore are equipped with a brake on each wheel. E-bikes that meet the EU 15194 pedelec standard or must be type certified e-bikes (ie throttle e-bikes, bikes with motors larger than 250 W or able to go faster than 25 km/h) have brakes designed for the extra weight of the vehicle, typically hydraulically operated (Bike Europe 2016a). Such brakes have more than enough power to achieve the maximum deceleration rate possible given factors such as tyre friction coefficient and rider balance. Depending on the approach taken to other criteria, the Transport Agency could consider adopting a reference to European e-bike standards (as Australia has done) in order to improve the safety of brakes throughout the e-bike fleet.

7.6.1.4 Braking systems for e- bike kits and homebuilt e- bikes

In New Zealand, it is not clear if bikes that have been retrofitted or built up using a kit either professionally (by a cycle mechanic in a shop) or at home must comply with the standard. This can lead to a performance deficiency, especially in the case of a donor bike having rim brakes and weaker wheels that end up 'out of true' due to the extra weight of the electrical components (Harwood 2016). Brakes must also be adequate for the extra cargo carrying capability of e-assist, especially in hilly terrain. This suggests a need to include a term such as 'must have an effective brake on each wheel' in the Land Transport Rule: Light-vehicle Brakes and/or in the definition of a class AB power-assisted pedal cycle.

7.6.1.5 Braking systems for SSEBs and mopeds

For SSEBs that meet the requirements for importation and certification, moped braking standards are set in the Land Transport Rule: Light-vehicle Brakes 2002 (NZ Transport Agency 2002) which specifies Australian Design Rule 33A for Motorcycle and Moped Braking Systems (Department of Transport 1985). No change appears to be warranted.

7.6.1.6 Regenerative braking

In addition to wheel brakes, some e-bikes are equipped with regenerative motor braking. When a brake lever is actuated by the rider, the switch that disengages the motor also effectively 'reverses' the motor and uses the captured energy to recharge the battery. One of the research team members has an e-bike with perhaps the best known regenerative braking system on the market, the Bion-X, and has found maximum regeneration to be similar to light pressure on a disc brake lever, accompanied by slight vibration in the rear wheel. No mention of regenerative braking issues affecting safety (ie loss of traction) was found in this research.

7.6.2 Mobility scooter braking systems

Most mobility scooters have wheels that are too small for a wheel brake to be fitted. Motor braking is sufficient for deceleration from the typical 6 to 15 km/h top speed of a mobility scooter, and to hold the vehicle in place when stopped (Thoreau 2015b). The rider operates the tiller to slow down. An electromagnetic or mechanical brake on the axle is sometimes provided as a parking brake, emergency brake, or to hold the scooter in place when it is in ‘freewheel mode’ (ie the motor is disengaged) (Disabled World 2015). Some high-end (eg the NZ$9,000+ Newage) mobility scooters with larger wheels offer wheel mounted disc brakes. The UK regulations (section 8.4.4) state the braking must be effective, which would enable an enforcement officer to determine whether a homebuilt powered mobility scooter was safe to operate. The New Zealand standard does not mention any braking requirement other than specifications for emergency brakes (Standards New Zealand 2013).

7.6.3 Other LPV braking systems

As with mobility scooters, brakes on other LPVs are dependent on wheel size. Small wheeled devices (ie-skateboards and small e-scooters) are motor braked. As the size and speed capability of e-scooters increases, the number (none, 1, 2) and power of brakes (friction brake, drum brake, caliper brake, disc brake) fitted also increases. Self-balancing devices are designed to be decelerated using motor braking; the rider adopts a rearward lean to engage the motor braking.

Some e-skateboards and hoverboards have pressure sensors or infrared sensors on each footpad that must be blocked by both feet for the motor to operate, and ensure the device stops quickly if the rider dismounts or falls (Goldberg 2016). Regenerative braking also features on some other LPVs, particularly self-balancing devices. Some may also be combined with a conventional friction-based brake for greater emergency stopping. Additional information on braking performance is provided in section 10.3.2.

8 Existing standards and regulations

8.1 General legislation in New Zealand

This section presents legislation that applies to more than one LPV type. Further detail is provided later in this report under type-specific headings.

8.1.1 Vehicle classes and definitions

Existing legislation provides for the relevant classes of vehicles in this study, as listed in table 8.1.

Table 8.1 Relevant existing New Zealand vehicle classes (NZ Transport Agency 2015e)

Class	Definition
AA (Pedal cycle)	A vehicle designed to be propelled solely by human power.
AB (Power-assisted pedal cycle)	A pedal cycle to which is attached one or more auxiliary propulsion motors having a combined maximum power output not exceeding 300 W. Refer section 8.3.2.
LA (Moped with two wheels)*	A motor vehicle (other than a power-assisted pedal cycle) that has two wheels; a maximum speed not exceeding 50 km/h; and an engine cylinder capacity not exceeding 50 ml[(a)] or a power source other than a piston engine.
LB (Moped with three wheels)	A motor vehicle (other than a power-assisted pedal cycle) that has three wheels; a maximum speed not exceeding 50 km/h; and an engine cylinder capacity not exceeding 50 ml or a power source other than a piston engine[(b).]
Mobility devices	Vehicle designed and constructed for use by persons who require mobility assistance. Maximum power output 1,500 W. Refer section 8.4.2.
Wheeled recreational devices	Scooters, skateboards, in-line roller skates and similar wheeled devices (but excluding cycles with wheels greater than 355 mm). Maximum power output 300 W.

(a) Note: one millilitre (ml) is equivalent in volume to one cubic centimetre (cc). Hence the common reference to '50 cc engines'.

(b) Note: the limit of 2kW for 3-wheeled mopeds applies to vehicles registered prior to May 2011.

It is useful at this stage to also recall the legal definitions for 'vehicle' and 'motor vehicles', as found in the Land Transport Act (MoT 1998). A 'vehicle' is defined as follows (emphasis added):

> *(a) means a contrivance **equipped with wheels, tracks, or revolving runners** on which it moves or is moved; and*
>
> *(b) includes a hovercraft, a **skateboard, in- line skates, and roller skates**; but does not include—*
>
> *(i) a perambulator or pushchair:*
>
> *(ii) a shopping or sporting trundler not propelled by mechanical power:*
>
> *::*
>
> *(viii) a **wheelchair** not propelled by mechanical power:*

(ix) any other contrivance ***specified by the rules not to be a vehicle*** *for the purposes of this definition:*

(x) any rail vehicle

Meanwhile, a 'motor vehicle' is defined as follows:

(a) means a vehicle ***drawn or propelled by mechanical power****; and*

(b) includes a trailer; but

(c) does not include—

(i) a vehicle running on rails; or

: :

(vi) a ***pedestrian- controlled machine****; or*

(vii) a vehicle that the Agency has declared ***under section 168A is not a motor vehicle****; or*

(viii) a ***mobility device***

The Land Transport (Road User) Rule (NZ Government 2004) section 1.6 *Interpretation* states that a 'wheeled recreational device':

- *means a vehicle that is a wheeled conveyance (other than a cycle that has a wheel diameter exceeding 355 mm) and that is propelled by human power or gravity; and*
- *includes a conveyance to which are attached 1 or more auxiliary propulsion motors that have a combined maximum power output not exceeding 300 W* (NZ Government 2004)

If a vehicle or type of vehicle is propelled by a motor that has a maximum power output greater than 300 W but not exceeding 600 W, the Transport Agency may, by notice in the Gazette, declare the vehicle or type of vehicle is not a motor vehicle (Land Transport Act 1998, section 168A 3). Under Schedule 1 Objective of Rule, clause 5(2), wheeled recreational devices are described as including scooters, skateboards and in-line roller skates (ibid). The dimension of 355 mm is roughly equivalent to 14 inches. Children's bicycles are typically manufactured in 12, 16 and 20 inch wheel sizes (International Bicycle Fund 2016), with 18 and 24 inch wheel sizes to a lesser degree. Section 11.1 of the Rule states 'a driver of a wheeled recreational device must remain as near as practicable to the edge of the roadway'. In New Zealand, the following are examples of vehicles that meet the definition of wheeled recreational devices, or (if over 300 W power) are considered to be motor vehicles but have difficulties meeting the safety standards and other requirements[24]. This means that technically the latter cannot be operated on public roads (NZ Transport Agency 2016a):

- motorised skate boards, scooters and roller skates (typically <300 W power)
- powered self-balancing devices, eg hoverboards and unicycles (typically >300 W power)

Thus, it can be seen that motor vehicles, cycles, mobility devices and wheeled recreational devices are all subsets of 'vehicles'; whether they are completely mutually exclusive subsets will be discussed further.

[24] There is still the possibility that a device with output power between 300–600 W could be gazetted under section 168A of the Land Transport Act to be not a motor vehicle.

Note also pedestrians, prams and unpowered wheelchairs are not considered to be vehicles of any kind. This is in line with the Land Transport (Road User) Rule 2004 (RUR) definition of a 'pedestrian' as 'a person on foot on a road[25]; and includes a person in or on a contrivance equipped with wheels or revolving runners that is not a vehicle'.

8.1.2 Requirements for use on paths

RUR section 11.1 Use of Footpath and Roadway and 11.1A Use of Shared Path stipulate usage rules on paths as summarised in table 8.2.

Table 8.2 Summary of Road User Rule section 11.1/11.1A

<table>
<tr><th>Operator type</th><th colspan="2">Footpath (RUR 11.1)</th><th colspan="2">Shared path (RUR 11.1A)</th></tr>
<tr><td>Pedestrian</td><td colspan="2">When practicable, must remain on the footpath when provided
Must not unduly impede the passage of a mobility device or wheeled recreational device</td><td></td><td rowspan="4">Must use the path in a careful and considerate manner
Must not use the path in a manner that constitutes a hazard to other persons using it
May not duly impede the passage of any other user, regardless of priority signed or marked</td></tr>
<tr><td>Cyclist</td><td colspan="2">Not allowed to ride on a footpath[(a)]</td><td rowspan="3">Must not operate the cycle or device at a speed that constitutes a hazard to other persons using the path</td></tr>
<tr><td>Mobility device</td><td></td><td rowspan="2">Must operate the device in a careful and considerate manner
Must not operate the device at a speed that constitutes a hazard to other footpath users</td></tr>
<tr><td>Wheeled recreational device</td><td>Must give way to pedestrians and drivers of mobility devices</td></tr>
</table>

[(a)] As of the time of writing, there is a parallel research project assessing footpath cycling. Note there is an exception under RUR clause 11.11 for 'a person who rides a cycle on a footpath in the course of delivering newspapers, mail, or printed material to letterboxes'.

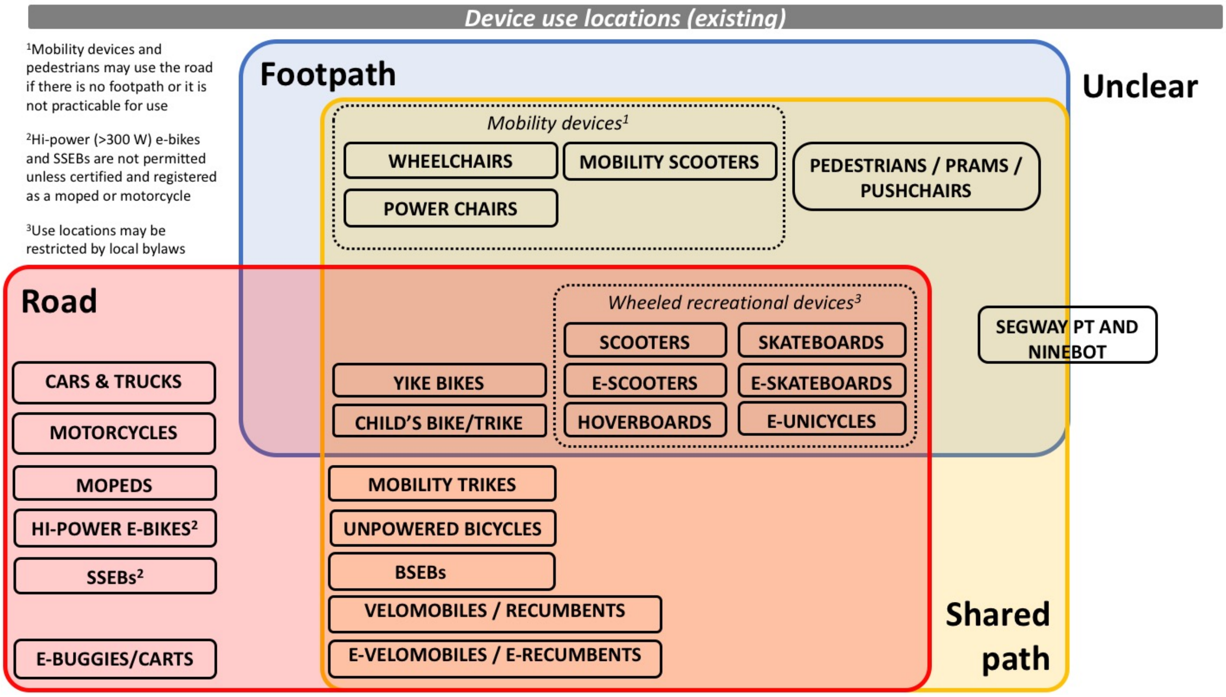
The RUR 11.1A(4) also allows for priority assignment of shared paths via signs or markings in favour of either cyclists or all other path users. In other words, the rule is silent on any priority distinction between mobility devices, wheeled recreational devices, and pedestrians. On footpaths, only wheeled recreational devices are obliged to give way to other legitimate users.

Unpowered devices like skateboards can be banned from using specific footpaths by local bylaws. Unlike mobility devices and pedestrians, there is no rule stating that a user of a wheeled recreation device (or any unpowered vehicle) must use a footpath when one is provided.

Figure 8.1 shows the various device types considered (as well as some traditional vehicles/devices, for comparison) according to where they may be operated. It should be noted for some devices such as Segways and higher-powered electric wheeled devices, the current legislation is unclear on where such devices can be legally used.

[25] Here 'road' refers to the broader definition that includes the road corridor and other public places where pedestrians typically travel.

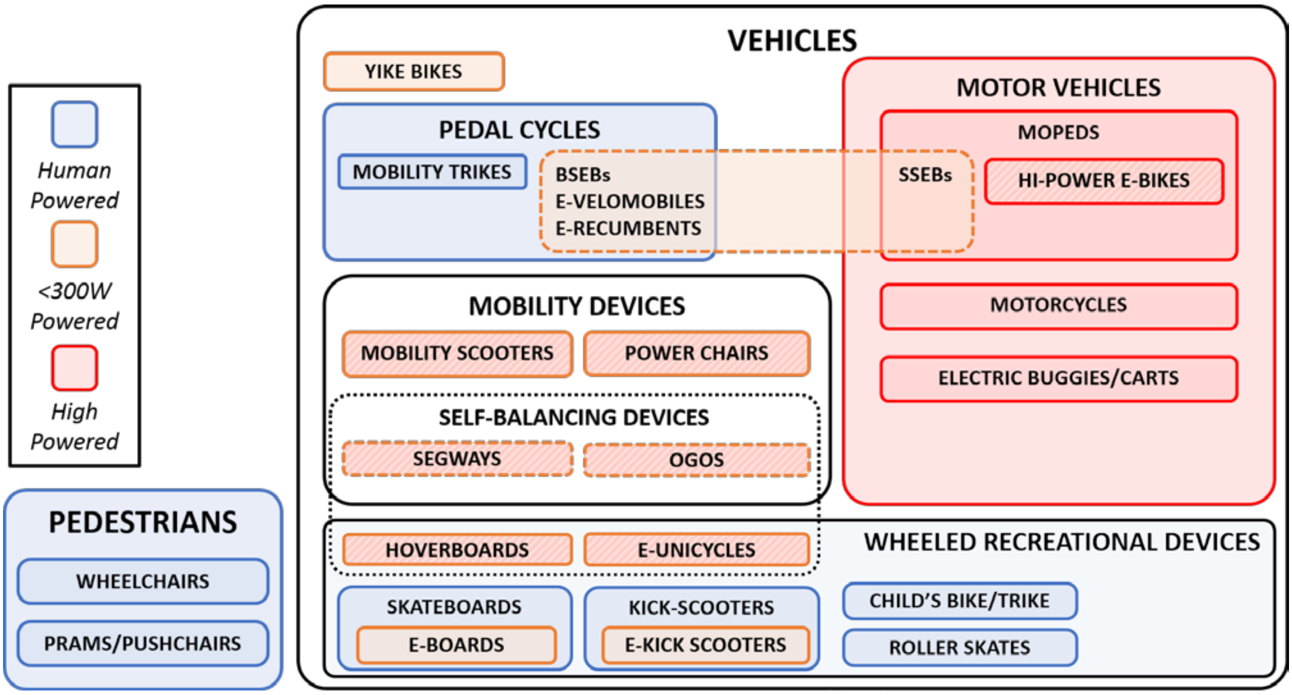
Figure 8.1 Where devices can be used under existing definitions



8.1.3 Summary of legal status

Figure 8.2 summarises graphically the legal status of different road users under current New Zealand legislation. Device power is indicated by the different colours; devices that fall in the >300 W to 2 kW power range are shown with a hatched pattern. As the power rating of many self-balancing devices is not published, their status is not clear in the current legislation.

Figure 8.2 Status of different vehicles and users under current New Zealand regulation



8.1.4 Helmets

The RUR section 11.8 'Safety helmets for cyclists' stipulates a 'person must not ride, or be carried on, a bicycle on a road unless the person is wearing a safety helmet of an approved standard that is securely fastened' (emphasis added). The judge in *Gallagher vs Police* (1999) noted it is possible a person riding a *three-wheeled* cycle does not have to comply with this Rule; however, to date that has not been tested in Court.

A motorcycle helmet is required for riders of mopeds capable of 50 km/h (RUR 7.12). It might be impractical to require a motorcycle helmet for users of S-pedelecs (even though they are capable of motor assistance up to 45 km/h) because the S-pedelec is designed to be propelled by both human and motor power, and a rider pedalling might overheat physiologically when wearing a helmet without the ventilation that a cycle helmet provides. This brings up the quandary where the operator of an electric moped might argue there is little to no performance difference between a moped and a S-pedelec, so why should the moped rider not be able to use a cycle helmet? On the other hand, the S-pedelec rider may have bought that bike (rather than a moped) partly to incorporate exercise into their travel, with attendant potential public health benefits. The simplest approach would be to require S-pedelec riders to use cycle helmets, although given the higher speed there could be a benefit to encouraging or requiring the use of helmets which meet the proposed EU standard NTA 8776 for S-pedelec helmets (NEN 2016). Such helmets have increased protection while recognising the need to provide adequate ventilation and light weight. Manufacturers are beginning to produce compliant helmets.

At present, there is no requirement in New Zealand for riders of mobility scooters or any other wheeled recreational device to wear a helmet. There have been a number of calls by some parties to mandate these at least for children (Safekids NZ 2013; Wolfaardt and Campbell 2013). In some countries, helmets are required for all riders of larger and faster LPVs other than mobility scooters (eg Segways). Segway also strongly encourages riders to wear an approved cycle helmet.

8.2 Battery and electrical requirements

8.2.1 Battery fires

There have been a number of hoverboard fires attributed to faulty batteries and poor or non-existent battery management systems, resulting in government investigations and partial bans (Geggel 2015; Molina and Weise 2015). The issue is not limited to hoverboards, as lower priced e-bikes have also been implicated in fires (Barry 2016; Shan 2016). According to Benjamin (2015b), battery fires are rare but the following steps can be taken to reduce the risk:

- Ensure that the battery has an official CE mark (EU) or UL mark (USA) indicating compliance with minimum standards.
- Use only the correct charger and do not charge a damaged battery.
- In a commercial environment, charge batteries on a non-flammable rack positioned near a doorway and equipped with a fire extinguisher, smoke detector, timer to cut power at the end of the day, single easily detached power cable, and wheels.
- If a battery does catch fire, use a fire extinguisher and then cool the battery down to avoid re-ignition.

8.2.2 New Zealand

The *Household and similar electrical appliances – safety* standard covers battery operated devices and is harmonised with international standards, which are used by laboratories and manufacturers to verify that products perform as they should (Standards New Zealand 2011).

According to the Energy Safety department of Worksafe NZ:

- When a vehicle gets to a certain size and needs to be road registered, the requirements that apply are much more stringent.
- If LPVs integrate charging circuits rather than be charged through a separate power supply, then they will be subject to more stringent requirements.
- Lithium batteries sold independently have to be covered by a supplier declaration.
- Battery chargers for household purposes are required to comply with an appropriate standard and carry a supplier certification confirming this.
- Self-balancing scooters and their chargers must be tested to an appropriate standard and there must be a supplier declaration. (P Morfee, 7 November 2016, pers comm)

8.2.3 Australia

Standards Australia is working on the development of industry standards and guidelines for battery storage, handling, transport and recycling (Standards Australia 2016). When released, the standard will assist the industry, regulators and transportation companies to deal with safety issues as the fleet grows and batteries must be replaced.

The standard AS 5732 *Electric vehicle operations – maintenance and repair* (Standards Australia 2015) specifies requirements and guidance on the safe and appropriate handling procedures for those within the mechanical repair, body repair and refinishing industries when working on plug-in electrical vehicles, hybrid electric vehicles, battery electric vehicles and plug-in hybrid electric vehicles. However, it is not likely to be appropriate for the lower voltages of LPVs, unless on-board charging is integrated (ie mains power plugged directly into the vehicle, as noted by Worksafe NZ).

8.2.4 Europe

In the UK and Europe, e-bike electrical systems are covered by EPAC type regulations and the Machinery Directive. E-bikes that are not type or individually approved must meet applicable general safety and electrical requirements on electromagnetic compatibility and traceability (in the event of electrical interference) (European Parliament and Council of the European Union 2006; European Parliament and Council of the European Union 2014). Batteries must also comply with the RoHS Directive prohibiting certain hazardous components such as lead and mercury. A battery that meets EU requirements will have a CE marking on it; however, users should be cautioned not to be misled by the similar looking 'Chinese Export' label (cemarking.net 2016). The USA-based UL certification is another generally accepted mark of meeting quality and reliability requirements.

Batteries for light EVs covered in this research are now covered by the EU standard EN 50604-1:2016, which sets out requirements to protect against overcharging, deep discharging, short circuits, mismatched chargers, vibration resistance and extreme temperatures.

8.2.5 North America

Testing standards authority UL has developed an accredited USA and Canada national standard *ANSI/CAN/UL 2272 Standard for electrical systems for personal e-mobility devices* (UL 2016). The standard is limited to electrical safety, and does not cover the use of such devices.

8.2.6 International battery transportation requirements

International rules are extremely strict on the transportation of lithium batteries:

> *If the lithium batteries are contained in the bicycle or packed with it, they are not required to have a Class 9 hazard label and there is no requirement for a Shipper's Declaration for Dangerous Goods for consignments of these batteries. Nevertheless, they must meet the packing instructions of the relevant transport regulations (ADR, IATA, IACO or IDMG). And, in the event of an incident involving these batteries, the incident reporting requirements apply. Furthermore, only batteries that have successfully passed the test procedures of Part III, Sub-Section 38.3.1 of the UN Manual of Tests and Criteria qualify under this exception. This also applies to so-called "OEM" or "aftermarket" batteries. Any battery manufacturer or distributor should be able to provide documentation, confirming that the batteries have been so tested* (Bike Europe 2016a)

Some small LPV manufacturers advertise that their lithium ion batteries are under 100 Wh capacity and therefore exempt from international dangerous goods regulations (DGR). Such claims are incorrect, as according to the International Air Transport Association (IATA 2015 #3184) 'devices such as balance wheels, air wheels, solo wheels, mini balance boards and hoverboards, are classified as UN 3171, battery-powered vehicles...and therefore must be packed in accordance with (DGR) Packing Instruction 952...if the lithium ion battery is removed from the vehicle and packed separate from the vehicle in the same outer packaging, then...Packing Instruction 966 applies'. Instruction 966 requires the battery to have no more than 30% charge, a Materials Safety Data Sheet, maximum weight of 5kg, handling label, documentation and strong outer packaging. Instruction 952 is similar but requires immobilisation of the vehicle in the box.

8.2.7 The future of light electric vehicle batteries

Battery technology will continue to improve, with higher capacities at lower weight and volume. For example, two major battery makers announced in 2016 improvements that reduce heat, increase capacity by up to 60%, and increase the typical lifespan from three to 12 years (Oortwijn 2016b). A longer lasting, cooler operating battery will help reduce the cost, environmental impact and safety risk associated with LPVs.

8.3 E-bikes

8.3.1 Overview

A selection of overseas regulations and the key regulatory criteria of labelling, allowance for throttle control, motor cut-out speed in km/h, stated maximum continuous power rating, maximum bike weight (without rider), and minimum age requirements is summarised in table 8.3. Each of the criteria is discussed in turn in the previous section as well as in the section on regulatory options. A dash indicates the criterion is not applicable or information was not found.

Table 8.3 Selected e- bike regulations

Place	Terms/notes	Label	Throttle	Km/h	W (max)	Kg	Age	Helmet
Australia	Power-assisted bicycle	-	Yes	-	200	-	-	Yes
	Pedelec		No	25	250	-	-	Yes
Canada		Yes	Yes	32	500	-	-	Yes
Ontario		Yes*	Yes*	32*	500*	120	16	Yes*
Toronto		Yes*	Assist only	32*	500*	40	16*	Yes*
China	Pedal assist only	-	No	26	-	40	-	No
	Pedal or throttle		Yes	26		50		No
	Electric bicycle		Yes	50		55		No
EU	Pedelec	Yes	Max 6 km/h	25	250	35	-	No
	Powered cycle	Yes	Open	25	1,000	35	Varies	No
	S-pedelec and moped	Yes	Yes	45	4,000[a]	-	Varies	Varies
Switzerland	Slow electric cycle	-	No	25	500	-	14[b]	No
	Fast electric cycle	Yes	No	45	1,000	-	14	Yes
Israel		-	-	25	250	30	14	No[c]
Japan	Max. assist ratio 2:1[d]	-	-	24	-	-	-	≤12
New Zealand	Class AB	-	Yes	-	300	-	-	Yes
	Other powered cycles[e]	-	Yes	-	300–600	-	-	-
UK	Pedelec	Yes	Max 6 km/h	25	250	40	14	No
	S-pedelec	Yes	Max 6 km/h	45	250	60	14	No
USA	Electric assist bicycle	-	-	32	750	--	Varies[f]	Varies
California	Class 1	Yes	No	32	750	--	-	No
	Class 2	Yes	Yes	32	750	-	-	No
	Class 3	Yes	No	45	750	-	16	Yes

* Not stated, however regulation at higher government level applies

[a] Although new regulations fully effective on 1 January 2017 permit up to 4 kW for the moped category in which S-pedelecs are now classified, most S-pedelecs need only a 350 W motor to achieve 45 km/h (Brown 2014).

[b] In Switzerland, riders under 16 must have a moped licence for the slow e-bike class. All riders must have a moped licence for the fast e-bike class (Touring Club Suisse 2016).

[c] Israel instituted an all-ages mandatory helmet law in 2007, but after a campaign based on epidemiological and population health statistics showing a decline in cycling participation rates it was revised in 2011 so it does not apply to adults riding on urban roads.

[d] Japanese regulations require the motor power to progressively taper off above 10 km/h to zero at 24 km/h, and the primary power must be via pedalling (Saito et al 2015).

[e] According to the Vehicle Compliance Rule 2002, an e-bike with motor power more than 300 W but less than 600 W cannot be a Class AB cycle. However, under section 168A of the Land Transport Act, the Transport Agency can declare such e-bikes not to be a motor vehicle subject to specific requirements.

[f] A minimum age is not included in US federal law. Twenty-nine states have no minimum age, 19 states limit e-bikes to 16 or older, and the remaining states use values between 14 and 18 years of age.

Note whereas the EU regulations apply to all EU countries, places such as the USA and Canada may have different layers of regulation at national, state/provincial and city level, and the laws passed at a local level may supersede those standing at the national level (eg compare Canada, Ontario and Toronto). Furthermore, even within the EU, ‘Member states have the right to lay down the requirements which they consider are necessary to ensure the protection of road users (ie may fix the conditions for allowing non EC type-approved vehicles on its roads)' (Crown Prosecution Service 2016). It is unknown if and when each state will adopt any or all aspects of EU standards.

8.3.2 New Zealand

8.3.2.1 Definition

Section 8.1.1 summarised the relevant vehicle classes covered in this report. Generally, e-bikes are included in the class AB (power-assisted pedal cycle), which limits maximum output power to no more than 300 W but otherwise considers them the same as a class AA pedal cycle, ie a vehicle designed to be propelled through a mechanism solely by human power. E-bikes with greater power output, or where pedals were absent or only vestigial would usually be included in the LA/LB (moped) classes.

The legal definitions of 'cycle' and 'power-assisted cycle' are contained in the RUR (NZ Government 2004):

> ***cycle***
>
> *(a) means a vehicle that has at least 2 wheels and that is designed primarily to be propelled by the muscular energy of the rider; and*
>
> *(b) includes a power-assisted cycle.*
>
> ***power- assisted cycle*** *means a cycle to which is attached 1 or more auxiliary propulsion motors that have a combined maximum power output* ***not exceeding 300 W***

When the RUR came into effect in February 2005, the power output of a power-assisted cycle was restricted to 200 W, but this was raised to 300 W only four months later (MoT 2005).

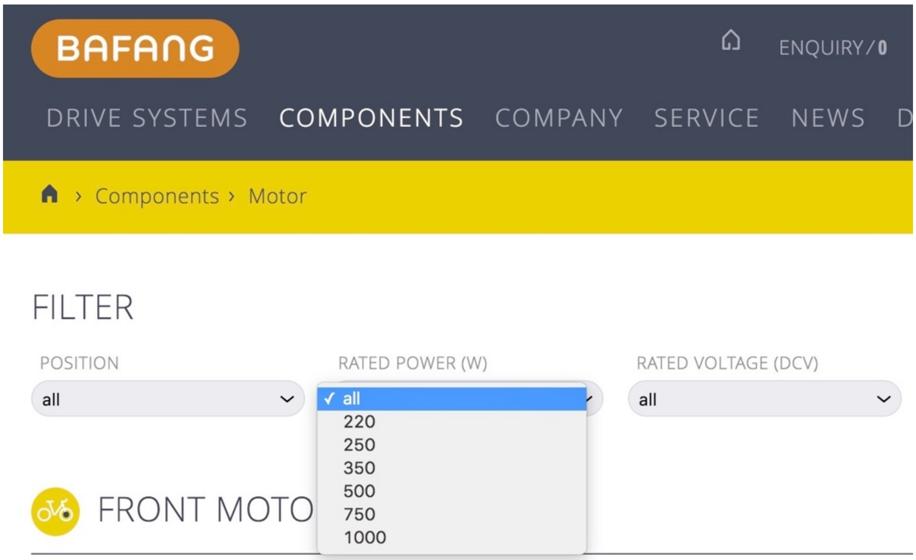
Power-assisted cycles have been officially declared not to be a motor vehicle by Gazette Notice 2013 issue 94 (NZ Transport Agency 2013). The notice refers to cycles powered by electric motors only, because petrol engine kits being fitted to cycles are more powerful than 300 W. As discussed in section 2.8, an electric two-wheeler that is predominantly propelled by electric motor rather than pedals would be considered a moped, irrespective of its power output.

8.3.2.2 Power limit issues

The literature review did not yield any other jurisdictions using a 300 W power limit. The largest volume e-bike equipment maker in the world, BAFANG, manufactures over one million e-bike and e-kick scooter motors annually, with about half of these delivered to Europe. Motors are offered in four location configurations (front hub, rear hub, mid-drive and front wheel for e-kick-scooters) and with continuous power ratings from 220 W to 1,000 W[26]. There are no BAFANG motors made with a rated power of 300 W (figure 8.3). There is one rated at 350 W, so the temptation would be there for manufacturers to claim that, due to inefficiencies in energy conversion from motor to drive unit, 'in practice' it meets the 300 W power output limit.

[26] www.szbaf.com/en/components/motor.html

Figure 8.3 Screenshot of rated power options for Bafang e- bike motors



Most reviewed New Zealand online and physical retailers claimed to be selling only 'New Zealand standard' 300 W models (see also section 7.1). Although it is technically possible to constrain the continuous motor power to 300 W via the controller without affecting the necessary production of higher peak power for acceleration or hills, no industry members asked by the researchers would acknowledge that they had done this. A survey respondent indicated the New Zealand industry does not actually have the ability to import or sell a 300 W motor, and stickers and claims to the contrary are false and borne of competitive necessity. During the literature review, workshops and stakeholder interviews, the researchers were unable to identify an e-bike motor with a genuine 300 W rating.

It may be argued the discrepancy between the 300 W limit and what is being manufactured is not an issue, because the law provides a margin over the usual 250 W pedelec. Importers and retailers are not required to design or market to the limit. However, retailers are in a competitive environment where they would be at a disadvantage if they did not claim to offer a 300 W model. Effectively, they must choose one of the following actions:

- Select a 250 W/25 km/h EU model. As competing models are not speed limited, most New Zealand retailers do not appear to be doing this.
- Custom specify a 250 W/unlimited km/h model for the New Zealand market. Although this complies with existing rules, this may not satisfy customers given the limitations of a 250 W motor in hilly environments and/or the prevalence of higher-powered models in the marketplace being sold as 300 W.
- Custom specify a 350 W (or higher)/unlimited km/h model for the New Zealand market, and claim it is 300 W. This appears to be the most frequently selected option given the lack of enforcement. Some interviewed industry members indicated they were being forced into this option due to competitive pressures and were strongly in favour of aligning New Zealand with overseas rules.
- Select a 350 W/32 km/h USA market model. Although this may require removal of any non-complying label, this option is chosen because USA models are widely available through existing channels.

8.3.2.3 Applicable standard

The AS-NZS pedal cycles safety standard 1998 applies to all class AA pedal cycles and class AB power-assisted pedal cycles (Standards New Zealand 1998). It was developed to be generally consistent with international standard *ISO 4210:1996 Cycles – safety requirements of bicycles*. As currently published, it includes a reference to power-assisted bicycles up to 0.2 kW (200 W) of power. This presumably refers to the initial limit in New Zealand, which at the time achieved consistency with the then same limit in the Australian regulations (prior to their adoption of the EU standard). The standard also includes provisions for consistency with the international standard for bicycle safety, ISO 4210 (International Organization for Standardization 2014). Appendix A of the standard sets out minimum requirements for the owner's manual in the areas of assembly, preparation for riding (rider fit and tyre pressure), use (brakes and gears, wet weather braking), maintenance, recommendation for use of a torque wrench on fittings, and warnings related to handlebar ends and fork repair/replacement. It should be noted the international manufacturers of bicycles generally utilise an international template that covers common requirements of the EU and USA.

There is scope for the Australian/New Zealand standard to be updated as it is nearly 20 years old. In addition to existing EU standards for pedelecs and motor vehicle standards for type regulated e-bikes, a new international e-bike standard is in development (Bike Europe 2015).

8.3.2.4 Usage locations

Footpaths. No pedal cycles (power assisted or unpowered) are allowed on footpaths, except as allowed under current exceptions for delivery purposes or if the wheels are smaller than 355 mm diameter.

Shared paths and roads. By default, e-bikes are permitted on all shared paths and roads where unpowered cycles are allowed, unless prohibited by local bylaw.

Off- road trails. On public lands, the Department of Conservation's (2015) unpublished guideline aims to:

- *Enable lower powered electric bikes (≤300watts) on (grade 1 and 2) off-road biking tracks and cycle ways so that families and those less physically able can enjoy our places*
- *Treat higher powered electric bikes (>300watts) as motorbikes as these are an inappropriate fit with other off-road visitors.*

The guideline also sets out principles taking into account natural, historic or cultural values, demand, potential user conflicts, current access by motorised vehicles and the agreement of all land owners along a given track.

The NZ Cycle Trail (2015) e-bike policy mirrors the Department of Conservation approach but excludes the consideration of values and includes grade 3 trails.

The Wellington City Council's (2016) *Open space access plan* sets a principle of allowing e-bikes on designated off-road tracks, but requires a motor cut-out speed of 25 km/h (effectively excluding most e-bikes designed specifically for the New Zealand and USA markets). The track designations were based upon consideration of public safety, user group conflict and enjoyment, and environmental impacts. These considerations mean designated tracks are 'suitable commuter link tracks' or those with adequate width and sightlines.

8.3.3 Australia

Up until mid-2012, e-bikes in Australia were limited to 200 W – whether throttle activated or pedal assist only. At that point the Australian Government adopted a threshold of 250 W as per the EU standard in order to open up the market to the much wider range of e-bikes available internationally (Johnson and Rose 2013). The vehicle standard (Australian Design Rule – Definitions and Vehicle Categories) 2005 states:

Power-assisted pedal cycle (AB)

A pedal cycle to which is attached one or more auxiliary propulsion motors having a combined maximum power output not exceeding 200 watts; or

A 'Pedalec' (where Pedalec is defined as) a vehicle meeting European Committee for Standardization EN 15194:2009 or EN 15194:2009+A1:2011 Cycles - Electrically power assisted cycles - EPAC Bicycles (Department of Infrastructure and Regional Development 2005).

In this definition, the spelling of 'Pedalec' may be an error, as the second vowel in the European portmanteau 'pedelec' is the first letter of the word 'electric'). Various states such as South Australia still refer to the prior 200 W limit in order to cover throttle activated e-bikes (Department of Planning Transport and Infrastructure 2014):

In South Australia, there are 2 categories of power-assisted bicycles that may be used legally on our roads; Power assisted bicycles with up to 200 Watts of power (the power is controlled by a throttle or accelerator) or Power assisted bicycles with no more than 250 Watts of continuous power which meet the definition of a pedalec (the power is controlled by the rider using the pedals).

Given there are no known manufacturers of 200 W continuously rated motors, it may be importers do not and never have actually complied with the regulations. Australian retailers sell 500 W and 1,000 W motor kits with an optional throttle, simply stating the bike will not then be strictly legal.

8.3.4 Europe

8.3.4.1 Pedelecs

In Europe, the acronym electrically power-assisted cycles (EPAC) means:

cycles of a type which have a maximum continuous rated power of 0,25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h[27]*, or sooner, if the cyclist stops pedalling.* (European Committee for Standardization 2009).

The common synonym for EPAC in Europe is 'pedelec'. For these e-bikes, EN 15194:2009 contains the vehicle standards that pedelecs are assessed by. Pedelec EPACs are exempted from motor vehicle-type approval[28] by Directive 2002/24/EC; manufacturers need only to submit a declaration of conformity with applicable standards (European Parliament 2002). While the focus is on pedal assistance, throttles are allowed on EU market e-bikes as long as they cut out at 6 km/h. Known variously as 'start assist', 'push assist', or 'walk assist', their function is:

mostly activated via a button, more rarely via a twist grip. It propels the pedelec up to 6 km/h (a legal limit) without any need to be pedalling. It's handy on ramps or when walking uphill. (Budde et al 2012)

[27] Note that the standard provides for a 10% measurement error, resulting in some EU compliant pedelecs having slight motor assistance up to 27.5 km/h

[28] Under EU rules, type approval means a manufacturer certifies independent testing has been conducted by an accredited laboratory to establish conformity with technical requirements for a product (source: Directive 2007/46/EC)

8.3.4.2 Open throttle, speed, or higher power e- bikes

If the e-bike has any one or more conditions including a throttle that operates the motor at speeds above 6 km/h (‘open throttle’), motor assistance at speeds higher than 25 km/h, and/or power greater than 250 W, then it is not a pedelec and is considered a motor vehicle subject to type approval under Regulation 168/2013 (European Parliament 2013). The higher power limit facilitates a greater range of cargo and child carrying bicycles.

Regarding open throttles, the UK (where large numbers of ‘twist and go’ throttle e-bikes have been sold) led a market-driven argument that all e-bikes should be treated equally, while others philosophically wanted open throttle e-bikes categorised similar to mopeds under the more stringent Type L1e-B rules – giving an advantage to pedelecs (Bike Europe 2016b). The new regulation compromises by retaining pedelecs as ‘not a motor vehicle’ and permitting open throttles under the powered cycle Type L1e-A motor vehicle technical standards. Some industry participants are seeking further clarification, holding that open throttles are or should be permitted in the 250 W, 25 km/h e-bike class along with pedelecs (ibid).

In contrast to pedelecs, which need only a *declaration* of conformity, a *certificate* of conformity with relevant standards is required for type approved e-bikes. In all member states, type approval has the following additional requirements:

- Key components (frame, handlebars, motor, battery, rims, lighting, and the console) can only be replaced with equivalent type approved components
- Moped and S-pedelec riders must wear a helmet, carry insurance, driver licence, and be of the minimum driving age.

In some (but not all) member states, a vehicle licence plate is required. A summary of the regulation is provided in table 8.4.

Table 8.4 Summary of EU Type Regulation 168/2013 (effective 1/1/2017)

Category	Description	Power	Motor cut- out	Type approval
Pedelec	Motor only functions on condition the cyclist pedals.	<= 250 W	<= 25 km/h	Declaration of conformity with EN 15194
Powered cycle	Designed to pedal; auxiliary motor with primary aim to aid pedalling. May have a throttle. Can include vehicles with 2, 3 or 4 wheels.	<= 1000 W	<= 25 km/h	Certificate of conformity with Type L1e-A
Moped	Includes SSEBs, electric mopeds and S-pedelecs.	<= 4000 W	<= 45 km/h	Certificate of conformity with Type L1e-B

A few key member state differences include:

- Norway permits 500 W for bicycles designed for two riders (eg tandems), if the vehicle has been approved for such use by the Norwegian Labour and Welfare Administration, and only one rider needs to provide human propulsion (Norwegian Ministry of Transport 1994).
- Switzerland states the motor cannot provide assistance without pedalling for all e-bikes. Noting 75% of their territory is mountainous, slow e-bikes (pedelecs limited to 25 km/h motor assistance) may have motors up to 500 W (in contrast to the 250 W specified under EU definitions); riders under 16 must have a moped licence (Touring Club Suisse 2016).

8.3.4.3 S- pedelecs in Europe

While S-pedelecs are to be in the moped category with a power limit of 4 kW, in practical terms a 350 W motor is adequate to achieve 45 km/h with pedalling on level ground. In fact, the Bosch 'performance speed' 45 km/h, 350 W system is simply a reprogrammed version of the same 250 W motor found in the 25 km/h systems (Brown 2014).

With regard to S-pedelecs, the legislation further stipulates they shall have a:

> *(...) mass in running order ≤ 35 kg and shall be fitted with pedals enabling the vehicle to be propelled solely by the rider's muscular leg power. The vehicle shall feature adjustable rider positioning in order to enhance the ergonomic posture of the rider for pedalling. The auxiliary propulsion power shall be added to the driver's pedal power and shall be less than or equal to four times the actual pedal power...the maximum peak power shall be < 1,6 X maximum continuous rated power, measured as mechanical power at the shaft of the motor unit* (Bike Europe 2016a)

A typical rider generates around 150 W on flat ground and 250 W on hills (Parkin and Rotheram 2010). Applying the factor of four, a motor would therefore be limited to roughly 1,000 W of continuous power. This is an upper limit; because as noted previously, lower continuous power ratings can still deliver assistance that may overcome physical fitness or topographical barriers for most people. These additional requirements help clarify the ergonomic and therefore human power potential of an S-pedelec relative to a SSEB or moped. S-pedelec specific laws include:

- Germany requires S-pedelec riders to have collision insurance, wear a helmet and have a driver licence. S-pedelecs may be used on cycle paths if the motor assistance is turned off or if the path is signposted for moped use (Kalkhoff 2016).
- Switzerland allows fast e-bikes (S-pedelecs) to have motors up to 1,000 W, must be registered and have a licence plate displayed; all riders must have a moped licence and wear a helmet; and are permitted on facilities where mopeds are prohibited if the motor is turned off (Touring Club Suisse 2016)

With respect to S-pedelecs and helmets, Bike Europe (2016c) writes:

> *It is unclear how the member states will rule on the conditions for use of these vehicles. Some ministries still seem totally unaware of the issue of electric bikes in type-approval. Others have started up a decision process. The German and Dutch ministers seem to be in favour of a moped helmet. The Belgian minister has been advised that a bicycle helmet should do the job. In the meantime, some helmet manufacturers are ready for possible moped helmet obligations on speed pedelecs. Both Cratoni and Abus have developed a pedelec model that complies with standard ECE 22.05.*

Two other issues driven by the industry remain to be settled in Europe: whether open throttles should be allowed in the type-exempted pedelec class and whether S-pedelecs that exceed the 'factor of 4' (ratio of motor power to human power) stipulated in the vehicle safety regulations should be allowed (ibid).

8.3.5 United Kingdom

E-bikes are also known as electrically assisted power cycles (EAPC, in a variation of the EU's EPAC) in the UK (Department for Transport 2015). According to the DfT's information sheet, the EU standard has been adopted with conversion of motor cut-out speed to miles per hour (15.5 mph is equal to 25 km/h) and the following requirements:

- Lights and reflectors meeting the UK Road Vehicle Lighting Regulations, including front and rear lights, rear reflector and pedal reflectors (Secretary of State for Transport 1989)
- Labelling: e-bikes must be marked with the maximum speed the motor can propel the bike and the continuous power rating (current vehicles or EU standard vehicles) or be affixed with a plate that specifies the manufacturer name, continuous power rating and the nominal voltage of the battery (vehicles made prior to April 2015)
- Standards and approval requirements: e-bikes must meet applicable pedal cycle (UK Government 2015) and braking standards (International Organization for Standardization 2014). E-bikes that are not type or individually approved must meet applicable general safety and electrical requirements (European Parliament and Council of the European Union 2006)
- Age: UK riders must be at least 14 years of age.

All e-bikes above 250 W and/or 15.5 mph (25 km/h) are classed as mopeds and must be type approved (Muir and Garidis 2016). Throttle activated e-bikes were sold in the UK until recently. According to the Department for Transport's (2015) information sheet:

> *Because of the particular benefits for elderly and disabled users, pedal cycles providing electrical assistance without use of the pedals - usually called "Twist and Goes" - are included in the…GB classification provided they are capable of pedal operation and comply with the above restrictions on maximum motor power and assistance cut-off speed. However, under European law new "Twist and Go" vehicles will, from January 2016, have to meet a range of technical requirements before they can be used on roads. This will normally be established by "type approval" at the manufacturing stage but importers and individuals will be able to seek an individual approval for vehicles that have not been type approved.*

Regarding 'twist and goes', the Bicycle Association UK Executive Director notes:

> *The previous regulations dating back to 1982- a British Standard- were not incontestably clear regarding the legality of bikes with throttles, allowing 'twist and go'. In consequence, since then some models have been sold of this type, but generally very cheap, low quality Chinese imports. The new regulation makes it quite clear that 'twist and go' bikes are not exempt from type approval, and fall in the category of mopeds. However since the numbers of 'twist and go' models in circulation are relatively small, and because of their poor quality have a short life, such models purchased prior to the new regulation coming into force will be exempt from type approval. The DfT were loath to introduce a retrospective regulation, particularly given the small estimated numbers involved. This does, however, point up the importance of pressing ahead quickly with regulation to avoid an outcry from consumers already in possession of models requiring type approval* (P Darnton,10 September 2016, pers comm).

One UK manufacturer, Juicy Bikes (2015), has not given up on the 'open' throttle:

> *Twist-and-go Type Approval has yet to be outlined by the DFT. So, from January 1st 2016, all Juicy Bikes will be configured to conform with the 6km/h 'start up assistance' throttle outlined in the amendment. When the Type Approval process has become defined, and our bikes are then shown to comply with the criteria that process stipulates, we'll be able to restore the full speed throttle in the controller configuration.*

S-pedelecs are currently regulated in the same way as a moped, meaning registration, tax, insurance and motorcycle helmet are required.

8.3.6 United States of America

In the USA, the US Consumer Product Safety Act authorises the Consumer Product Safety Commission (CPSC) to promulgate rules governing e-bikes and lodge these rules in the Code of Federal Regulations. The CPSC defines 'low-speed electric' bicycles as a two or three-wheeled vehicle with fully operable pedals, a top speed when powered solely by the motor under 20 mph (32 km/h) and an electric motor that produces less than 750 W (16 CFR Part 1512 (2002). The definition is also found in the US Code (15 USC §2085 (2002)). This simple standard has been widely adopted at the state level, but does not cover the many nuances of the rapidly evolving e-bike marketplace. In practical terms, the majority of e-bikes are equipped with 250 to 350 W motors and a very small number have 500 W motors.

California's recent rulemaking provides an interesting case study. One author of this report was a participant and submitter during the rule development and observed a number of possible approaches (such as a weight limit) dropped from the final regulations. As presented in table 8.5, the 2015 law establishes three classes of e-bikes (State of California 2015). As the most populous state in the nation, it sets a precedent that will likely be emulated nationwide. Tennessee and Utah emulated it in 2016 and the system is under consideration in Colorado, Oregon, New York and Wisconsin (PeopleForBikes 2017b).

Table 8.5 Summary of e- bike regulation in California

Class	Description	Throttle	Power	Motor cut- out	Shared path?	Age
Class 1	Low-speed pedal-assisted electric bicycle	No	<= 750 W	<= 32 km/h	Yes	n/a
Class 2	Low-speed throttle-assisted electric bicycle	Yes	<= 750 W	<= 32 km/h	Yes	n/a
Class 3	Speed pedal-assisted electric bicycle Helmet, speedometer, prohibited on shared paths or protected cycleways unless authorised locally	No	<= 750 W	<= 45 km/h	No	>= 16

These three classes have been adopted by the Bicycle Product Suppliers Association (BPSA) 'in order to modernize electric bicycle law in the USA...to categorize electric bicycles and properly regulate them based on their maximum assisted speed' (PeopleForBikes 2017a).

The Californian regulations include a labelling requirement, prohibition on tampering with or modifying an e-bike to change its speed capability (unless the owner then appropriately replaces the classification label), and stipulate that a person operating any class of e-bike is not subject to financial responsibility (insurance), licensing, registration or licence plate requirements. Also, the California regulations continue to define an SSEB as a moped with a maximum speed of 30 mph (48.3 km/h) and treat such vehicles as completely separate from e-bikes.

On the Canadian Bion-X e-bike system, the start assist button is reprogrammed by the manufacturer for the North American market to act as a throttle up to the cut-out speed; the harder the rider presses on the button, the more torque the motor supplies. A member of the research team commutes with a Bion-X system and rarely uses the throttle button, as the pedal torque assistance (a) requires no thought or action; (b) improves range compared with use of the throttle button alone; and (c) feels more natural.

Nevertheless, a start assistance button (permitted under the EU 15194 standard) may address the concerns many survey respondents have with a potential EU-style prohibition on standard throttles.

New York City is the best-known example of an American jurisdiction that has banned all e-bikes. According to Gan (2016), the ban may be a result of takeaway food delivery riders. Most delivery riders use SSEBs, which are not perceived as bicycles by the public (McLeod 2015). There is a movement to realign New York state law with federal law and therefore permit electric assist bicycles (Gan 2016).

8.3.7 Japan

Under Japanese road laws, an e-bike that can run under its own power, without the cyclist pedalling, is in the same category as a motorcycle with an engine size of 50 cc or less and therefore require rider licensing and vehicle number plates. Bikes sold in Japan that meet the legal definition of an e-bike provide ‘electric assist’ while pedalling only. Throttle-activated models are available but subject to enforcement action if unregistered.

In Japan, there are no legal standards regarding battery and motor outputs. It is understood this is due to the fact that motor assist rate and ceiling speed are already established:

- Rules as at 2001: motors can provide full power assistance up to 15 km/h and limited assistance between 15 km/h and 24 km/h (Kokayu 2001). These speeds were established based on common understanding of the speeds of practical and sport bicycles, respectively. As the e-bike speed approaches 24 km/h, the assistance rate decreases proportional to speed so that there is ‘not a dramatic change in driving force at 24 km/h’ (ibid).
- Current rules: the assistance rate rules were simplified and raised, so motors can provide up to a motor to human assistance rate of 2:1 (Yamaha 2013).

Legal e-bikes have the Traffic Safety mark from the Japan Traffic Management Technology Association, the Bicycle Association Approved mark from the Bicycle Association of Japan and the Safe Goods mark of the Consumer Product Safety Association.

8.3.8 China

The land use and transportation systems of China and New Zealand are dissimilar. However, consideration of Chinese regulation is useful because of the many visitors and immigrants from China. According to Aia (2013), e-bikes are divided into three categories as of a 2013 revamp of the Chinese legislation (table 8.6). The western equivalents have been determined based upon interpretation of the source material.

Table 8.6 Chinese e- bike classes (based on Aia 2013)

Chinese class	Western equivalent
An intelligent e-bicycle (max weight 40kg) needs pedalling first to start the motor to move the wheels. This type is greener and more environmentally friendly, and could better suit the comparatively narrow roads in cities.	EU standard pedelecs (BSEB) without throttle
A pedal-assisted e-bicycle (or pedelec, max weight 50 kg) is flexible to pedal or electric, which enables commute in small cities or urban-rural transfer.	Twist and go e-bike (BSEB)
A pure e-bicycle (max weight 55kg) better suits rural areas where the road condition is good and the distance is greater.	Scooter style electric bike with vestigial pedals (SSEB)

Furthermore, the new legislation raises the e-bike motor cut-out speed limit to 26 km/h from 20 km/h and requires that electronic speed limiters are not removable (ibid). Chinese e-scooters (SSEBs) are treated like mopeds in New Zealand, with a top speed of 50 km/h.

8.3.9 Labelling

Labelling an e-bike enables simpler enforcement of one or more e-bike classes.

8.3.9.1 Labelling in the EU

According to the EU standard EN 15194 the frame must be visibly and durably marked with the word 'EPAC' (electrically power assisted cycle), the cut-off speed of the motor in km/h, and the electric motor maximum continuous rated power in watts (European Committee for Standardization 2009; Bike Europe 2016a).

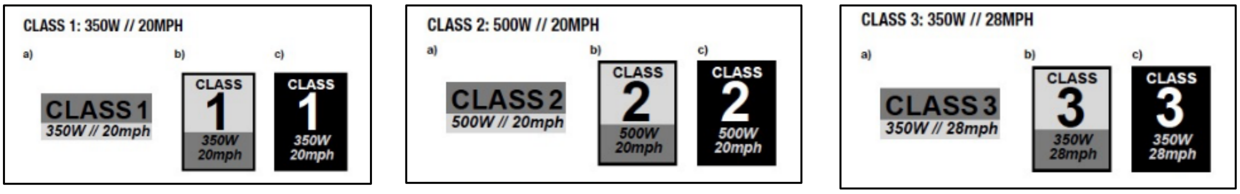
8.3.9.2 Labelling in the UK

As noted in section 8.2.4, e-bikes must be marked with the maximum speed the motor can propel the bike and the continuous power rating (current vehicles or EU standard vehicles) or be affixed with a plate that specifies the manufacturer name, continuous power rating and the nominal voltage of the battery (vehicles made prior to April 2015).

8.3.9.3 Labelling in California

Given the multiple classes of e-bikes, labelling has been designed that aids in quick comprehension and ease for enforcement. A generic sample (figure 8.4) of labelling compliant with Californian Assembly Bill 1096 outlines the class number, power rating of the motor and motor cut-out speed (PeopleForBikes nd). Note the wattages indicated are examples only; the bill brings California in line with the rest of the USA by specifying an e-bike may have up to 750 W.

Figure 8.4 Sample California class labels (wattage is an example, up to 750 W permitted)



8.3.9.4 Labelling for kit e- bikes

At present, motors often feature a power and motor cut-out speed label. This may be enough, although with enforcement being the aim of a labelling requirement it would be preferable if the police officer could just look for the label on the frame.

8.4 Powered mobility devices

8.4.1 Overview

Mobility devices can potentially cover a variety of different devices. However, by far the biggest contributor to this category in New Zealand are electric mobility scooters.[29] In practice, mobility scooters are treated similarly to pedestrians in many ways (eg allowed to use footpaths), they are still vehicles and

[29] Under current legislation, human-powered mobility tricycles (commonly used by disabled riders) are not classed as 'mobility devices', because the RUR requirement to be 'designed and constructed… for use by persons who require mobility assistance' only applies to powered vehicles, and no separate notice has been published under section 168A(1) of the Land Transport Act 1998 declaring them to be a mobility device. The Transport Agency is currently investigating resolving this anomaly.

not legally considered 'pedestrians' – refer to table 8.2 for the differences in their required operation. A summary of the status of mobility scooter users in various countries based on work conducted for the RCA Forum (Newman 2013) is provided in table 8.7.

Table 8.7 Legal status of mobility devices in selected countries

Country	Pedestrian	Bicycle	Road vehicle	Scooter
New Zealand[(a)]	✓			
USA	✓			
Australia	≤ 10 km/h		> 10 km/h	
UK	≤ 6 km/h	12.9 km/h limit	≥ 6 km/h	
Denmark	walking speed	15 km/h limit	✓	
Sweden	≤ 5 km/h	≥ 6 km/h		
Norway	walking speed	> walking speed	(uncertain)	
Belgium	walking speed	> walking speed		
France	≤ 6 km/h	≥ 6 km/h		
Netherlands	✓	✓		
Switzerland	✓	✓		
Ireland			✓	
South Africa			✓	
Canada	✓		✓	✓

(a) Mobility scooters are treated similarly to pedestrians, but do not have the same legal status as noted in section 8.4.2 of this report.

Further information on selected countries is provided in the following sections.

8.4.2 New Zealand

Mobility scooters have a specific vehicle classification under New Zealand legislation and do not require registration or a driver licence. Mobility devices are defined in the RUR, section 1.6 *Interpretation* as:

- *a vehicle that—*
  - *is designed and constructed (not merely adapted) for use by persons who require mobility assistance due to a physical or neurological impairment; and*
  - *is powered solely by a motor that has a maximum power output not exceeding 1 500 W; or*
- *a vehicle that the Agency has declared under section 168A(1) of the Land Transport Act 1998 to be a mobility device.* (NZ Government 2004)

As discussed in section 8.1.1, under the Land Transport Act (1998) mobility scooters are exempted from being considered 'motor vehicles'. At present, there is no requirement that riders of a mobility device must be disabled and no minimum age, so any person may ride one.

In New Zealand, mobility scooters may be operated on the footpath or on the leftmost practicable side of the road. Section 11.6 of the RUR states a 'pedestrian or rider of a mobility device or wheeled recreational device must not remain on the roadway, including a pedestrian crossing or school crossing point, longer than is necessary for the purpose of crossing the roadway with reasonable dispatch'. Under schedule 1, clause 5(3), the RUR also states ‘mobility devices are restricted to the footpath, where this is practicable’, although clause 11.1(3) goes further to say that if riding on the roadway, the user should keep ‘as near as practicable to the edge of the roadway’.

Some users may attempt to claim their e-bike, e-trike, or other LPV is a mobility device. The legislation states that a cycle is not considered a wheeled recreational device unless the wheels are no more than 355 mm (14 inches) in diameter; nor is a cycle a ‘mobility device’. In the case of *Gallagher vs Police* (1999), the appellant submitted that his cycle was in fact an ‘invalid wheel-chair’ because he suffered from a physical incapacity; however, the judge ruled the definition of a cycle is based on its *physical appearance* and not on its particular use.

The AS/NZS 3695.2:2013 standard for requirements and test methods for electrically powered wheelchairs (including mobility scooters) applies to devices with a maximum speed not exceeding 15 km/h, intended to carry one person of mass not greater than 300 kg (Standards New Zealand 2013).

8.4.3 Australia

In Queensland, a mobility scooter with a maximum speed of less than 10 km/h is treated as a pedestrian and registered as a motorised wheelchair. A device capable of over 10 km/h is a road vehicle, and so must be registered and licensed, and the operator must also be registered (Queensland Government 2015).

In New South Wales, a motorised wheelchair and a mobility scooter are both limited to no more than 10 km/h and riders are considered a pedestrian (Centre for Road Safety 2015). However, Road Rules section 15 (e) provides that a vehicle includes a ‘motorised wheelchair that can travel over 10 km/h’ while section 18 (a) defines a pedestrian as ‘a person driving a motorised wheelchair cannot travel at over 10 kilometres per hour (on level ground)’ (New South Wales Government 2014). No other information could be found regarding mobility devices that are defined as vehicles; however, registration would likely be required as in Queensland. Major retailers in NSW such as Advanced Scooters reference only the 10 km/h limit in their online page on NSW rules and state registration is not required (as would be the case given the treatment of riders as pedestrians).

A search of all Acts and Rules on the Victorian Law website returned no results for mobility scooter. A motorised wheelchair capable of more than 10 km/h is defined as a vehicle (Victoria Government 1983), although VicRoads makes no mention of this legal definition in a mobility scooter publication where the 10 km/h limit is emphasised (VicRoads 2010). In fact, the guide states mobility scooters cannot be registered as a vehicle.

Accordingly, it appears mobility scooters and motorised wheelchairs capable of speeds faster than 10 km/h may be able to use the road in at least some Australian jurisdictions. As noted in section 8.4.2, the Australian/New Zealand standard on motorised wheelchairs and mobility scooters defines these devices as capable of up to 15 km/h.

8.4.4 United Kingdom

Unlike Australia, the UK differentiates between low-speed footpath mobility scooters and higher-speed road capable mobility scooters. Table 8.8 presents a summary of the rules governing mobility scooters, based upon information published by the Department for Transport (UK Government 2016).

Table 8.8 Summary of UK mobility scooter rules

System	Criteria	Rule
Vehicle	Speed	Class 2: 4 mph (6.44 km/h); class 3: 8 mph (12.9 km/h)
	Motor power	Not specified
	Dimensions	Maximum width 0.85 m
	Weight	Maximum weight 150 kg unladen
	Braking	Must be 'effective'
	Registration	Class 3: must be registered; exempt from road tax
	Safety equipment	Class 3: horn, mirror, directional indicators with hazard function, front and rear lights and reflectors; amber flashing light (if used on dual carriageways)
User	User restrictions	Must 'have trouble walking (injury, disability, medical condition)' or be operated for demonstration purposes, training others, or maintenance support
	Age	Class 3: minimum 14 years
	Driver licensing	Not required; should be able to read a car number plate at 40 ft (12 m)
Environment	Footpath	All classes
	Road	Class 3 scooter may use road if travelling above 4 mph but must not use bus lanes, cycle-only lanes, or motorways.

The rules do not appear to specify how disability is to be proven. According to Thoreau (2015a) 'it is not clear whether these rules are being enforced'. The 12.9 km/h limit is 2.1 km/h lower than the otherwise similar New Zealand mobility scooter that can attain 15 km/h.

8.4.5 United States of America

In the USA, powered mobility devices are classified as an 'other power-driven mobility device' (OPDMD) by the Department of Justice, which has established an Americans with Disabilities Act (ADA) based policy called Credible Assurance (US Department of Justice 2014):

> *An entity that determines it can accommodate one or more types of OPDMDs in its facility is allowed to ask the person using the device to provide credible assurance that the device is used because of a disability. If the person presents a valid, State-issued disability parking placard or card or a State-issued proof of disability, that must be accepted as credible assurance on its face. If the person does not have this documentation, but states verbally that the OPDMD is being used because of a mobility disability that also must be accepted as credible assurance, unless the person is observed doing something that contradicts the assurance. For example, if a person is observed running and jumping, that may be evidence that contradicts the person's assertion of a mobility disability. However, it is very important for covered entities and their staff to understand that the fact that a person with a disability is able to walk for a short distance does not necessarily contradict a verbal assurance -- many people with mobility disabilities can walk, but need their mobility device for longer distances or uneven terrain. This is particularly true for people who lack stamina, have poor balance, or use mobility devices because of respiratory, cardiac, or neurological disabilities. A covered entity cannot ask people about their disabilities.*

8.5 Other LPVs

8.5.1 Overview

A summary of existing regulations is presented in table 8.9. A dash indicates the criterion is not applicable or information was not found.

Table 8.9 Selected other LPV standards or regulations

Place	Terms/ notes	V max	W max	Width max	Weight max	Age	Helmet	Locations
Norway	Self-balancing electric vehicles	20 km/h	-	85 cm	70 kg	-	-	-
California	Self-balancing electric personal assistive mobility device (EPAMD)	12.5 mph (20 km/h)	750 W	65 cm	-	-	-	Paths[a]
California	E-skateboard	15 mph (25 km/h) [b]	-	-	-	16	Yes	Paths or roads[c]
Queensland	Personal mobility devices (PMDs) [d]	20 km/h w/ 12 km/h control	-	85 cm	60 kg	12	Yes	Paths[e]
New Zealand	Wheeled recreational devices	-	300 W	-	-	-	-	Paths
Singapore	PMDs	25 km/h cycle paths /shared paths 15 km/h footpaths		70 cm	20 kg	-	-	Paths or roads

[a] According to the California Vehicle Code, 'speed must be reasonable and prudent regarding weather, visibility, pedestrians, and infrastructure conditions; speed must not endanger the safety of persons or property'

[b] California's speed limit applies at the user level, not the device level

[c] California allows e-skateboards on roads with a posted speed limit of 35 mph (60 km/h) or less, unless operated in a cycle lane.

[d] Queensland stipulates that PMDs have two wheels, thereby excluding e-unicycles.

[e] Queensland allows PMDs to be operated in the road for up to 50 m if the footpath is obstructed.

8.5.2 New Zealand

E-kick scooters and e-skateboards with less than 300 W power are considered wheeled recreational devices in New Zealand.

Yike Bikes do not meet the RUR definition of a wheeled recreational device (despite being powered by a 200 W motor under the part (b) limit) as they cannot be propelled by human power or gravity as per part (a) of the definition. They also cannot be considered a power-assisted cycle (due to no capability to pedal). Under section 168A(4) of the Land Transport Act 1998, the Transport Agency has declared the Yike Bike is not a motor vehicle and that the rider of a Yike Bike on any road or footpath must:

- wear an approved cycle helmet
- meet the provisions of clause 11.1 in the RUR 2004 that apply to 'wheeled recreational devices' (NZ Transport Agency 2014a).

Yike Bikes can be used on the footpath, if users comply with the requirements for wheeled recreational devices, although it is likely that most users are not aware of this. The literature review did not yield any overseas legislation specifically classifying Yike Bikes in other jurisdictions.

Self-balancing devices with a combined motor continuous power rating of 300 W or less are considered a wheeled recreational device. Few manufacturers list the continuous power rating of their device, instead referring only to the battery watt-hour rating (as consumers appear to be more interested in range). If the device has a continuous power rating above 300 W, then it would not be considered a wheeled recreational device. Because they are not considered a cycle or a mobility device (notwithstanding New Zealand case law on the Segway), this means a higher-powered device would be classified as a motor vehicle, unless specifically gazetted (none have been).

8.5.3 Australia

Following a safety review and consultation, the Australian Capital Territory is changing rules to permit Segways on footpaths, shared paths and roads where there is no footpath or nature strip:

> *Segways will generally be treated as pedestrians with some additional requirements placed on them, such as wearing an approved bicycle helmet and having lights, reflectors and a bell or other warning devices fitted to the Segway. The findings of the review showed that there is no reasonable basis for prohibiting Segways from being used on footpaths and shared paths in the ACT.* (ACT Government 2016b)

New South Wales banned all hoverboards in late 2015 in response to the battery fire issues with lower-quality models (Transport for NSW 2015). In a press release, the Transport Minister stated, 'Our road safety experts in the Centre for Road Safety are currently working with their counterparts across the country on national laws and safety standards for these personal electric transport devices, so we can figure out how and where people can use them safely' (ibid). According to the Australian Local Government and Municipal Knowledge Base, 'Austroads is currently (September 2016) in the process of developing a regulatory framework for personal electronic transportation devices (PETDs) in Australia. The framework will outline which devices are classified as PETDs and where on the network PETDs would be permitted to operate, for instance footpaths, bicycle paths, local roads, arterial roads, etc' (LGAM 2016).

For self-balancing 'personal mobility devices' in Queensland, including Segways and hoverboards, the government web page states personal mobility devices must only be used on paths, cannot be operated by children under age 12, and children between 12 and 15 must be supervised (Queensland Government 2015). Furthermore, they must:

- be designed for use by a single person only
- be self-balancing while in use and be powered by an electric motor
- have two wheels that operate on a single axis

- have a control to limit speed to 12 km/h or less and have a maximum speed of 20 km/h
- have a maximum width of 850 mm and a maximum weight of 60 kg – when not carrying a person or load.

By this set of requirements, Queensland omits the single-wheeled e-unicycle. Riders must wear an approved bicycle helmet, keep left on paths, give way to pedestrians, have a working warning device (such as a bell or horn), and have a working white front light and rear reflector when travelling at night. They may only be used on paths unless it is 'impractical not to, or if there's an obstruction on the path or nature strip – in these cases you're allowed to travel up to 50m on the road' (ibid).

In Victoria, the regulations state motorised devices with a power output of more than 200 W or which can exceed 10 km/h are classified as 'vehicles', but as they do not reach the minimum requirement under the Australian Design Rules (Vehicle Standard (Australian Design Rule – Definitions and Vehicle Categories) 2005), they cannot be registered (Pratt et al 2016).

8.5.4 Europe

In the EU, LPVs such as self-balancing devices, e-scooters and e-skateboards are to be excluded from new vehicle type approval regulations coming into force on 1 January 2017, although member states may continue to promulgate alternative regulations:

> *Two other categories that are excluded from type-approval are self-balancing vehicles (for instance Segway) and vehicles with not one seating position (for instance Trikke, Egret, etc.). As a result of this exclusion, member states may decide individually on the rules they apply to these vehicles. Consequently, the manufacturers may be confronted with very diverging requirements.* (Bike Europe 2016a)

A new harmonised voluntary safety standard (CEN TC 354) is being developed in part by the Motorized Leisure Vehicles Not Intended for Public Roads Working Committee, which is described as:

> *responsible for the product standardization of motorised recreational vehicle without licensing for public traffic which are determined for the transport of persons and goods (e.g. with internal combustion engines or electric impulse). The product standards are applicable for example, for go-carts, quads, mini motorcycles, motorised two-wheeled vehicles and motor cross vehicles. Competitive vehicles and play vehicles are excluded. Important standardization aspects are, e.g. safety related technical requirements for characteristics, test procedures, marking and performance.* (DIN Standards Committee 2016)

Despite the name of one of the participating committees in the working group alluding to a potential focus on private space, the standard will cover devices that are intended for use in the public right of way. According to Oortwijn (2016c), the standard:

> *…will provide safety requirements for personal light electric vehicles (PLEV)…intended primarily for the transportation of one person in (an) urban environment…The standard will "exclude vehicles having a maximum speed above 25 km/h…in public spaces, they are already permitted on cycle tracks and sidewalks at a maximum speed of 6 km/h. 'Due to the permitted tolerance, members of the working group have anticipated a possible future regulation with the addition of a specific button to switch to pedestrian mode,' mentions Emmanuel Husson. He continues: 'The vast majority of manufacturers already offer a speed regulation system that could be useful if future legislation imposes a speed limit to be respected'.*

Norway defines a self-balancing electric vehicle as limited to 70 kg, width not exceeding 85 cm and speed not exceeding 20 km/h (Norwegian Ministry of Transport 1994).

8.5.5 United Kingdom

In the UK, self-balancing devices are banned from pavements and public roads, as noted under the Segway topic (section 8.6).

8.5.6 United States of America

With a focus on hoverboards and as noted in section 8.2.5, UL has developed a standard for the electrical safety of 'personal e-mobility devices'; however, this does not consider the use of the devices.

Regulations on self-balancing devices in many states refer to electric personal assistive mobility devices (EPAMDs), although these rarely explicitly state that a user must be mobility impaired. More information on EPAMDs is provided in section 8.6.5.

A ban on e-skateboards has been recently reversed in California (California Legislature 2015), although riders must:

- be at least 16 years of age and wearing a helmet
- have a front light on the board or on the rider visible at least 300 feet in front of the board
- have a rear reflector on the board or on the rider
- have a white or yellow reflector on each side
- only ride on streets with a speed limit of 35 mph (60 km/h) or less, unless ridden in a cycle facility
- not operate at speeds above 15 mph (25 km/h).

The California legislation exempts electrically powered skateboards from classifications of motorised skateboards that are currently prohibited. Local authorities (including universities) continue to remain able to prohibit or restrict the use of any type of wheeled device, including e-skateboards.

8.5.7 China

In China, e-kick scooters and self-balancing devices have become increasing popular despite being in a legal grey area (Liu 2016):

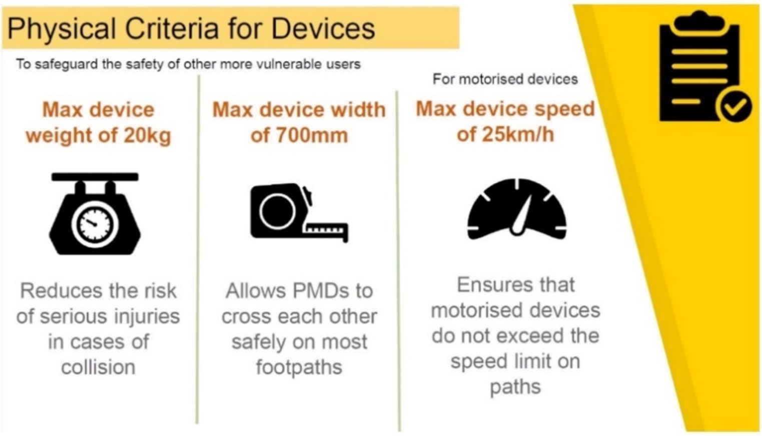
> *Under China's current Road Traffic Safety Law, electric scooters and unicycles are classified as neither motorised vehicles nor non-motorised vehicles. This has made it somewhat difficult to ascertain their legal status when it comes to accidents and other traffic incidents.*
>
> *At present, the authorities in a number of cities – notably Beijing, Shanghai, Shenzhen, Wuhan, Nanjing, Suzhou, Hangzhou, Nanchang, Xiamen and Sanya – have deemed the use of self-balancing electric unicycles and electric scooters as contrary to regulations. Three cities – Beijing, Shanghai and Wuhan – have gone as far as to ban their use entirely. Overall, Wuhan has taken the hardest line, with users subject to an Rmb50 fine every time they are stopped by the police.*
>
> *Given that the underlying traffic and transport problems that spurred the uptake of electric scooters remain unresolved, it is expected that the civil authorities will soon have to address the legal standing of such devices.*

8.5.8 Singapore

Singapore's Active Mobility Advisory Panel conducted public surveys, focus group sessions and experiential surveys during peak hours to arrive at recommendations on a range of LPVs termed 'personal mobility devices' (PMDs) (Active Mobility Advisory Panel 2016). The panel recommended the minister adopt a range of behavioural rules for PMDs, such as require devices to have lights; limit their speed to 15 km/h on footpaths and 25 km/h on roadways; and prohibit devices not meeting certain physical characteristics. Those requirements have been adopted by government and are now published online, along with a list of non-compliant devices (Singapore Land Transport Authority (LTA) 2016).

This framework is illustrated in figure 8.5.

Figure 8.5 Regulatory framework for personal mobility devices (PMDs) in Singapore



The LTA has also produced a chart for the applicable locations where PMDs are permitted (figure 8.6).

Figure 8.6 Locations where PMDs are permitted (source: LTA)

Mode / Type of PMD	Footpaths [Speed Limit of 15km/h]	Cycling/Shared Paths [Speed Limit of 25 km/h]	Roads
Personal Mobility Aid *e.g. motorised wheelchairs, mobility scooters*	✓	✓	×
Conventional Bicycle	✓	✓	✓
Personal Mobility Device e.g. kick-scooter, electric scooter, hoverboards, unicycles	✓	✓	×
Electric Bicycle	×	✓	✓

8.6 Segways

The Segway brand has achieved public recognition as a generic category of self-balancing LPV. Accordingly, the literature review found enough references in legislation and associated documents to address the Segway type device separately from all other LPVs. It should be noted some of the standards and regulations described in section 8.5 also cover Segways.

8.6.1 New Zealand

Segways are specifically mentioned by the Transport Agency as LPV that meet the definition of motor vehicle (and therefore should not be used on the footpath) but do not meet some of the required standards, and therefore cannot be used on a road (NZ Transport Agency 2016a). Presumably the latter reference refers to being used on a roadway (the portion of a road generally used by motor vehicles).

A motor vehicle is defined by the Land Transport Act 1998 as 'a vehicle drawn or propelled by motor power'. There are several exceptions given to this definition, but Segways are not explicitly mentioned. Three possible exceptions that a Segway could fall under are:

> *(vi) a pedestrian-controlled machine; or*
>
> *(vii) a vehicle that the Agency has declared under section 168A is not a motor vehicle; or*
>
> *(viii) a mobility device*

A pedestrian controlled machine is intended to describe a machine that is operated by a pedestrian standing on the ground behind it (e.g. lawn mower or mechanical roller) and the person has to walk to keep up with the machine. If the person is standing on the device and is moved by it, they are no longer a pedestrian (T Hughes, pers comm). Therefore, a Segway would not qualify as a pedestrian-controlled machine. There have also been no specific gazette notices declared under section 168A regarding Segways. The Transport Agency has indicated in online information that Segways are not considered mobility devices (NZ Transport Agency 2016b), although this is not officially documented within the Land Transport Act or gazette notices.

There is reasonable cause to consider Segways a personal mobility device, and therefore provide their users the same opportunities as mobility scooters. In 2012, a disabled Segway user was prosecuted by NZ Police for using a Segway on a footpath. The District Court ruled in favour of the Police, but, on appeal to the High Court, the judge ruled in favour of the defendant and ordered a reversal of the original ruling, saying:

> *On the balance of probabilities, I am satisfied that the Segway [Personal Transporter] ridden by Mr Summers on 14 June 2011 was a vehicle that came within the exception provided for in section 2 of the Act, being a mobility device, because it was designed and constructed (that is not merely adapted) for use by persons who require mobility assistance due to a physical or neurological impairment; and it was powered solely by a motor that has a maximum power output not exceeding 1500 watts. For this decision to provide any useful guidance as to whether other Segway users comply with section 2(a) of the act, the vehicle used plainly will also need to be constructed with the same maximum power output constraints* (Summers vs New Zealand Police 2012)

This case law suggests that people with mobility impairments should be allowed to use Segways on New Zealand footpaths, as mobility devices, ie in a similar way to how mobility scooters are allowed. The judge was satisfied the Segway was originally developed with its potential use as a mobility device in mind; he was less sure whether all Segways met the criteria of a 1,500 W maximum power output. For those models that do, however, it would seem they would automatically be classified as a mobility device under the Land Transport Act. There may be some question of whether able-bodied people should also be allowed to use them; however, current New Zealand legislation is framed around the attributes of the *vehicle*, and not the attributes of the *user*. There is not currently any regulation regarding whether or how people should have to prove they have a disability to use a mobility device, and this sentiment is echoed by the case of Gallagher vs New Zealand Police (1999), which deemed vehicle definitions 'are not based on the subjective views of the user or on the use to which the particular user wishes to put the thing'. Alternatively, in the USA the principle of 'credible assurance' has been employed for this purpose as noted in section 8.4.5.

8.6.2 Australia

The Australian states of Queensland and Northern Territory have a specific classification for Segway-type self-balancing devices that allows them to be used by anyone on footpaths and shared paths. In ACT, Western Australia, Victoria and Tasmania only people accompanied by a licensed Segway tour operator can use Segways on footpaths, shared spaces and bicycle lanes.

In ACT, Segways are only permitted to be ridden if hired from a commercial lakeside operator (Lawson 2016). However, wider Segway use and categorisation as a bicycle was being considered by the government as of March 2016 (ibid). The article cites a government discussion paper that includes the following safety findings:

- A Canadian study in which 143 riders rode an average of about 63 km each on footpaths, bicycle paths and roadway shoulders resulted in no serious injuries.
- Since January 2013, Canberra's Segway operator had submitted about 18 incident reports, mostly resulting in grazes, cuts and bruises, with three 'more serious' incidents.
- The risk of injury is similar to pedestrian activity and lower than cycling activity.

The actual discussion paper and consultation materials were not found on the ACT government website.

Additional regulations that apply to Segways and other self-balancing devices such as hoverboards is presented in section 8.5.3.

8.6.3 European Union

In the EU, the overall situation is similar to the USA, but it is implemented in several different ways for historical reasons. In some countries, a separate classification has been created, much like in the USA. Use is typically permitted on footpaths, shared spaces and cycle lanes, and/or on roads. In many countries, the Segway PT is treated as an electric bicycle (despite the higher power output), so it can be used wherever bicycles are allowed (this includes footpaths in many jurisdictions). In a few places, it is registered as a type of mobility scooter or a type of moped, and operated according to local rules. The one standout exception to this is the UK, where Segway PTs are not permitted on roads or footpaths.

8.6.4 United Kingdom

Segway PTs cannot be used on the road or on the footpath in England and Wales. The following guidance has been issued by the Crown Prosecution Service.

8.6.4.1 Segway (and other self- balancing scooter) use on roads

> *The Department for Transport view is that the Segway Personal Transporter is a motor vehicle. The Vehicle Excise and Registration Act 1994 (VERA) states that every mechanically propelled vehicle used or kept on a public road should be registered and licensed. As self-balancing scooters are mechanically propelled they require registration and a vehicle registration licence (tax disc). Additionally, the user would need a driving licence and motor insurance. Other legal requirements relate to construction and use, and to lighting.*
>
> *The DfT considers the Segway Personal Transporter to be a motor vehicle for the purposes of the Road Vehicles (Construction & Use) Regulations 1986. To obtain registration, a vehicle would need to comply with basic safety standards. Most two-wheeled vehicles being registered*

are made in accordance with the European rules which came into operation on 17 June 1999.This is known as the European Community Whole Vehicle Type Approval (ECWVTA) and applies to vehicles capable of more than 4mph. A vehicle with a certificate of conformity to ECWVTA is eligible for licensing and registration in the UK.

The DfT is not aware of any self-balancing scooters which have ECWVTA. Indeed, the European Commission have indicated to the DfT that:

'No EC whole vehicle type- approval has been sought as the Segway is not primarily intended to travel on the road. If this manufacturer (or manufacturer of a similarly propelled vehicle), should eventually decide to seek EC type approval for such a vehicle intended for road travel, [the Commission] consider that it would need to be on the basis of Directive 2002/24/EC on the type approval of two or three wheel vehicles…Member States have the right to lay down the requirements which they consider are necessary to ensure the protection of road users (i.e. may fix the conditions for allowing non EC type-approved vehicles on its roads).'

However, in this country we have not introduced separate legislation on this subject. Further there is no separate legislation for non-EC type-approved vehicles.

Two or three wheeled vehicles not approved to ECWVTA could theoretically meet the requirements of the Motorcycle Single Vehicle Approval (MSVA) scheme. If so, they would be eligible for licensing and registration. However, despite such requirements being less stringent, according to the Department for Transport it would nevertheless appear to be difficult for self-balancing scooters to be rendered capable of passing the MSVA inspection.

8.6.4.2 Segway use on pavements

Self-balancing scooters (such as segways, mini segways, Hoverboards and single wheel electric skateboards) may not be driven on a pavement in England and Wales. Under section 72 of the Highway Act 1835 (extends to England and Wales only) it is an offence to wilfully ride on the footway. Certain vehicles used by disabled drivers are exempted from these requirements but only where they use Class 2 or Class 3 invalid carriages. Self-balancing scooters are not classed as invalid carriages and so cannot be used on pavements. (Crown Prosecution Service 2016)

8.6.5 United States of America

Segways are permitted under the Americans with Disabilities Act (ADA) and many state laws. Under the ADA, the US Department of Justice Disability Rights Section has defined the Segway PT as an OPDMD (US Department of Justice 2016). Credible assurance of a disability is generally required (refer section 8.4.5).

If the OPDMD is being used by a person with a mobility disability they generally must be allowed into all areas where the public can go – including roads, footpaths, shared paths, parks, and public and private facilities accessible to members of the public. Local governments, businesses and organisations can restrict use based on an assessment of a class of vehicles (rather than a particular brand). Most states have passed legislation to allow OPDMDs on footpaths and urban streets with a speed limit of 30 mph (50 km/h) or lower. However, OPDMDs may be excluded from areas or streets with high pedestrian volumes.

In 2002, organisations such as America Walks and the American Council of the Blind unsuccessfully lobbied to prevent the legalisation of the Segway HT (as it was then known) for use on sidewalks. A position paper originally hosted on the council's official website has been removed, but a copy is still present on the International Center for Disability Resources on the internet (Crawford 2002). Most of the objections listed appear to be contradicted by the current specifications and operating characteristics of the Segway as found on the manufacturer's website, and ultimately the campaign failed to stop the legalisation of the Segway PT.

The California Vehicle Code (CVC) provides a definition covering Segways and similar self-balancing devices:

> *The term 'electric personal assistive mobility device' or 'EPAMD' means a self-balancing, nontandem two-wheeled device, that is not greater than 20 inches deep and 25 inches wide and can turn in place, designed to transport only one person, with an electric propulsion system averaging less than 750 watts (1 horsepower), the maximum speed of which, when powered solely by a propulsion system on a paved level surface, is no more than 12.5 miles per hour.* (State of California nd)

However, section 21280 of the CVC goes further than federal regulations to establish the rationale for permitting EPAMDs, rules of use and responsibilities of users. Benefits include the ability of EPAMDs to 'enable California businesses, public officials, and individuals to travel farther and carry more without the use of traditional vehicles, thereby promoting gains in productivity, minimizing environmental impacts, and facilitating better use of public ways' (ibid). Section 21281 sets out minimum device requirements including reflectors, stopping system, lights (if operated during hours of darkness), and a sound emitting device. Similar to New Zealand's RUR 11.1, other sections of the CVC set out rules of use for EPAMDs, summarised as:

- Speed must be reasonable and prudent regarding weather, visibility, pedestrians and infrastructure conditions; speed must not endanger the safety of persons or property.
- An EPAMD must not be operated with wilful or wanton disregard for persons or property.
- Users must yield the right-of-way to all pedestrians on foot, including persons with disabilities using assistive devices and service animals that are close enough to constitute a hazard.

Section 21282 of the CVC provides that local authorities may regulate the time, place and manner of EPAMD use (ibid).

9 Regulatory options

9.1 General

This chapter assesses a number of possible regulatory criteria for e-bikes and other LPVs (mobility scooters, self-balancing vehicles, electric kick scooters, e-skateboards etc). Infographics and tables (refer section 8.5.8) illustrate the physical criteria and allowable usage locations for PMDs in Singapore. This gives an example of how a regulatory framework in New Zealand might be constructed; ie using multiple criteria with justifications in terms of safety and effect on other road/path users, although the actual values and criteria chosen for New Zealand are likely to be different. The advantage of using a criteria-based system is that it can also be applied to any future vehicles/devices that appear in the New Zealand market.

9.1.1 Criteria applicability

Some criteria will be applicable to certain devices but not others. The various criteria considered are shown in table 9.1. Note that a tick (✓) represents a consideration, not necessarily the adoption of a criterion.

Table 9.1 Overview of criteria to be considered for regulatory frameworks for various LPV categories

System	Criteria to consider	Device categories		
		E- bikes	Mobility devices	Other LPVs
Vehicle	Speed	✓	✓	✓
	Motor power	✓	(a)	✓
	Throttles	✓	n/a	n/a
	Dimensions	✓	✓	✓
	Weight	✓	n/a	✓
	Braking	✓	(b)	✓
	Standards	✓	✓	✓
	Certification/registration	✓	✓	✓
User	Mobility impairment		✓	✓
	Age	✓	✓	✓
	Driver licensing	✓	✓	✓
	Helmets	✓	n/a	✓
Environment	Usage locations	✓	✓	✓

(a) All known mobility devices fall within the current 1,500 W regulation.

(b) Most mobility scooters are motor braked; no precedent was found for regulation beyond existing standards.

9.1.2 General classes

Section 8.1 provides a full accounting of existing vehicle classes and associated legislation, with a graphical representation shown in figure 8.2. The literature review revealed many similar terms used for other LPVs, as listed in table 9.2.

Table 9.2 Terms for other LPVs

Term	Source	Notes
Wheeled recreational devices	New Zealand	Does not reflect the transportation-oriented nature of some other LPVs
Personal electric transportation device (PETD)	Australia	Term under consideration by Austroads for single rider devices for recreational or commuting use
Personal e-mobility devices	UL, North America	Term used in context of electrical safety standard and not related to any legislation
Personal light electric vehicle	Europe	Term used in context of electrical safety standard and not related to any legislation
Personal mobility device (PMD)	Singapore	The word 'mobility' does not have a connotation of mobility impairment; same acronym and two of the same words as powered mobility device (NZ term that includes mobility scooters).
Electric personal assistive mobility device (EPAMD)	California Vehicle Code	Established for Segways without mention that users must be mobility impaired
Other power-driven mobility device (OPDMD)	US Department of Justice	The term is used for a class of devices including Segways in the context of rules for the implementation of the ADA.

Common words used in these terms include the following:

- Device vs vehicle: the term 'device' may help differentiate these mechanical contrivances from larger vehicles.
- Personal: helps reflect that all these contrivances are intended to be used by only one person.
- Mobility: use of this term can result in confusion with respect to devices designed for use by people with mobility impairments as well as existing New Zealand legislation.
- Power, electric or 'e': all of these terms help differentiate motor-assisted devices from un-powered conveyances, while electric or 'e' helps differentiate the devices from traditional internal combustion vehicles (at least until such time as electric cars become prevalent, if at all).

While the term 'low-speed' is not commonly used in relation to the reviewed other LPVs, it may be appropriate to consider (as discussed in section 2.2.3. In terms of helping clarify the terms used in the vehicle classes, the research has identified the following key opportunities:

AB (power-assisted pedal cycle) class may be redefined to include more than one maximum motor-assisted speed for e-bikes.

Mobility devices may be redefined to include not only powered mobility scooters but also any other LPVs intended for, or used as a mobility device. This may necessitate implementation of requirements to prove or provide credible assurance of an impairment as is the case in the USA. This would permit mobility impaired users of LPVs otherwise prohibited from the footpath to use the footpath, and close an existing loophole that allows anyone to ride a mobility scooter on the footpath.

If mobility devices remain available to all persons regardless of disability and the definition revised to exclude reference to impairment, then the term PMD or personal transportation device (PTD) could be used for all LPVs other than e-bikes, including mobility scooters. While simple to administer and understand, increasing numbers of able-bodied persons may choose to use mobility scooters on footpaths leading to an increase in conflicts and injuries.

Wheeled recreational devices currently include those with a motor of up to 300 W and many of the devices covered by this research. Austroads is considering the term PETDs, as noted in section 8.5.3. The term 'recreational' or 'transportation' may misrepresent users' intentions; the more neutral term 'mobility' has a different connotation in New Zealand. Administratively it would be easier to retain the existing wheeled recreational devices class for unpowered devices, and add PETDs, but this could lead to confusion given the similar appearance of unpowered and powered versions of the same device types.

If there are to be separate categories reflecting the differences between low-speed models designed for footpath use and higher-speed models designed to be used on paths or roads, then this could be accommodated through the definitions, additional classes, sub-classes, or rules. Fewer classes will be simpler to administer and enforce, and easier for the public to understand. On the other hand, a blanket approach may reduce mobility options.

Separate classes of powered and unpowered pedal cycles already exist as previously noted. If separate classes for powered and unpowered mobility scooters and other devices were not established, then the powered aspect could be captured in databases such as CAS through a tick-box for 'electric powered' across all vehicle types.

9.1.3 Arguments against over-regulation

Reasons for regulating LPVs, based on their safety and health features have been presented in chapter 7, and the regulatory frameworks currently in place in New Zealand and overseas have been presented in chapter 8. In addition to these factors, some researchers have raised concerns relating to the potential outcomes of certain regulatory approaches that should be taken into account when developing the regulatory framework.

Dill and Rose (2012) raise the question of introducing policies aimed at increasing the number of people who use e-bikes, to help obtain the personal and social benefits that can arise from people choosing to ride e-bikes rather than use less active forms of transport.

McMullan (2016) warns against over-regulating vision requirements for mobility scooter users, suggesting current research is inadequate and governing health professionals and policy makers may not understand the abilities and needs of the low vision mobility scooter user. The researcher worked with four mobility scooter users with low vision and found each had methods of self-regulation to ensure their own safety, although observed some details during the study that could 'cast doubt on participants' ability to self-regulate and self-educate". The researcher recommended education would be more effective than regulation, as the latter could act as a barrier to scooter use and cause some people to stop using their scooter altogether, which would significantly decrease their quality of life. The researcher's concluding comment was: 'It would be difficult to match the quality of life allowed by the scooter through any other intervention other than returning their eye sight and their mobility. While to onlookers a person with low vision using a mobility scooter may seem risky, to the user the alternatives are more so.'

A number of workshop participants and survey respondents felt strongly that over-regulation would be counterproductive to mode choice and mode shift goals, suggesting instead the answers lie in education to improve behaviour and/or reducing motor vehicle speeds through engineering and enforcement.

9.1.4 Appropriate speed on footpaths

This discussion concerns footpaths only; refer to the next section for a discussion regarding shared paths.

In order to inform a potential regulatory or advisory approach governing LPVs, it is useful to first consider the typical speed of various pedestrian types. According to the *Pedestrian planning and design guide*

(Land Transport NZ 2007, p3-3), the 'vast majority of people walk at speeds between…2.9 km/h and 6.5 km/h'. A selection of specific pedestrian types and their speeds is presented in table 9.3. The elite marathoner value is presented for context – the principal values for consideration are the typical jogging and running speeds of average people. The maximum unpowered kick scooter speed is based upon the author's anecdotal observation on flat ground in Christchurch.

Table 9.3 Range of walking and running speeds

Person or activity type	Speed (km/h)	Sources
Elderly pedestrian	4.4	Land Transport NZ (2007)
Fit adult pedestrian	5.5	Land Transport NZ (2007)
Typical jogger	10–12	Derived from Virkler (1998)
Fit runner	14	Calculated based on Hart (2015)
Unpowered kick scooter	15	John Lieswyn
Elite marathoner	21	D. Kimetto, World Record

In Singapore, a simple 15 km/h default speed limit applies to all wheeled users of a footpath and 25 km/h for shared paths and cycle paths. Three different vehicle speed maximums were commonly cited in the consultation undertaken for this research. The pros and cons of each is given in table 9.4.

Table 9.4 Potential LPV speed limits for footpaths

Speed (km/h)	Pros	Cons
6	Equivalent to a brisk walk Most comfortable for pedestrians with mobility/vision/hearing impairments Consistent with typical 'turtle'/'footpath' mode on many LPVs and top speed of UK class 2 mobility scooters	Significantly reduced speed compared with the highest speed of most devices and preferred speed of most users Difficult to achieve on a bicycle without wobbling, especially for novice cyclists learning to ride
10	Equivalent to a jogging pace Suitable for young cyclists	May seem overly restrictive to some device users, especially e-bikers and also riders of unpowered bicycles. Applying a speed limit less than running speed unlikely to be seen as reasonable by LPV users
15	Roughly equivalent to a running pace Median value in typical operating speed range (5–25 km/h) of an LPV Enables legal use by slower LPVs such as the majority of hoverboards which can go up to 12.9 km/h Minimises travel time Consistent with maximum speed for powered wheelchairs and mobility scooters in AS/NZS 3695.2:2013	Less compatible with walking pace pedestrians than alternatives

If a national default standard or guidance is established, it is likely implementation would need to be at RUR level. Signs and/or markings would clutter the built environment, be costly and create an ongoing maintenance issue.

9.1.5 Speed limits on shared paths

A speed limit may be appropriate for certain types of paths and might be combined with permissibility of various types of e-bikes or LPVs. Some policy makers and advocates have considered dealing with some of the design issues of shared paths by imposing a legal speed restriction on such paths (DTMR 2014; Dessent 2015), ie even if an e-bike or other LPV is capable of a higher speed, an operating speed limit would apply to overcome design deficiencies. The Australian report *Speed limit setting on shared paths* (Rees 2011) found jurisdictions typically rely on education and advisory signage to encourage appropriate travel speeds rather than regulatory speed limits.

There is already power to establish speed limits for roads via the Setting of Speed Limits Rule (NZ Transport Agency 2003) at 'designated locations'; this could be clarified to apply to paths of various types. Inclusion of guidance on speed limits for shared paths within the Setting of Speed Limits Rule and/or the *Cycle network guidance* (CNG) would help improve consistency between local authorities.

While unpowered cyclists are currently bound by urban speed limits regardless of having a speedometer, the occasion for exceeding urban speeds is generally limited to steep downhills or low-speed shared use zones. A wider application of regulatory speed limits for shared paths could be unrealistic given the limited resources available for enforcement. Based on available police resources[30], the cost of signage, and the potential difficulties posed by many unpowered vehicles, entry-level e-bikes and other LPVs lacking speedometers, the enforcement of posted speed limits may prove to be prohibitive on a wide scale. Therefore, users are likely to regard posted speed limits as guidance rather than regulation.

It is not appropriate to establish a national standard speed (such as 25 km/h, as Singapore has done) for all shared paths as the safe operating speed will depend on the land use context, path dimensions, user volumes and user composition.

9.2 E-bikes

9.2.1 Speed

As discussed in section 7.1, speed is more directly related to safety outcomes than power. Managing speed at the *user* level via compliance with speed limits is discussed in section 9.1.5. The following options discussion covers managing speed at the *vehicle* level by instituting a maximum motor-assisted speed. To achieve this smoothly, the controller will taper off the level of assistance approaching the threshold speed. This, in theory, puts less onus on the user and can be regulated at the point of manufacture, import or sale.

25 km/h would maximise safety relative to other potential higher values but also makes e-cycling less attractive relative to driving motor vehicles, and hence may actually reduce safety at the population level (again, 'safety in numbers'). However, many respondents to the survey conducted for this research noted that unpowered commuting cyclists regularly exceed 25 km/h and supported a higher value. Although it would limit model choices, some suppliers already ship from Australia and harmonisation with the Australian

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[30] NZ Police representatives consulted for this research indicated enforcement of path speed limits would probably not be a high priority or commonplace occurrence.

approach could further benefit suppliers and consumers. It appears the prevalence of speed limiter tampering is higher in countries with a 25 km/h limit than in the USA, where the limit is 20 mph (32 km/h).

32 km/h would encompass e-bikes designed for the USA market. It is also roughly equivalent to the speed capability of most existing (ungoverned) e-bikes already on New Zealand roads. This value received the most support from e-bike owners surveyed as part of this research. This option reduces the incentive to tamper with speed restrictions and improves the attractiveness of cycling relative to other motorised travel modes. The Transport Agency may also consider whether 35 km/h, as an increment of 5, is simpler than 32 km/h. By first principles, the lower value would be safer.

45 km/h (subject to additional restrictions not applicable to pedal cycles in general) would enable users who want to travel faster but still to cycle (as opposed to just riding a moped), to ride S-pedelecs. It also maximises travel time competitiveness with other modes, especially for longer journeys on suburban, rural and inter-urban routes with fewer potential conflicts. Any shift from motor vehicles to e-bikes is likely to lower the total social cost of crashes, as the lighter weight of an e-cyclist will do less harm to other road users in a collision.

A benefit of permitting S-pedelecs (with a 45 km/h power assistance limit) is that a wider range of rider needs can be met.[31] while still providing rulemaking flexibility; the same may be achieved by bringing this type under moped rules as in the EU. However, the Californian legislation recognises that a class 3 e-bike (an S-pedelec) is still a bicycle in the traditional sense (as opposed to a moped), and cannot be operated by throttle only. In California, class 3 e-bikes are not subject to registration requirements and therefore are more accessible than mopeds.

No maximum motor- assisted speed. Opponents to blanket motor assistance speed thresholds for e-bikes that are to be used in mixed traffic environments may suggest unsafe speed behaviour is a matter of road use appropriate to the conditions and capabilities of the vehicle. In other words, much like motor vehicles, users of e-bikes should simply abide by the prevailing posted speed limit or other regulatory speed restriction. It may then be argued that a speedometer would help a cyclist to not exceed a posted speed limit. This is the background to California's requirement that class 3 e-bikes must have speedometers. Advantages of this option include:

- It does not require enforcement of speed governors, which can be subject to tampering (section 7.1.2). NZ Police has identified this as an issue given current resources.
- It does not introduce an extra burden on importers who are currently bringing in ungoverned e-bikes, although it should be straightforward to source models destined for overseas markets where the speed restrictions already apply.

The disadvantages of this option include:

- Permitting ungoverned LPVs while achieving road safety objectives to minimise harm may require the establishment of speed limits with limited enforceability (refer section 9.1.5).
- Riders tend to adopt a speed they consider to be safe around other path users rather than watching numerals on a display. This may lead to speed compliance issues.

[31] Rider needs vary depending on the location and trip needs; 25 km/h may be appropriate in town or city centres, 30 to 35 km/h in local or suburban streets, and 45 km/h on arterial or rural roads

- A comparison between pedal cycles and motor vehicles is not entirely relevant, given the latter invariably require features such as motorcycle helmets, safety belts and other in-vehicle protection systems to minimise the severity of higher-speed crashes.
- All other countries reviewed for this research set a maximum motor-assisted speed.

9.2.2 Power

This assessment of limiting power is based upon previous discussions:

- Continuous power rating is the preferred measure (section 2.2).
- There are potential safety benefits of regulating power (section 7.2.1).
- There is a case for power levels higher than 250 W to accommodate heavier loads and steeper gradients (section 7.2.2).
- The existing 300 W power limit is not consistent with overseas values and creates marketplace issues that should be resolved (section 8.3.2).

There is justification for retaining a relatively low power limit in order to set a ‘cap’ on speed capability, should users tamper with the e-bike motor assistance cut-out limit. However, power requirements are affected by factors such as gradient, gross vehicle weight, wind resistance and temperature. Providing separate power limits for sub-classes of e-bikes (as in the EU) could help achieve multiple policy goals, but it may be simpler to select a single higher limit (as in the USA) that applies to all classes and rely instead on speed as the primary performance related criterion. Five possible power values are considered.

250 W would be consistent with the pedelec class in Europe and Australia, and for many topographies and riders would be sufficient. Having a lower power class with a lower acceleration capability may be more suitable for younger riders. There is also a view that permitting higher power but constraining motor cut-out speed would encourage consumers to tamper with the speed limiter (directly in the controller software or by ‘fooling’ system sensors). However, the Swiss approach recognising topographical requirements also has merit.

300 W is the existing limit and would be the simplest option. While 300 W would encompass the 250 W EU standard, it has led to numerous false claims by importers due to competitive pressures within the marketplace (section 8.3.2). This research found strong support from survey respondents and key stakeholders for an alignment with either the 250 W EU standard or a higher standard used overseas (chapter 3).

500 W would support the use of e-bikes in hilly topographies and/or e-bikes used for carrying cargo, pets and/or children. Stipulating too low of a power rating can limit the uptake of e-cargo bikes for carrying people, pets, and goods delivery and/or use in hilly places like Wellington and Auckland. This value aligns with the current Swiss limit, which was set at double the EU’s pedelec power limit to facilitate e-bike use in a hilly country.

750 W is referred to in USA legislation as equivalent to one horsepower (perhaps simply a convenient differentiator between e-bikes and motor vehicles). In practical terms, the USA marketplace is occupied primarily by 250 and 350 W e-bikes, with a few 500 W models. Policy makers in New Zealand could de-emphasise power as a criterion by adopting a single value applicable to any class of e-bike. The USA limit of 750 W seems to be high enough to provide for heavy loads and steep hills, while not being so high as to blur the line between a bicycle and a moped.

1,000 W is the value used in the EU 'powered cycle' class, in line with the EU's 'power of four' rule for S-pedelecs that limits continuous power to four times the human input (a typical rider generates 250 W to climb a hill). As noted previously, the disadvantage of this relatively high level is the incentive to tamper with the governor may be higher given the potential speeds owners could reach.

9.2.3 Throttles

As discussed in section 2.5, the motor power of an e-bike can be controlled by PAS (magnetic or torque) and/or throttles (push button or twist 'n' go). Experience from other countries shows the most contentious issue regarding e-bike regulation is the presence and role of a throttle. Two basic options are considered: permitting open throttles or only pedelecs where the motor is only activated if the rider pedals.

9.2.3.1 Rationale for throttles

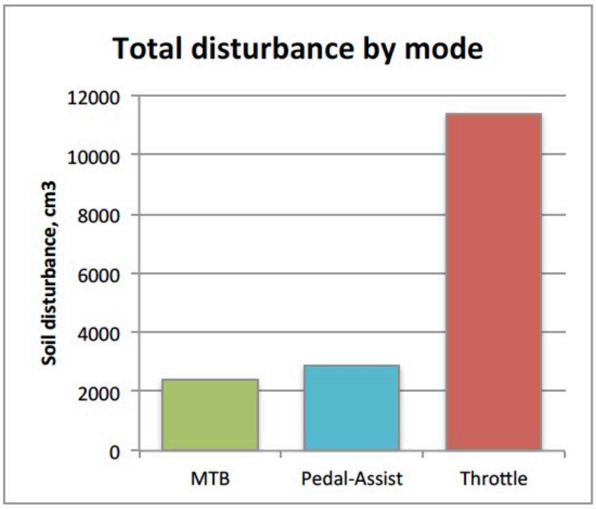
Open throttles (also called a throttle e-bike or twist and go e-bike) can be used even when the rider is not pedalling, at any speed (up to the threshold speed, if applicable). The term 'open' differentiates a full-speed throttle from a 6 km/h start assist throttle permitted under EU standards and rules. If the user is not required to pedal at all, it could be questioned whether the e-bike is still a bike, or rather a form of electric scooter. On the other hand, throttles may offer a number of advantages:

- A reduction in instability during acceleration from a stop. Magnetic and even some torque PAS are not sensitive enough to activate the motor until the bike has started to move, which can be a challenge for a heavy bike and/or on an uphill gradient.
- Provide nearly instantaneous power delivery, which can be particularly useful when the user needs a quick acceleration, eg to avoid conflicts with motor traffic.
- Enable people with mobility impairment or fitness limitations to gradually increase their capabilities, and feel comfortable knowing if they cannot continue pedalling they still have a means to get home or to a safer place.
- Some e-bike owners consulted in this research who have open throttles indicated they do not use the throttle as a 'cruise control' at the limit of the cycle's speed; constant use of the throttle drains an e-bike battery rapidly and hence throttles are used sparingly.
- Open throttles enable riders of lower-priced magnetic PAS equipped e-bikes to more accurately control speed in constrained situations such as shared paths.
- Prohibiting open throttles would limit the market to models designed for the European pedelec class, which would increase the price of e-bikes in general and reduce the 'safety-in-numbers' effect of more people riding.
- Despite philosophical opposition from some stakeholders (Bike Europe 2015), allowing open throttles aligns with EU regulations effective 1 January 2017.
- While there are arguments for greater or lesser safety with or without open throttles, no empirical studies were found providing evidence of such claims.

Pedelecs with the option for push (start) assist throttles limited to <6 km/h are more beneficial in health terms than those where human power is optional (ie throttle e-bikes). The majority of major brand pedelecs are now coming equipped with a torque PAS (section 2.5.6), that retains the feel and handling properties of an unpowered pedal cycle (section 2.5.3).

Off-road, pedelecs are easier to control than a throttle e-bike over bumps and in tight situations. As indicated in figure 9.1, research conducted on mountain bike trails in Oregon found in contrast to throttle e-MTBs, pedelec e-MTBs do not disturb trail surfaces substantially more than unpowered MTBs (IMBA nd).

Figure 9.1 Comparison of soil disturbance for unpowered, pedelec and throttle MTBs (source: IMBA)



9.2.3.2 Rationale for pedelecs without throttles

The rationale for pedelecs is also based upon the disadvantages of throttles as follows.

- A throttle is an additional control on what may already be a complex handlebar (to some users), which places an additional demand on user cognition. Increasing the cognitive load may mean the user is distracted from other operational tasks, such as paying attention to surrounding traffic.
- Several survey respondents indicated bikes with throttles were difficult to learn how to ride at first.
- Throttles may also increase speed differentials with unpowered cyclists during initial acceleration (ie when queued cyclists at a traffic signal receive the green light) and therefore increase the risk of collisions with those riders.
- Unintended acceleration due to accidental activation of the throttle could occur.
- Controlling power via a throttle can seem less natural compared to having to pedal the bike, and thus the user is more likely to experience unanticipated levels of acceleration.
- Throttle e-bikes usually have a magnetic PAS that drives the bicycle up to a maximum power level set on the handlebar console or motor power switch. This can be frustrating and complex for some users, and may lead to unintended speeds not appropriate to surrounding traffic or shared path conditions.

Requiring S-pedelecs not to have a throttle may be acceptable given S-pedelecs are generally high-end vehicles with adequate power and responsive torque sensors. This would also exclude SSEBs that might be designed to otherwise meet all the S-pedelec class requirements – ensuring an S-pedelec remains a bicycle in form and function.

9.2.3.3 Discussion

For e-bikes, some survey respondents described throttles as an ‘auxiliary’ means of activating the motor and did not consider many people would rely on the throttle alone. This may be especially true for users who have longer trips to make, as not providing any human power can drain the battery rapidly. There is strong support among the industry and existing users not to regulate open throttles.

When the concept of European style 'push-assist' throttles limited to 6 km/h was explained to stakeholders, this was generally seen as addressing the key benefits of a throttle except for one: providing mobility impaired riders with the certainty they will be able to complete their journey regardless of physical condition.

The direction both the EU and California are taking in terms of providing separate categories for pedelecs and throttle e-bikes is described in section 8.3. Separate categories in New Zealand would enable the creation of an incentive for pedelecs if that is considered desirable. If open throttles were permitted, they could be disadvantaged by specifying a lower-speed capability than the other e-bike classes. This disadvantage might be based on the philosophical case that a pedal cycle is not a pedal cycle if you do not have to pedal, and the potential for improved health when human propulsion is needed versus 'twist and go' operation.

In summary, the safest and most pleasurable e-bike might be one that has both a torque sensor and a start assist button. A start assist feature can overcome the limitation of some torque sensor systems that do not offer instant acceleration (ie there remains a delay until the cycle has attained some motion). However, this is not currently a common feature set on lower-priced bikes specified by New Zealand importers. This feature set would not necessarily address the concern of people with mobility impairments or fitness limitations. Throttle e-bikes might be reserved only for those with a bona-fide disability.

9.2.4 Dimensions

As detailed in section 8.5.8, the Active Mobility Advisory Panel (2016) recommends the Singaporean government adopt a maximum width of 700 mm for conventional (unpowered) bicycles, but does not make any recommendations for regulating the width of e-bikes.

In New Zealand, the Land Transport Rule vehicle dimensions updated at the end of 2016 increase the maximum allowable width of bicycles from 1.0 to 1.1m, thus there is already a restriction that applies to e-bike widths. The majority of commercially available cargo bikes fall below this maximum width. Retaining this existing maximum will help avoid issues for other users on facilities of restricted width such as shared paths or separated cycleways.

9.2.5 Weight

The survey responses and literature review on safety (chapters 3 and 5 respectively) indicate the increased weight of e-bikes affects their ease of manoeuvrability and consequences of crashes compared with unpowered bicycles. As discussed in section 8.3, the regulations from Europe, China and Singapore involve weight restrictions for various types of e-bikes. In some cases, limiting the weight may also serve as a proxy for limiting the motor power; however, the researchers recommend the former criterion should not be used to replace the latter. Conversely, limiting the motor power may have a limiting effect on the viable weight of a device.

The researchers do not consider it necessary to limit weight, as the benefits of encouraging more utility cycling are considered to outweigh any safety gains. If weight is included as a criterion, the additional weight of the frame and container used in a cargo bike should be taken into consideration in setting a reasonable threshold.

9.2.6 Braking

As noted in section 7.6.1, brake requirements are defined in AS/NZS 1927:1998 *Pedal bicycles – safety requirements* (Standards New Zealand 1998). While the standard includes mention of a 0.2 kW motor option in the definition of a pedal cycle, the braking performance specification does not mention any need for electrically assisted cycles to have a more powerful braking system than an unpowered cycle. The standard could be updated to provide for more powerful brakes on class AB power-assisted pedal cycles. This is covered in more detail in the next section.

Braking systems for e-bike kits and homebuilt e-bikes are not explicitly covered at present. This suggests a need to include a term such as 'must have an effective brake on each wheel' in the Land Transport Rule: Light-vehicle Brakes and/or in the definition of a class AB cycle (NZ Transport Agency 2002). The most current e-bike and/or pedal cycle safety standard should be referenced in the rule.

9.2.7 Standards, certification and registration

9.2.7.1 Standards

Declaration to meet the applicable product safety standards, including AS/NZS 1927, is required for all manufacturers in New Zealand or importers (section 8.3.2). However, these standards are dated. In addition to the EU standard for pedelecs, a new ISO standard for all e-bikes is in development. Land Transport Rules and applicable New Zealand standards could be updated to be consistent with (or simply refer to) international standards. The advantage of retaining the status quo is reduced importer compliance costs and therefore lower consumer costs. The adequate maintenance and safety of all e-bikes would remain a function of cycle shops and ultimately the owners.

9.2.7.2 Certification

Certification to meet technical standards is more rigorous than a declaration of conformity and is intended to ensure vehicle safety. Certification and the vehicle standards are incorporated into various Land Transport Rules (www.nzta.govt.nz/resources/rules/). Vehicle standards do not currently apply to class AA and AB pedal cycles. In Europe, e-bikes that are not pedelecs or have a maximum motor-assisted speed higher than 25 km/h must be type approved and certified to meet vehicle standards. If New Zealand adopts the EU framework for throttle e-bikes and/or S-pedelecs, including requiring type approval with references to vehicle standards, many models designed for America would not be legal here.

Certification only addresses the safety of the e-bike when new; if the vehicle standard were to apply for these classes of e-bikes then some means of confirming that users were replacing key components (frame, handlebars, motor, battery, rims, lighting, and the console) with equivalent approved components would be needed. Three options for implementing the ongoing maintenance aspect of meeting vehicle standards are suggested as follows.

1 As with mopeds, a WOF could be waived – although this will minimise cost, it will not help ensure certain classes of e-bikes are safe. The maintenance requirements of a pedal cycle (especially a heavier e-bike) are higher than for mopeds, which are designed with weighty/durable components similar to those found on motorcycles.

2 Enforcement of the component replacement aspect could be left to the courts in the event of a serious injury – as few injury crashes are likely to result in a prosecution, this would **not** be the most effective way to maintain safe vehicles (but it would be the lowest cost approach).

3 Authorised existing service centres could be given the ability to complete a warrant of fitness type scheme. This would have the best chance of success in delivering a safe e-bike fleet. Many users are already paying for maintenance, and the marginal cost of implementing the scheme may not be significant in terms of the total maintenance expenditure. Cycle shops are more likely to advise component replacement with original equipment quality parts if they are part of the process.

The Transport Agency could investigate the administration and user costs of extending ongoing vehicle standards compliance to e-bikes that are deemed to be subject to those standards. Alternatively, provision could be made for one or more classes that are not treated the same as pedal cycles but the reference to vehicle standards could be omitted.

9.2.7.3 Registration

Registration is a thorny issue. According to the Transport Agency[32], the primary purposes of the Motor Vehicle Register are:

- *enforcement of the law*
- *maintenance of the security of New Zealand*
- *collection of charges imposed or authorised by an act*
- *administration and development of transport law and policy.*

The benefits include gathering information on the composition of the e-bike fleet, providing a means to communicate safety information or product recalls to owners, and ensuring that the e-bike is maintained appropriately. On the other hand, to many impediments will constrain the market and reduce the safety in numbers effect. In Europe and the USA, the lower speed classes of e-bikes are treated the same as unpowered pedal cyclists, who are not subject to registration. In Europe, S-pedelecs (e-bikes with motor power in the range of 1,000 to 4,000 W and motor assistance provided up to 45 km/h) are defined as a motor vehicle and must be registered. In order to further incentivise pedelecs (for reasons previously noted), a registration requirement might also be stipulated for e-bikes with an open throttle. Carriage of a proof of registration card might be sufficient, as a requirement to display a number plate could be confusing and require manufacture of special size plates.

Another advantage to registration is that traceability and theft recovery potentially improves, although a national voluntary registration[33] could be a more effective way to reduce theft and aid recovery.

9.2.8 Age

Section 6.2 shows that the cognitive ability and motor skills of younger users are not yet fully-developed, and teenagers in particular are more prone to risky behaviour. Older users, on the other hand, may suffer reduced mobility, reduced reaction times and physical deterioration which could increase their likelihood of being involved in a crash and, more importantly, the consequences of those that do occur (section 6.3). Internationally, several localities have a minimum age for e-bike use, but none have an upper limit (see section 8.3.1); any concerns with elderly riders might be better addressed through requiring a competency test above a certain age, rather than an across the board upper threshold.

A rule permitting footpath cycling by those aged 12 and under (and accompanying adults) has been assessed in separate research (Abley Transportation Consultants and Mackie Research & Consulting 2016). This research report does not recommend e-bike use on footpaths. If a minimum age of 16 is implemented for one or more classes of e-bikes, then this may promote unpowered or lower-powered cycling on the road for a period of four years during which the child can gain experience. An advantage to selecting age 16 is that official identification (eg driver licence) is more often carried. NZ Police consulted for this research indicated that despite a legal requirement for members of the public to provide details during a traffic stop, in practical terms it is easier to rely upon a driver licence.

[32] www.nzta.govt.nz/vehicles/how-the-motor-vehicle-register-affects-you/

[33] Voluntary cycle registration schemes have been implemented in Beijing, London, Vancouver, and many US cities. The NZ Police snap.org.nz website is another means of registering any high value item.

Age limit options are as follows. Some options may be combined (eg a minimum age and a maximum age).

9.2.8.1 No age restrictions

This would involve self-regulation by users and/or their parents. This would not achieve any safety improvement over the existing unrestricted situation.

9.2.8.2 Minimum age of 12

This exceeds the age (10) typically considered to be appropriate for independent riding in traffic (section 6.2). As noted previously, research has concluded that a rule permitting those aged 12 and under (and accompanying adults) to ride on the footpath has merit (Abley Transportation Consultants and Mackie Research & Consulting 2016). If several classes of e-bikes are adopted including both pedelecs and throttle e-bikes, this age could apply just to lower speed (ie 25 km/h) pedelecs. Exceptions might be allowed for organised and supervised tours and/or off-road use.

9.2.8.3 Minimum age of 14

This is consistent with the value the Children, Young Persons and Their Families Act 1989 uses as the cut-over from child to young person. This age would be more liberal and potentially result in higher levels of cycling compared with 16 years, but harder to enforce as 14 year olds do not typically carry a driver licence[34]. In many countries, the minimum age is 14 (table 8.3).

9.2.8.4 Minimum age of 16

This is easier to enforce as most people aged 16 and older carry a driver licence. It may be especially appropriate for e-bikes that can match urban motor vehicle traffic speeds. The higher cognitive load requirements of throttle e-bike operation (relative to simply turning the pedals, as with an unpowered cycle) could be addressed with a minimum age of 16. For S-pedelecs capable of continuous speeds similar to urban motor vehicle traffic, a full knowledge of traffic law is considered necessary and therefore a driver licence and minimum age of 16 may be appropriate.

9.2.8.5 Competency test and permit for young riders

On e-bikes capable of speeds above 25 km/h, a competency test and permit for young riders instead of blanket minimum age would offer more flexibility but at an increased cost.

9.2.8.6 Maximum age of 75

This would help address safety concerns with increasing frailty (section 6.3); however, it may be discriminatory against those who remain competent and fit into older years. Safety gains may be offset by decreased mobility and health benefits. A competency test for older riders may be a challenging proposition unless associated with driver licensing, which is not being considered for pedal cycles in general. It would also be at an increased cost administratively.

9.2.9 Driver licensing

There is no current requirement or move towards requiring unpowered cyclists to hold a driver licence. Some EU member states (but not American states adopting the Californian/BPSA classifications) require 45 km/h S-pedelec riders to hold a driver licence (section 8.3.4). An S-pedelec rider can consistently attain peak speeds between 40 km/h and 45 km/h on the flat, and research shows an average speed

[34] Legally, details must be provided to a police officer on request. However, police consulted in this research advise that it is easier to confirm details if a licence is carried.

about 7–8 km/h faster than for unpowered riders (section 5.1), which even the fittest unpowered rider would not likely be able to maintain. Given these peak speeds are similar to those attained by moped riders who must hold a licence, there is a case for considering a licence requirement. As S-pedelecs are expected to be a relatively small proportion of the e-bikes sold in New Zealand, the impact of licensing on uptake will probably be no more than minor.

9.2.10 Labelling

As noted in section 8.3.9, EU rules and USA states adopting the Californian/BPSA classification system specify tamper-proof labels including EPAC or type (EU) or class (USA), motor cut-out speed and rated motor power. Labels are an effective means of providing information to consumers and assist in enforcement. If New Zealand adopts a variation of either the EU or BPSA classifications, a New Zealand-specific label would need to be developed. However, this is considered a low-cost requirement. For any pedal cycle retrofitted with an electric motor kit, a compliant label could be provided by the kit supplier or a retailer to be affixed by the installing mechanic or consumer.

9.2.11 Helmets

Riders of S-pedelecs may point to the ability of an unpowered rider to achieve 45 km/h or more, especially on a downhill. However, S-pedelecs are capable of sustained speeds close to that of mopeds, whose riders are currently compelled to wear a motorcycle helmet. As of the writing of this report, two manufacturers have developed helmets complying with the draft NTA 8776:2016 S-pedelec helmet standard (NEN 2016). Depending on the timing of policy and rule making, it may be appropriate to require or recommend riders use a helmet complying with the final S-pedelec helmet standard. S-pedelec helmets are further discussed in section 8.1.4. California requires class 3 S-pedelec riders to wear a cycle helmet; adult riders (older than 17 years) are not required to wear a helmet on any other type of pedal cycle (section 8.3.6).

9.2.12 Usage locations

9.2.12.1 Footpaths

A separate Transport Agency research project is considering footpath cycling for children. As e-bikes are proposed to be limited to those who are older than 12, 14 or 16 (section 9.2.8), it is not anticipated they would be permitted on any footpath.

9.2.12.2 Shared paths

Around the world, e-bikes limited to 25 km/h (or 32 km/h in the USA) are allowed on shared paths, although local authorities are permitted to designate prohibitions for certain locations.

An exception is the S-pedelec: Germany and Switzerland permit them on shared paths and cycle facilities (respectively) only if the motor is turned off, while they are simply not allowed on shared paths in California (section 8.3). The German/Swiss approach would be difficult to enforce but makes more sense especially in rural shared path settings. A blanket prohibition on S-pedelec shared path use is simple, but especially in New Zealand networks with a high proportion of shared paths where the alternative is high-speed, high-volume arterial roads, then it may be too restrictive.

A typology of shared pathways, applicable to most New Zealand situations, could be developed f various e-bike classes (if more than one class is adopted). The typology might take into account shared path width, user volumes, and/or standard (eg a ‘cycle superhighway’ with few driveways and pedestrians between urban areas). A default national policy and guidance could be established within the online CNG to help local authorities consistently approach the designation of (or application of speed limits) on shared paths for one or more classes of e-bikes.

9.2.12.3 On-road cycle facilities

It is assumed that all types of e-bikes would be permitted in standard cycle lanes. California initially considered prohibiting e-bikes (or at least class 3 S-pedelecs) from protected cycle lanes, but ultimately prohibited only mopeds from these facilities. No other jurisdictions are known to prohibit any type of e-bike from on-road cycle facilities, and this research did not yield any justification for doing so as a default.

As noted in section 5.1, the incidence of overtaking increases slightly for faster riders using e-bikes but dramatically for slower riders using e-bikes (versus the same groups using unpowered cycles). The latter may be a proxy for a large potential audience (those for whom an e-bike addresses critical barriers to cycling, and may not be experienced riders). Therefore, wider cycle lanes would help minimise conflicts (section 10.3.1).

9.2.12.4 Off-road trails

Various policies and guidelines have been developed to manage e-bike access designated ‘commuter link’ trails and wider trails in Wellington’s Open Space network; most grade 1, 2, and 3 parts of the NZ Cycle Trail network; and designated grade 1 or 2 trails in the Department of Conservation public lands (section 8.3.2). Evidence is emerging that low-powered (eg 250 or 350 W) torque PAS e-bikes (ie without a throttle) are appropriate for more challenging mountain bike trails. A national policy or guideline document could be a template or reference for local jurisdictions and improve consistency from the user’s perspective.

9.3 Other LPVs

The following assessment of regulatory criteria has been informed by the preceding research and the vehicle data summarised in appendix B.

9.3.1 Speed

The importance of a device-level speed restriction is dependent on what is speed limit is adopted for vehicles on footpaths (section 9.1.4) and the access criterion for other LPVs (section 9.3.11). Options above 35 km/h have not been considered as there are fewer LPVs that can attain such speeds, and would effectively be similar to no speed restriction.

10 km/h would maximise safety in pedestrian interaction situations; however, disadvantages include:

- It would create a differential with the existing standard (15 km/h) for mobility devices.
- Many LPVs can exceed this speed and it would be difficult to ensure compliance of a lower speed at the point of manufacture or import, given that most LPVs are not manufactured in New Zealand and many are purchased online.
- It would be difficult to enforce on paths and roads given current enforcement resources and priorities.
- A speed limit designed for pedestrian interaction does not account for potential use on roads.

15 km/h would be consistent with the maximum speed of mobility scooters sold in New Zealand, but has the same compliance and enforcement disadvantages as mentioned for 10 km/h.

25 km/h aligns with EU and Australian rules for pedelecs and is consistent with the capabilities of many devices. Adoption of this value would be similar to the Singaporean approach, which specifies a maximum vehicle speed of 25 km/h (applicable when used on shared paths and cycle paths) and a maximum user speed of 15 km/h (applicable to footpaths).

35 km/h encompasses many more LPVs and improves travel time competitiveness compared with other motorised modes. Based on the safety analysis (section 5.3), other LPVs are generally considered to be less safe than bicycles in mixed traffic conditions where this top speed would be most appropriate.

No speed restriction would be the simplest approach, but has similar disadvantages as noted for e-bikes (section 9.2.1).

9.3.2 Power

For powered mobility devices, the marketplace has a large range of models available that fit within the current 1,500 W limit. There is no evidence to suggest a change is needed. If mobility devices were to be included in a broader class as part of a simplification of vehicle classes (section 9.1.2), then the broader class could set 1,500 W as a cap for all devices or differentiate between types within the class. Although more complex for the public, the simplest solution from an administrative standpoint would be to retain separate power limits for mobility devices and all other LPVs.

Self-balancing devices require more power to ensure stability during sudden leans or bumps. This is the key performance measure and a case where more power equals greater safety (instead of more power equalling greater speed and therefore less safety). Therefore, power limits should be set substantially higher than 300 W or not be applicable to self-balancing devices. If self-balancing devices are to be allowed on footpaths, limiting the achievable rate of acceleration could also improve the safety of devices by limiting the differences between devices and pedestrians. However, it would be impractical to introduce acceleration or a proxy like torque without an accompanying testing regime, as these values are not commonly included in manufacturer specifications.

The following power options are considered for other LPVs.

250 W would limit product choices much more than for e-bikes. This is because most countries do not set a power limit on other LPVs, and manufacturers have therefore developed many models that have ratings higher than 250 W. This option would be more appropriate if a top speed is adopted of less than 25 km/h (section 9.3.1) and/or other LPVs are limited to footpaths only (section 9.3.11). As noted previously, mobility devices and self-balancing devices would need to be excluded.

300 W is the simplest option as it is the existing limit. The same disadvantages as with the 250 W option apply.

750 W would be consistent with California’s approach to e-skateboards. It is not known if that approach was based on a scientific assessment or just adopted in line with the USA e-bike rules, which were originally set because 750 W is roughly 1 horsepower (the traditional threshold for definition of a motor vehicle in the USA). This option would encompass virtually all known other LPVs except Segways (a full size Segway has two 750 W motors, although the continuous power across both motors is not likely to be 1,500 W due to the operational design). If the Segways are to be permitted, they would then have to be assigned a separate class or clearly defined as a mobility device.

1,500 W would be simple from the standpoint that only one value would be needed for all other LPVs including mobility devices. It is expected 1,500 W would be sufficient for self-balancing devices, given that this is the power of a full-size Segway. This option also provides the potential for mobility devices to be amalgamated into a broader class. It does not address potentially unsafe speeds for e-scooters and e-skateboards and should only be considered in conjunction with a limit on speed.

No power limit would be consistent with most other countries and would remove significant uncertainty for suppliers and consumers (given that manufacturers generally do not publish continuous rated power specifications for other LPVs). As with higher limits such as 1,500 W, this option should only be considered in conjunction with a limit on speed. Unlike e-bikes, no devices are known to be marketed to tamper with the speed governors on other LPVs. Therefore, removal of the existing 300 W power limit may not result in adverse safety outcomes.

9.3.3 Dimensions

Mobility scooters are typically between 50 and 70 cm wide (appendix B). No restrictions on the physical size of mobility scooters were identified in any of the overseas regulations reviewed.

In theory, mobility scooters could cause a problem if they were so wide they impeded other users on footpaths or shared paths. Such a width would likely render the devices impractical in a household setting and therefore there is little demand or supply of very wide devices. The survey for this research did not reveal any significant concerns from the part of users or non-users about the size of mobility scooters, so there does not appear to be any need to consider restricting their width.

For all other LPVs, as noted in table 8.9, overseas width regulations range from 65 cm (California) to 70 cm (Singapore) and 85 cm (Norway, Queensland). These restrictions provide for operation of LPVs on footpaths without causing problems to other users. Of the 48 devices considered by the Singaporean panel, only one, the Segway x2 SE was wider than 70 cm; this Segway is advertised as an all-terrain model, suitable for outdoor work environments such as farms or construction sites, and therefore is less likely to be used on public footpaths. Accordingly, the 70 cm value may be sufficient to accommodate most PTDs currently manufactured.

In New Zealand, there is potential for wide LPVs to cause problems for other users on narrow footpaths. While the number of Segway users is not expected to increase dramatically, there is potential for Segway tours to become more popular if the rules are changed to allow them on the footpath, and encountering multiple wide LPVs at a time would be more of a concern for other footpath users. Therefore, there is reason to consider addressing the width of these devices through regulation.

In the absence of any published justification or research on dimensions affecting safety, a 70 cm width appears to be a simple value that would encompass most vehicles (refer appendix B). Further primary research could be undertaken to confirm these values.

9.3.4 Weight

Mobility scooters weigh between 50 and 200 kg (appendix B). It is acknowledged that a heavier device colliding with another user or physical object would cause more damage than a lighter device travelling at the same speed. However, no restrictions on the weight of mobility scooters were identified in any of the overseas regulations reviewed.

For all other LPVs, as noted in table 8.9, overseas weight regulations range from 20 kg (Singapore) to 60 kg (Queensland) to 70 kg (Norway). Of the 48 devices considered by the Singaporean panel, 19 of the 48 devices reviewed weighed more than the 20 kg threshold. None weighed more than 60 kg.

The weight range of devices in this category varies significantly. Although greater mass can increase the severity of injury in any crashes that occur with other vulnerable users, weight can also be associated with the on-board redundant safety technologies and materials used which protect the operator in the event of collision with motor vehicles (Xu et al 2016). Three possibilities for weight restriction include:

1 No weight restrictions

2 Limit the weight of other LPVs to maximise safety of other vulnerable users, but minimise the range of devices available (eg 20 kg)

3 Limit the weight of other LPVs to maximise safety of riders and other path users as well as the range of devices available (eg 60 kg).

9.3.5 Braking

Braking systems for mobility scooters and other LPVs are discussed in section 7.6. The literature review undertaken for this research and field testing did not reveal any performance deficiency that could be remedied more effectively through regulation than the existing process of compliance with applicable standards. Section 9.3.6 covers certification of LPVs to applicable standards more broadly.

While a homebuilt self-balancing device will not be common due to the technical sophistication required, vehicles such as motorised shopping trolleys and motorised chilly bins (portable ice coolers) are potentially unsafe. For example, motorised coolers commonly sold through auto parts stores online are equipped with a single low-quality pedal cycle brake. To ensure deficient homebuilt or low-quality production LPVs can be assessed at the roadside for braking safety, the phrase 'must have an effective stopping system, including using brakes and/or motor control' could be added to legislation and/or rules. While the interpretation of 'effective' would be up to the officer, a performance standard would be difficult to assess at the roadside.

9.3.6 Certification and registration

At present, there is no requirement for owners to certify LPVs. Manufacturers must declare compliance with applicable electrical, vehicle and other product safety standards (section 8.2). As noted in section 8.5.4, the EU is working on CEN TC 354, a safety standard for personal light electric vehicles. When published, this standard could be referenced in Land Transport Rules and in the establishment of any vehicle class in which LPVs would be included.

The purposes and merits of registration have been discussed in relation to e-bikes (section 9.2.7). Registration could also assist with determining the composition of the vehicle fleet (planning purposes) and contacting owners (eg in the event of a safety defect or recall). If registration was implemented, a permit or label could be issued. Disadvantages to required registration include the administrative burden, cost to consumers and potential barrier to uptake. The UK requires a simple mail-in registration for class 3 road legal mobility scooters. Vehicle information required is limited only to the make, model and year of manufacture. No registration plate is required to be displayed. No other countries appear to require registration of other LPVs.

9.3.7 Mobility impairment

If most or all LPVs covered in this research are ultimately permitted on footpaths (in some cases only subject to certain speed regulation), then there will be no barrier for mobility-impaired persons to choose one of these devices. If a device a mobility impaired person wants to use is not permitted on footpaths, there may be a need to consider exceptions.

At present, there is no requirement in New Zealand that the user of a mobility device be disabled. The UK requires mobility scooter users to have an injury, disability, or medical condition (section 8.4.4), while the USA requires credible assurance of a disability (section 8.4.5). Limiting mobility devices to those with a bona fide need to use them is in the public interest as it reduces the number of powered devices with whom pedestrians must share the footpath.

If this principle is adopted, the legislation needs to account for the fact that the nature of what is considered a mobility device is evolving. This research has found e-scooters with a seat are lower cost alternatives to mobility scooters that can easily be carried on board public transport while some self-balancing devices are the preferred means for some people with declining stamina to stay mobile and engaged in their communities. It could be argued the definition of mobility device may need to be expanded, and this would be feasible if it could be assured the users really need the device and any preferential access the 'mobility device' classification entails. For example, if Segways were ultimately not permitted for the general public in New Zealand, it could be they are permitted for persons who are disabled.

If powered mobility devices are to be restricted to impaired users only, further explore and consider whether a permit scheme such as mobility parking permits or the 'credible assurance' policy in force in the USA is more appropriate for New Zealand. That said, it is prudent to bear in mind the warnings from McMullan (2016) (section 9.1.3) that more information is required to appropriately define the requirements for operating a mobility scooter and over-restrictive regulations will significantly decrease the quality of life of would-be mobility scooter users.

9.3.8 Age

9.3.8.1 Mobility devices

At present, there is no minimum age for use of mobility device in New Zealand and many other countries. The UK requires mobility scooter users to be at least 14 years old. A minimum age requirement denies mobility-impaired children who have the maturity and physical ability as determined by parents, guardians and/or doctors to access an important means of travel and engagement with their environment. The issue is that there is no requirement to prove or provide credible assurance of disability (section 9.3.7).

9.3.8.2 All other LPVs

No age restrictions would involve self-regulation by users and/or their parents. This would not achieve any safety improvement over the existing unrestricted situation. However, some LPVs are specifically designed for children (eg low speed hoverboards and e-scooters). No minimum age is considered appropriate for LPVs limited to 15 km/h or less because (pragmatically speaking) children are already using footpaths on unpowered kick scooters at these speeds.

If separate LPV speed classes (eg 15 km/h and 25 km/h) are not adopted (section 9.3.1), then it may be necessary to consider a minimum age due to risks inherent in their use that are higher than for unpowered versions of wheeled recreational devices (section 6.2).

Minimum age of 12 exceeds the age (10) typically considered to be appropriate for independent cycling in traffic (section 6.2). Queensland requires LPV users to be 12 years of age. This option is also consistent with footpath cycling rules research (Abley Transportation Consultants and Mackie Research & Consulting 2016), which concluded a rule permitting those aged 12 and under to ride on the footpath has merit.

Minimum age of 14 is consistent with the value that the Children, Young Persons and Their Families Act 1989 uses as the cut-over from child to young person. This age would be more liberal and potentially result in higher levels of independent travel (relative to being chauffeured in a car) compared with 16 years, but harder to enforce as 14 year olds do not typically carry a driver licence, as previously noted. In many countries, the minimum age is 14 (table 8.3).

Minimum age of 16 could be the minimum for unsupervised use of an LPV. The prevalence of official identification being carried rises with the availability of a driver licence, providing an easier means of enforcement for police.

9.3.8.3 Potential variations

- Two classes of PETDs – for low speed (ie 15 km/h or less) devices, no or a lower minimum age may be required, given that children are already using footpaths on unpowered kick scooters that can attain such speeds. A higher minimum age could then be required for higher speed (ie up to 25 km/h) devices. Some higher-speed devices have smartphone controllers a parent can use to lock in a lower top speed.
- Supervised and unsupervised ages may help address safety, but would not address devices designed for children and might be used for self-directed travel to school. Although **not** likely to be widely enforced, such a rule would help guide and support parents or guardians.
- Exceptions might be allowed for off-road use by organised and supervised tours.
- Future partly or fully autonomous LPVs could improve safety to the point where a minimum age is no longer necessary.

An upper age limit is not considered necessary, as it is expected that people who are over the age of 75 will select a traditional three – or four-wheel mobility scooter if they can no longer safely operate a two-wheel scooter or self-balancing device.

9.3.9 Driver licensing

Requiring a driver licence could help improve safety by ensuring that mobility scooter and other LPV users have adequate knowledge of traffic rules and the physical capability to avoid crashes (ie adequate vision). However, people with diminished eyesight can probably still safely operate a lower-speed LPV (section 6.3). As with age, the application of this criterion is dependent upon speed capability and usage location.

It was suggested in workshops conducted for this research that a driver licence requirement with a special mobility device or low-speed vehicle endorsement would be favourably received by older persons who would then be able to retain their driver licence for identification purposes, but not for operation of a car. However, the driver licence is not intended to be an identification document.

New Zealand motor vehicle drivers are required to obtain a *Medical certificate for driver licence* from a doctor when renewing their licence 'at age 75, 80, and every two years after that' (NZ Transport Agency 2014b). When a doctor has concerns about medical fitness, they may require a second opinion from an occupational therapist (ibid).

A mobility scooter is often the next choice when a motorist can no longer drive due to medical reasons. The need for a medical or general fitness assessment is determined by the driver, family members and/or doctor. Occupational therapists and other professionals offer needs assessments for older persons, including keeping mobile and equipment needs (Ministry of Health 2011). Such assessments offer the opportunity to confirm if a person is fit to operate a mobility scooter, but are usually only applied to the minority that require financial assistance via ACC or Enable New Zealand (C Porter, 2016, pers comm).

Some LPVs currently marketed (such as high-end e-skateboards) can attain speeds of 40 km/h or more and future vehicles may be capable of even higher speeds. If a vehicle speed capability limit is not adopted, then it may be appropriate to require riders of vehicles capable of speeds similar to urban motor traffic to hold a driver licence. This should be synchronised with any requirement that applies to any S-pedelec class.

9.3.10 Helmets

As noted in section 8.1.4, there is no mandatory helmet law for riders of mobility scooters or wheeled recreation devices. It does not seem appropriate to extend the law to mobility scooters, especially as many of these can only travel 6 km/h. There have been calls for the mandatory helmet law to apply to child scooter riders and skateboarders (Safekids NZ 2013; Wolfaardt and Campbell 2013).

Existing pedal cycle helmet requirements could be extended to any vehicles similar in performance and usage to pedal cycles (ie capable of 20–25 km/h and permitted to be used in mixed traffic on the carriageway). This may maximise individual user safety. Some authors have questioned the cost/benefit and efficacy of mandatory helmet laws (Clarke 2012; Watkins 2014; Teschke et al 2016), although there is no expert or social consensus on this topic.

Requiring helmets may depress uptake, with consequent implications for health, the environment and transport mode choices. If helmets are required only for LPVs and not for other wheeled recreational devices, then it may also be difficult to identify whether the rider is in violation of the law.

If LPVs are permitted, the efficacy of mandatory helmet legislation and whether LPVs permitted to use the road should be subject to the same helmet wearing requirement as pedal cyclists, will need to be looked at. The issues to be taken into consideration could include user age, device stability and speed capability.

9.3.11 Usage locations

As noted in section 8.4, other jurisdictions have different classes of powered mobility device/mobility scooter which each have a different legal status in terms of where they can travel and required behaviour. In Singapore, all compliant PMDs are permitted to use footpaths, but not roads. Australia is researching whether PETDs should be allowed to use footpaths and/or roads.

9.3.11.1 Footpaths

Concerns are typically raised when LPVs travel at faster speeds than pedestrians on footpaths. As noted in section 9.1.4, establishing a default speed limit of 6, 10 or 15 km/h (as per table 9.4) is one approach; another complementary or alternative approach might be defining particular device types that are permitted on footpaths by virtue of their (limited) speed capability. Two general approaches are considered, in addition to the behavioural constraints already set out in Road User Rule 11.1.

Allow LPVs that cannot exceed the adopted maximum speed on footpaths. Unless otherwise signposted, only permit LPVs (other than e-bikes) where the motor assistance ceases to propel at no more than the adopted maximum speed. This will tend to be the lighter and lower powered devices such as the typical 10 km/h hoverboards, smaller e-kick scooters and many mobility scooters.

Allow all LPVs that have speed control features or motor is turned off on footpaths. Unless otherwise signposted, permit LPVs (other than e-bikes) where the motor assistance ceases to propel at no more than the adopted maximum speed, OR it is equipped with at least one of the following features: adjustable speed control (‘turtle’ or ‘footpath’ mode, low power or low-speed setting) that is engaged while on the footpath, active speed feedback system, or autonomous speed control (section 7.1.3), OR it is operated without motor assistance (applies only to devices that can be propelled by human power alone).

While all the UK’s rules are worth considering, the one with the potential for reducing conflicts with pedestrians the most would be the requirement that higher-speed capable mobility scooters be fitted with a low-speed mode button on the console (section 8.4.4).

9.3.11.2 Roads

LPVs capable of speed similar to unpowered cyclists (eg 15 km/h or more) could be permitted to use the leftmost edge of the roadway or cycle facilities. Such devices are often primarily used for transportation or utility trips rather than recreation. This may include Segways, e-unicycles, Yike Bike, Ogo and larger e-scooters.

In the UK, only class 3 mobility scooters capable of 15 km/h are permitted to use the road other than for crossing the road. Lower-speed mobility scooter (eg a UK standard class 2 mobility scooter) users may, on occasion, have no choice but to use the road if the footpath is impassable or the street is a low-speed street without any footpath. Explicitly providing for road use could also suit New Zealand communities and developments with low-speed and/or shared street zones.

10 Complementary non-regulatory measures

Having recognised there are particular safety issues for e-bikes and other LPVs, and specific regulations may be required, it follows that education programmes and engineering treatments tailored to users of these devices will be necessary. Education and engineering can complement the regulatory measures to improve the health and safety outcomes.

10.1 Education

10.1.1 Educating users

Depending on the type of LPV, users may require education on the following aspects:

- rules for road, path and off-road use (where they can and cannot ride their device, give way rules, travel speed limitations
- other regulatory requirements, vehicle/device restrictions
- safe riding behaviour and techniques (effects of speed on judgement, stopping and impact etc, understanding how other users perceive them)
- courtesy and etiquette.

The first two points involve a transmission of the regulatory regimes discussed in chapter 9. The following discussion focuses on the importance of the latter points.

10.1.1.1 Educating e-bike users

If e-bikes result in a substantial increase in cycling, there will be an impetus for training all people on how to ride any type of pedal cycle. Rose and Cherry (2012) indicate developing requirements for enhanced rider education/training may be one way to reduce the risk of crashes involving e-bikes, but they do not provide any further recommendation about what this training might involve. Based on the EU pedelec information requirements (Bike Europe 2016a), training topics should include:

- all aspects of unpowered cycling training
- concept and description of electrically assisted cycling
- controls and console warnings
- starting and accelerating on a hill
- handling differences, especially for front wheel drive models
- cautions on washing and water penetration into electronics
- recommendations on battery charging, charger use and battery handling/recycling.

Riders of faster e-bikes should also understand that motorists may mistakenly believe they are riding unpowered bicycles and expect them to be travelling more slowly than they are, especially if their cadence and posture are similar to that of a slower cyclist.

When NZ Post introduced its e-bike fleet, training elements included safe practices for e-bike storage, maintenance and charging (M Northcotte, 1 December 2016, pers comm). Most of these practices are usually undertaken by property managers. However, there are also some health and safety issues around handling and moving the bikes that are relative to the staff who will be using them, such as moving the bikes in/out of the building, easy access for easy use – and enough room to store them to help with that, how to use stands for moving the 20 kg bikes and instruction not to lift them. Northcotte is currently developing e-bike specific training materials.

Juiced Bikes, a New Zealand distributor and retailer, has developed a safety information sheet that must be read and signed by customers (see appendix D). A copy is retained by the retailer.

10.1.1.2 Educating mobility scooter users

Newman (2015) reviewed several studies relating to the use of mobility scooters and concluded 'the literature suggests that prior assessment and training is necessary'. An example given to illustrate this comes from Nitz (2008) who assessed 50 able-bodied adults with an average age of 34 for competency driving motorised scooters; 66% of the group failed at least one of the 13 basic negotiation tasks in the test, which the researcher found to be an unexpected result, given the high rate of driver licence ownership among the participants.

Thoreau (2015a) found training the individual to use their mobility device is important; however, in practice this does not occur regularly. A survey of mobility scooter users in the UK (RICA 2014) found 59% had received some training in using a mobility scooter. Sullivan et al (2014) studied 30 mobility scooter users from Dunedin and found 77% had received a demonstration and/or instruction on how to operate their scooter, although it was noted only 10% received this from a health professional. McMullan (2016) recommended education would be more effective than regulation, as the latter could act as a barrier to scooter use and cause some people to stop using their scooter altogether; however, only two of the four participants in the study expressed interest in a mobility scooter training programme.

Ready to ride (NZ Transport Agency 2015b) gives useful and thorough information about choosing a mobility scooter, the associated regulations, safe riding practices and who to contact for further assistance. More information specific to senior drivers is also provided in *The road ahead* (NZ Transport Agency 2015c).

The SuperSeniors Website is run by the Office for Seniors through the Ministry of Social Development. It has a marketing campaign ('No car, no problem') and a page dedicated to mobility-scooter use: http://superseniors.msd.govt.nz/out-about/transport-driving/mobility-scooters.html

The page features links to the previously mentioned *Ready to ride* pamphlet and the Transport Agency's webpage on mobility scooter safety: www.nzta.govt.nz/safety/driving-safely/senior-drivers/mobility-scooters/

Mobility scooter training should be adapted to account for the other impairments that mobility scooter users may be subjected to, for example low vision and poor hearing. McMullan (2016) raises this point with respected to low-vision users saying 'trainers can be educated in nuances specific to low vision such as identifying moving objects, turning or using mirrors for lost visual fields and strategies identifying traffic at road crossings'.

Occupational therapists and other professionals offer needs assessments for older persons, including keeping mobile and equipment needs (Ministry of Health 2011). Such assessments offer the opportunity to confirm a person is fit to operate a mobility scooter.

10.1.1.3 Educating other LPV users

Safe Kids New Zealand provides guidance for using skateboards and scooters (Safekids NZ 2013); however, these are specified as being of the non-motorised variety. Currently, there is very little official, independent guidance (ie apart from that provided by manufacturers in user manuals) for users of LPVs such as electric skateboards, electric scooters, self-balancing unicycles and hoverboards. The safety findings (chapter 5) suggest it would be beneficial to develop specific user training for these devices. Segways are in a similar situation. Apart from the cursory information given on Yike Bikes in association with the declaration they are not considered to be a motor vehicle, there is little information given regarding how to use them safely on the road, although the need for this is less certain as Yike Bikes are relatively new and less widespread, therefore with no crash data to consider. Yike bikes can be used on the footpath, if users comply with the requirements for wheeled recreational devices (eg Road User Rule 11.1, refer table 8.2), although it is likely that most users are not aware of this.

10.1.2 Educating the general public

10.1.2.1 Educating the general public about e- bikes

E-bikes are a relatively new technology. Some pedestrians perceive them to be much faster than regular bicycles and therefore a threat to safety. Many traditional cyclists can also be biased against e-bikes. Several authors point out that e-bikes continue to lack ‘legitimacy’ on the road, and e-bike users tend to be characterised as ‘lazy’ ‘old’ and ‘cheating’ (Dill and Rose 2012; Popovich et al 2014). It is important to talk about actual risk to alleviate false public perceptions of risk.

Motorist-targeted information could point out the pedal cadence (rotation speed of the crank) of e-bike users looks different from that of traditional cyclists. Laboratory experiments conducted by Schleinitz et al (2016) found motorists were confused by the combination of fast speeds and low-perceived pedalling effort (exhibited through a slower pedal cadence) amongst e-bike users, which gave drivers the mistaken impression e-bike users were going slower than they were, leading to higher levels of ‘time to arrival’ misjudgements. This was reportedly the issue with a recent Palmerston North injury collision (Galuszka 2016). The educational message could be along the lines of ‘it is difficult to judge the speed of a cyclist – just because they aren’t wearing lycra doesn’t mean they aren’t travelling quickly!’

In recent years, increased efforts have been made to educate other road users about the rights and responsibilities associated with cycling on the road. For example, the road code now uses people on bikes in some of the illustrations for give way rules etc where motor vehicles were previously used, to emphasise that bicycles are considered vehicles and the same give way rules apply to/for them. Campaigns with messages such as ‘share the road’ and safe passing distances also help inform motorists about how they should interact with people on bikes.

10.1.2.2 Educating the general public about other LPVs

It would be beneficial to provide similar education regarding low-powered devices so other road and path users understand where they can expect these devices and how they are expected to interact with their users. The content will depend on the rules developed for each specific device; an important factor will be where the devices are allowed (eg if they are to be used in pedestrian spaces only, or on the road only, or are allowed both on- and off-road).

Survey respondents indicated a concern about the lack of clarity on where and how mobility scooters can be used. In a follow-up interview, one respondent with extensive experience in the elderly mobility sector noted a need for clear guidance and safety tips. When presented with a web link to the *Ready to ride* guide (NZ Transport Agency 2015b) the respondent was impressed and keen to circulate the document in her networks. There may be an opportunity to increase the circulation of this guide, especially if any changes to the regulations are made.

10.1.3 Methods of educating LPV users

Buyers of e-bikes or other LPVs (including conversion kits) could be educated about the legal requirements and safe use of their device. Training materials are currently being developed for e-bikes, although they could apply to any other LPVs as well (M Northcotte, 1 December 2016, pers comm). The materials are to include the following topics:

- operation of the controls/console
- handling and mounting/dismounting from a heavy device
- the sequence for changing position on the road (look, signal, move)
- consideration for the environment of shared spaces, shared paths and footpaths
- general observational skills
- corners and turning (just like driving, slow down before arrival)
- descending and using the brakes (or in the case of self-balancing devices, emergency stopping)
- recognising hazards
- judging speed and distance
- perception of your speed by other road users (you will be quicker than they think you are) and the need to slow down at conflict points.

Northcotte also recommends various ideas for communicating these messages:

- a poster format in the break room or bike storage area
- written content in the health and safety policy
- video instruction
- a handout at the point of sale and/or at other locations where users are likely to see it
- user manual information
- online information
- training module delivered in around 90 minutes where the trainees ride LPVs or e-bikes in a controlled environment to become familiarised with them; this could be optional or mandatory
- identify experienced champions in the office to act in a ‘buddy’ capacity on one-to-one basis for learning without fear of embarrassment
- inclusion in the Road Code and/or associated informational material such as the *Official New Zealand code for cyclists* (NZ Transport Agency 2009).

Newman (2015) points out for mobility scooters (and this may apply to other LPVs as well), point-of-sale training only works when users buy their devices from a retailer. If devices are purchased second hand, or remotely via the internet, users will not have the opportunity for point-of-sale training. A recent study of mobility scooter use in the UK (RICA 2014) found 51% of mobility scooters were bought from a shop, 30% were bought online and the remainder were bought informally (ie from friends or acquaintances or through newspaper advertisements). Therefore, only about half the target audience would be reached through point-of-sale education.

Furthermore, it can be difficult to ensure both retailers and customers adhere with the intended training content. Retailers may not want to spend the time training customers fully, and may not have the appropriate space to do so. Customers may be reluctant to partake in training, for example there is anecdotal evidence from retailers of mobility scooters who offer training to customers but are told ‘Sonny, I've been driving since before you were born' (as mentioned above, Nitz (2008) found people with driving experience are not necessarily immediately competent at operating mobility scooters).

The training requirement imposed on e-bike manufacturers in California is simply to include a single page disclosure with nothing else but a warning to seek advice on insurance. It would be possible to require much more than this, but again it depends on the user's motivation to read the information. Similarly, providing information through other means (eg online, pamphlets) or optional training programmes can be of benefit to those users who are motivated to seek it and know how to find it, but may not always reach the entire intended audience.

Making training a mandatory requirement moves it into the sphere of regulatory regimes (see chapter 9). For example, road users such as S-pedelec riders could be legally required to have a licence, and training or testing could be included as a step in the process to obtain this.

10.2 Promotion

Getting more people on bikes has a safety in numbers benefit (Jacobsen et al 2015). In 2016, electric power utility provider Mercury ran a multi-pronged promotion using e-bikes through:

- video advertisements presenting e-bikes as 'cool' and 'fun' shown on television and social media
- paid articles on Stuff.co.nz
- 'Have a Go' test ride events
- a $250 to $500 discount on the purchase of an e-bike from selected retailers, available to new customers (Mercury 2016a; Mercury 2016b)

Portraying mobility scooter and other device users in a positive and fun manner in communications and advertising similarly can boost the safety in numbers effect and support educational programmes. An interviewee commented that aspirational imagery is more effective for engagement of older persons.

10.3 Engineering

Different engineering standards and design guidelines are provided for the various types of traditional vehicles, eg trucks, buses, cars and bicycles, depending on their various characteristics and needs in specific traffic contexts or locations. As it has been recognised that e-bikes and other LPVs have specific characteristics, and new regulations may be developed, it is necessary to provide designers with information regarding how to best accommodate the users of these vehicles/devices within the contexts where it is intended they will be used.

10.3.1 Designing for e-bikes

The importance of design increases if New Zealand continues to permit e-bikes to attain higher speeds. Conversely, if a maximum motor assistance speed of 25 km/h is adopted, then many of the recommendations that follow will not be as critical.

While e-bikes do not necessarily have a higher top speed than a road bike, the average speed of an e-bike rider is faster than the average speed of a traditional cyclist as previously discussed in this report. However, speed gains associated with pedelecs can only be achieved in 'free-flow' conditions like carriageways and bike paths (Schleinitz et al 2016). Furthermore, an increase in e-bikes will increase the variance in speeds among the cycling fleet and the differential with pedestrians, particularly where uphill gradients are involved. While the variance within the e-bike fleet is smaller than the traditional bike fleet, it has been estimated the overall variance will increase with a higher proportion of e-bikes that are likely to operate at the upper range of the speed distribution (Dozza et al 2013).

The speed and relative ease of e-bikes enables people to make longer commutes and cycling becomes a possibility for a greater number of people, therefore increasing demand for cycling paths or suitable on-road provisions. Due to the wider demographic attracted to e-bikes, they may also be more likely to be used on pathways and exclusive cycle facilities than road bikes. Schleinitz et al (2016) suggest e-bikes need wider cycle paths to enable overtaking. Therefore, it should be considered whether it is necessary to increase the design speed used when designing such facilities.

At present, New Zealand design advice is to increase the width of cycle facilities once cycle traffic flows exceed 150 in the peak hour; this is a function of limiting the number of required passing manoeuvres to within a given level of service (NZ Transport Agency 2008). To achieve the same level of service when speed variance of the cycle fleet increases, the peak flow number will have to be reduced. Hence on average, cycle facilities will have to become wider if e-bike uptake increases. This will be especially prominent at intersections, where e-bikes are able to accelerate more quickly, but it is also the place within networks where demand on existing space is highest.

Austroads recommends pathways that are to be used by bikes be designed for a speed of at least 30 km/h, and provides minimum horizontal curve radii tables for speeds between 20 km/h and 50 km/h (Austroads 2009). Despite this guidance, many existing pathways have tighter curves that will affect e-bike riders travelling at higher average speeds more than traditional bike riders (Schepers et al 2014). There may be increasing calls to improve existing deficient path curves. The AASHTO guidance that is (indirectly) the original source for Austroads was updated in 2012 and includes a metric formula which may be easier to use than interpolating from the table in Austroads (AASHTO 2012).

While paths shared by pedestrians and cyclists are reasonably common, with e-bikes becoming more popular increasing the speed differential between bikes and pedestrians, the two user groups will more often require their own space. Some workshop participants and survey respondents consulted in this research argue that the aim should be to support the benefits of e-bikes, not just considering how to slow them down so they can share paths with pedestrians.

The higher average speed of e-bikes affects the design of pathways with intersecting driveways, as longer sight lines will be required. Being overlooked at driveways is the main mid-block crash type for pathways. Restrictions on parking can be specified to ensure intervisibility between drivers entering a driveway and pathway users, but existing boundary fences or building lines govern the intervisibility with drivers exiting a driveway, and while design guidance can indicate this as a factor, there is often not much that can be done practically to overcome these existing limitations. Hence, the main variable that can be controlled to reduce crash occurrences on pathways is the operating speed; from a safety perspective, the lower the operating speed the better.

Some policy makers have considered dealing with some of the design issues by imposing a legal or advisory speed limit on shared paths. If it is determined speed limits should be imposed on e-bikes in certain circumstances, it may be necessary to consider whether and how to require e-bikes to have a speedometer (refer section 7.1.4).

Dozza et al (2016) also note e-cyclists need better lighting, as faster speeds mean they need to see further ahead to allow time for planning; and they also point out that cars parked in bike lanes are more of a hazard to e-bikes, supporting the need for strengthened enforcement around this issue.

One aspect of electric assistance can be observed overseas, where the emergence of e-bikes results in larger bikes; either longer, or wider, or both. Such cargo bicycles are already increasing in number and availability within New Zealand. Some people make use of the motive support to transport goods, their pets, or their children, and the proportion of cycles that exceed standard dimensions increases accordingly. As mentioned in section 9.2.4, a rule change is in progress that will change the maximum allowable width of bicycles from 1.0 to 1.1m.

Figure 10.1 Cargo e- bike; Davis, California (source: Axel Wilke)

Cycle parking stands will need to be spaced further apart to accommodate these larger e-bikes. E-bike users consistently cite the need for more secure bike parking, as theft is a major concern with these more expensive bikes (Haustein and Möller 2016). Also, while parking for regular cycles may be space-saving (eg elevated or hanging bike racks) such systems often do not work for e-bikes, which are heavier, or suit less-mobile users (Dill and Rose 2012; Fyhri and Fearnley 2015; Haustein and Möller 2016).

Staggered barriers may exclude some bikes that physically cannot fit through the restriction, which would be a significant nuisance for their owners. Where long bikes overhang into the adjacent traffic lanes at refuge islands that are too narrow, this can present a safety issue. Based on overseas trends, the prevalence of wider and/or longer bikes will continue to increase, and this raises the question as to when design guidance should be updated.

At path transitions from road to path or vice versa, it is more difficult to negotiate these with larger bikes. In the USA, 20º–45º ramps are typically used, but it is difficult to align a cargo bike for a path transition at speeds above about 10 km/h at ramps with sharp intersection angles. Lieswyn and Wilke (2016) recommend using 17º–35º ramps, with a preference for the shallower end of the range.

10.3.2 Designing for other LPVs

A significant amount of guidance is already available regarding designing for users of mobility scooters. The New Zealand *Pedestrian planning and design guide* (PPDG) (Land Transport NZ 2007) includes users of mobility scooters in the category of ‘pedestrian’. But, as observed by Thoreau (2015a) ‘Mobility scooters cannot be considered equivalent to pedestrians. They are motorised devices that tend to be substantially heavier, and have potentially excessive speed as pedestrians’. That is why the PPDG includes guidance on design elements suited to mobility scooters, especially in terms of gradients and crossfalls, kerb crossings and access to infrastructure such as pedestrian crossing traffic signal call buttons. The New Zealand Standard 4121:2001 contains further information on requirements for designing for mobility impaired pedestrians, including those who use mobility scooters (Standards New Zealand 2001). According to field studies by van der Voordt et al (1996) a full turning circle (ie performance of a U-turn without a three-point turn) requires 2.0 m of path width. In constrained locations, King et al (2011) found depending on the scooter a three-point turn would save 42–54% of space compared with a full turn (conservatively, about 1.2 m is still required). Selected mobility scooter characteristics are presented in table 10.1.

Small wheeled LPVs such as e-skateboards and hoverboards require smoother surfaces to be operable at anything close to their speed capabilities. The most common issues for users of these small wheeled devices is the lip of channels at kerb ramps and poor footpath maintenance. If greater numbers of LPVs are permitted on paths (or on the road or in cycle lanes etc), this will increase the speed differential of users within the given facility; it may be necessary to reconsider the current standards for the widths of these facilities.

In the workshop tests, a research team member attempted emergency stopping manoeuvres on various LPVs side-by-side with a hydraulic disc brake equipped e-bike. Although unscientific, the self-balancing devices and e-kick scooters appeared to have comparable deceleration. In field tests by Lavallee (2004), testers described the deceleration of a Segway HT as 'astonishing'. Based on a literature review and online searches, some performance characteristics affecting geometric design are provided in table 10.1. Braking distance is from top speed, and for self-balancing devices is dependent upon user experience. A hyphen indicates no data was found.

Table 10.1 Selected LPV performance characteristics

LPV (no. wheels for mobility scooters)	**Climb angle (deg)**	**Accel. (to top speed)**	**Top speed (km/h)**	**Braking distance (m)**	**Turning radius (m)**	**Source**
Shoprider 889SL mobility (4)	9	-	12	-	1.5	www.shoprider.co.nz
DriveMedical Phoenix (3)	6	-	6.4	-	1.1	www.drivemedical.com
Radical mobility (3)	12	-	10	1.4 m	1.1	www.radicalmobility.com
Horizon Aztec 2 (4)	10[a]	-	13	-	-	www.horizonmobility.com
NV B4 enclosed mobility (4)	15	-	15	-	1.9	www.mynv.nz
95th percentile mobility scooter – minimum (desirable)					1.8 (2.0)	Palmerston North City Council research (2017)
Segway HT	20	7.09 sec.	20	5.21 m	0.0 m	(Lavallee 2004)
	-	20 m	20	<3.5 m	0.0	(Darmochwal and Topp 2006)
Yike Bike C	5	-	23	9.0 m	3.8	www.yikebike.com
Airwheel Q5 e-unicycle	15	-	18	-	< 1.0	www.theairwheel.com
Ninebot One E+ e-unicycle	15	-	22	-	< 1.0	www.ninebot.com
E-Twow S2 kick scooter	15	-	30	-	< 1.0	www.e-twow.com

[a] The Horizon mobility scooter has a maximum static tilting safety in all directions of 14 deg./25%/1:4

The geometric design requirements shown in figures 10.2 through 10.5 are based on the 95th percentile turning radius of commonly available mobility scooters (Palmerston North City Council 2017). Clearance requirements to fit between bollards or other physical barriers (figure 10.6) are based upon the 95th percentile width of the same set of scooters measured by Palmerston North City Council, plus a 0.2m allowance for mirrors and to account for driver error (ibid). These values are preferable over the advice provided in NZS 4121 (Standards New Zealand 2001) as the standard is focused on smaller wheelchairs.

Figure 10.2 Mobility scooter turning path through angled refuge (source: Palmerston North City Council)

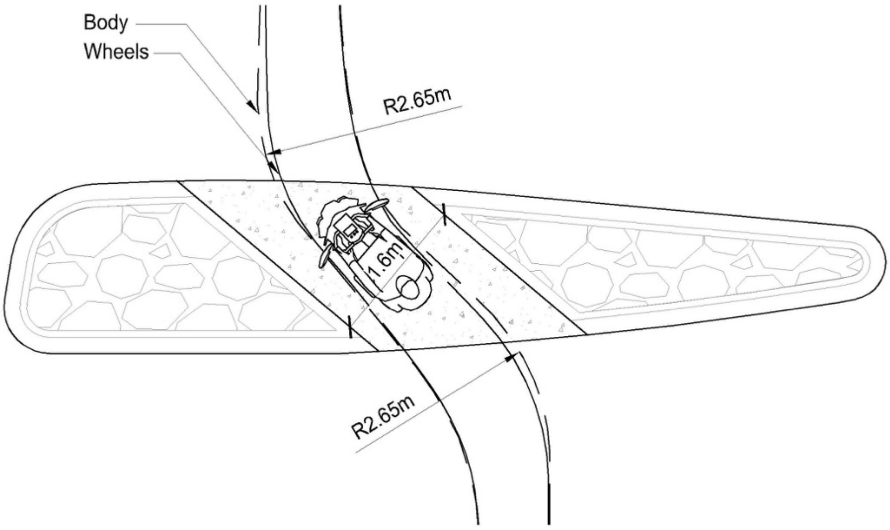


Figure 10.3 Mobility scooter turning path through chicane refuge (source: Palmerston North City Council)

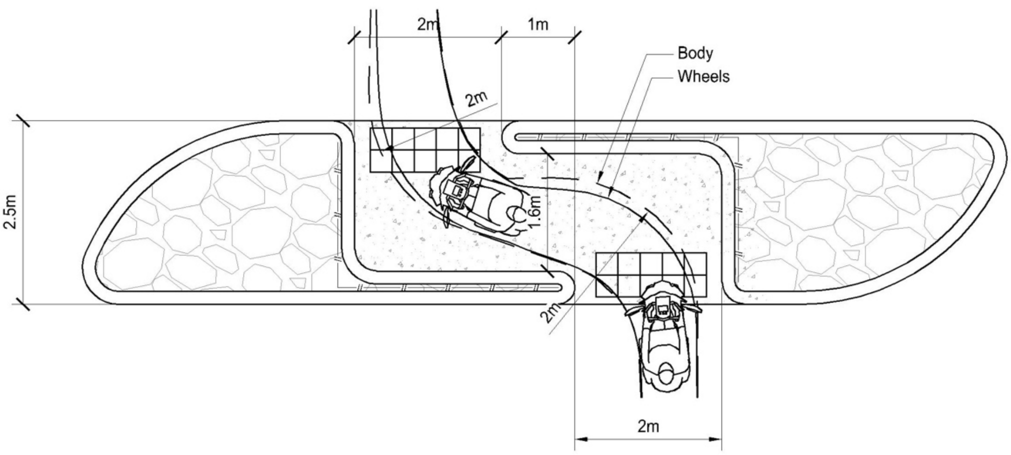


Figure 10.4 Mobility scooter turning path at kerb ramp (source: Palmerston North City Council)

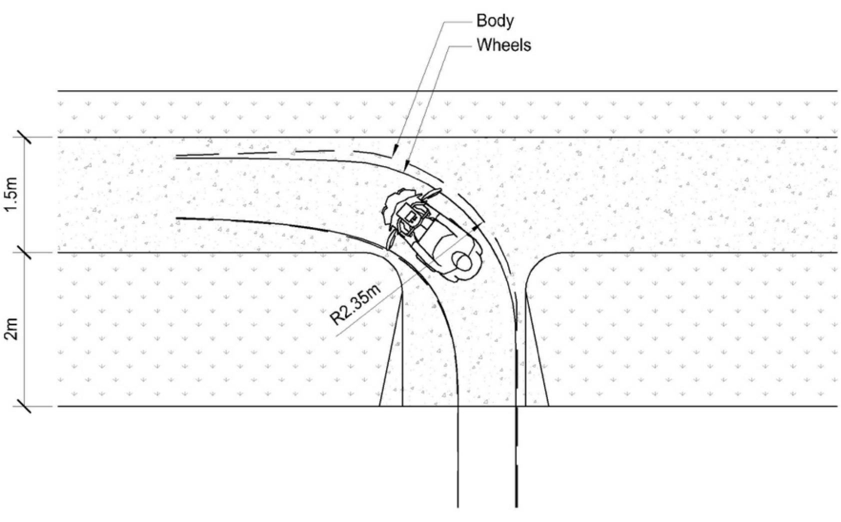


Figure 10.5 Mobility scooter turning path through staple barriers (source: Palmerston North City Council)

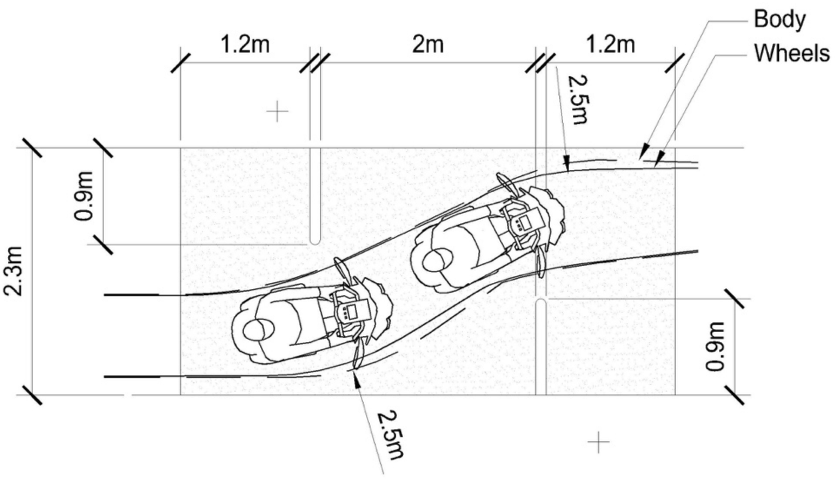
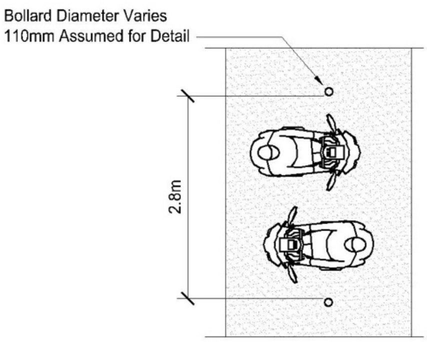
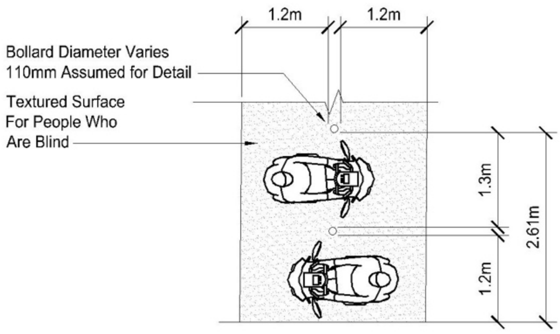


Figure 10.6 Mobility scooter width requirements at path barriers (source: Palmerston North City Council)





11 Conclusions and recommendations

Based upon the literature review and the other sources cited in this research report:

- E-bikes and other LPVs have the ability to broaden the appeal of travel choices which contribute to public health benefits and reductions in congestion.
- E-bike sales have grown very rapidly over the last three years, exceeding 13,000 in 2016. It is expected that sales will continue to grow rapidly for some time.
- Sales of other low-powered vehicles are relatively low (with the exception of mobility scooters at approximately 6,000 pa)
- There is scope for greater use of footpaths and shared paths by some LPVs.
- Speed is a better determinant for safety than motor power. On average, e-bikes travel about 3 to 8 km/h faster than conventional bicycles, however there is a wide range of top speeds.
- Limitations on user behaviour are an important factor for minimising negative impacts on other path and roadway users.

A more detailed summary of findings is presented in appendix A: Findings and indicative regulatory framework based on international experience.

It is recommended considering:

- including any LPVs intended for or primarily used by mobility impaired users within the definition of a mobility device
- classifications for e-bikes and other LPVs based on speed capability
- a maximum power-assisted speed and size for vehicles using footpaths
- relaxing maximum power limits for e-bikes and other LPVs designed for road use
- minimum age limits and driver licensing for higher speed e-bikes and LPVs
- helmet wearing by LPV users depending on speed capability
- further promotion of user behaviours that minimise conflict with existing path and roadway users (eg Road User Rule 11.1).

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Appendix A: Findings and indicative regulatory framework based on international experience

This appendix presents high-level conclusions and recommendations. Tables A.1 and A.2 (for e-bikes and other LPVs, respectively) set out a more detailed summary of the research findings and recommendations to inform future policy-making and potential changes in the regulatory framework.

Table A.1 E- bike findings and indicative regulatory framework

Topic	Findings and recommendations
Market outlook	• E-bikes are encouraging many non-cyclists to begin cycling. Unit sales of e-bikes have climbed rapidly from 2,300 in 2014 to 14,000 in 2016 and based on a medium growth rate scenario, unit sales are predicted to be over 35,000 in 2026. In a high growth scenario such as we are currently experiencing, sales may exceed 65,000 units in 2026. • Initially sold principally through specialists, e-bikes are now featuring in the line-ups of every major manufacturer and hence in the showrooms of traditional cycle shops.
Safety	• Safety concerns about e-bikes focus on higher speed; however, studies suggest a difference of between 3 km/h and 8 km/h. While peak speeds are similar to those of fit cyclists, e-bike users may appear slower to other road users given their potentially less sporting appearance. • Increased e-bike speed requires additional education for all road users and wider cycle facilities (especially those that are contained between kerbs, such as protected cycle lanes). *Recommendation 1: Consider including e-bike content in educational materials and programmes; development of a template for e-bike supplier and retailer adoption and distribution.* *Recommendation 2: Consider e-bike specific enhancements to the Cycling network guidance – planning and design* (CNG). .
Maximum motor-assisted speed	• Maintaining the status quo (no motor cut-out speed) will result in continuing development of faster e-bikes, without any regulations or standards regarding vehicle safety or use. • Maximum motor-assisted speed is an easier criterion to measure and enforce than maximum power. It directly affects safety and is regulated in all other jurisdictions reviewed for this research. • 25 km/h would be consistent with EU pedelec (and therefore Australian) rules. It would limit model choices, but harmonisation with Australia may ultimately benefit suppliers and consumers. Although safest, this option would be slower than that of many New Zealand unpowered cyclists, reduce travel time competitiveness and may reduce uptake of e-bikes. • 32 km/h would be most consistent with the existing fleet of ungoverned e-bikes and e-bikes designed for the USA market (20 mph cut-out); would reduce the incentive to tamper with speed restrictions; and improve the attractiveness of cycling relative to other motorised travel modes. • 45 km/h would be consistent with the EU's S-pedelec (a type of moped) and the USA class 3 speed e-bike (a bicycle); would offer New Zealand consumers an option that minimises the speed differential with other motorised modes in urban areas and make longer distance commutes more viable. All countries with this class also have a lower speed e-bike class. The USA approach would increase uptake while the EU approach would enable more stringent control over vehicle standards. • Overseas, e-bikes capable of speeds above 45 km/h are considered motorcycles subject to motor vehicle standards, certification and registration. *Recommendation 3: Consider defining class AB pedelecs as having a maximum motor-assisted speed (eg 32 km/h).* *Recommendation 4: Consider a new class for pedelecs with a maximum motor-assisted speed of 45 km/h.* *Recommendation 5: Continue classifying e-bikes that can exceed 45 km/h as mopeds or motorcycles.*

Topic	Findings and recommendations
Speed limits	• Posted speed limits or advisory speed limits are tools that could help address shared path conflicts. • Widespread and regular enforcement is unlikely and therefore advisory limits may be preferable. • Local bylaws may be needed to establish rules for environments where e-bikes should be operated without motor assistance or be prohibited. *Recommendation 6: Investigate a national guideline for advisory speeds on and access to shared paths.*
Power	• Manufacturer's rated continuous power is regulated in conjunction with maximum motor-assisted speed in western countries; in the USA, the 750 W rating approximates the historical one horsepower threshold for classification as a motor vehicle. • There is a good case for permitting power levels higher than 300 W to allow for carrying heavier loads and for steeper hills. *Recommendation 7: Consider aligning e-bikes with the EU's multiple levels or a value higher than 300 W.*
Throttles	• Major brands are moving towards mid-drive pedelec road and hybrid models, without throttles. All major brand e-MTBs are pedelecs due to the reduced surface erosion and superior control. • Prohibiting open throttles would increase average e-bike cost and therefore reduce uptake and potentially the 'safety in numbers' benefit of more people cycling. • Notwithstanding the market implications, a pedelec system (pedal assist with optional start assist throttle) is more desirable from a safety and health perspective than throttle e-bikes. *Recommendation 8: Consider separate classes for slower pedelecs and faster e-bikes and/or those with throttles, so that access restrictions and age limits can be imposed for the latter.*
Dimensions and weight	• Retaining the existing maximum width rule (of 1.1 m) for all pedal cycles would help avoid issues for other users on facilities of restricted width such as shared paths or separated cycleways. • The researchers do not consider it necessary to limit weight, as the benefits of encouraging more utility cycling are considered to outweigh any safety gains. *Recommendation 9: Consider not regulating the weight of e-bikes.*
Braking	• The Land Transport Rule on light-vehicle brakes specifies that class AB e-bikes must have at least one brake which could result in some homebuilt e-bikes having unsafe braking; production e-bikes typically meet applicable standards that require a brake on each wheel. *Recommendation 10: In order to ensure homebuilt e-bikes have adequate braking, consider a Land Transport Rule amendment to require two brakes: an effective brake on each wheel.*
Standards	• *AS/NZS 1927:1998 Pedal cycles – safety requirements* is out of date; the most current overseas standards for e-bikes are the EN 15914: 2011 and the upcoming ISO e-bike standard. • Several options have been presented for requiring throttle e-bikes and/or S-pedelecs to meet vehicle standards in order to improve vehicle safety but the simplest approach is to continue excluding all e-bikes from the requirement. *Recommendation 11: For class AB, advocate that Standards NZ undertake an update and/or refer to the upcoming ISO e-bike standard when published (and the EU standard for pedelecs, if New Zealand adopts it) in rules and legislation.*
Certification and registration	• EU member states (but not USA states adopting the Californian/BPSA classifications), require throttle e-bikes and S-pedelecs to be moped certified and registered, and that ongoing maintenance must maintain conformity with type certification. • High speed e-bikes (>45 km/h) are subject to motor vehicle registration overseas. • Certification and/or registration increases compliance costs on industry and consumers, may reduce uptake and therefore safety-in-numbers, and requires enforcement to be effective. *Recommendation 12: Consider treating slower e-bikes as pedal cycles not subject to registration; higher speed e-bikes to be entry certified and registered.*

Topic	Findings and recommendations
Age	• Most overseas jurisdictions that regulate minimum age use 14 years, a value the Children, Young Persons and Their Families Act 1989 uses as the cut-over from child to young person. • The specification of appropriate user ages is dependent on the type(s) of e-bikes made possible through the other regulatory criteria. As the power, speed and acceleration increase, so too should the minimum age. This report has presented options and their merits for further consideration. *Recommendation 13: Consider a minimum age for e-bikes depending on the chosen maximum speed.*
Driver licensing	• No reviewed overseas jurisdictions require riders of low speed e-bikes to hold a driver licence. • The EU (but not USA states adopting the Californian/BPSA classifications) requires S-pedelec riders to hold a driver licence. • If 45 km/h S-pedelecs are permitted in New Zealand, there may be justification for driver licensing in recognition of the similar speed capability to mopeds and general urban traffic. • As S-pedelecs are expected to be a relatively small proportion of the e-bikes sold in New Zealand, the impact of licensing on uptake would probably be no more than minor. *Recommendation 14: If a 45 km/h pedelec class is adopted, consider requiring users to hold any valid driver licence.*
Labelling	• EU and USA labelling including classification, motor cut-out speed, and rated motor power are effective means of providing information to consumers and assist in enforcement. *Recommendation 15: Consider requiring e-bikes to have a label meeting EU or USA requirements.*
Helmets	• Requiring 45 km/h or less e-bike riders to wear a bicycle helmet is the simplest approach from an enforcement standpoint. A new EU standard for S-pedelec helmets is in development taking into account higher speeds and the need for adequate ventilation. *Recommendation 16: When the EU standard for S-pedelec helmets is published, consider adding it to the list of approved cycle helmet standards in RUR 11.8.*
Usage locations	• No overseas rules permitting e-bikes on footpaths were found and such use is not appropriate. • There is no precedent or justification to ban e-bikes (other than S-pedelecs) from shared paths. • A blanket prohibition on S-pedelec use of shared paths may be too restrictive given the nature of rural and suburban shared paths with very low pedestrian use in New Zealand. *Recommendation 17: Continue to permit e-bikes to use shared paths and cycle facilities by default, and allow local jurisdictions to set bylaws on access as considered locally appropriate.* • Evidence is mounting that EU and USA class 1 pedelecs do not cause substantially more damage or conflict off-road than unpowered mountain bikes. *Recommendation 18: Consider the development of a national guideline on e-bike access to off-road trails where unpowered bikes are permitted.*

Findings for other LPVs (including mobility devices/scooters) are listed in table A.2. Many of the recommendations are made under the assumptions that a class of LPVs will be established, explicitly permitting their use in New Zealand. References to LPVs in this table exclude e-bikes.

Table A.2 Other LPV regulation conclusions

Topic	Findings and recommendations
Market outlook	• Although an ageing population would seem to portend an increase in mobility scooters, sales trends are generally flat. The future outlook is highly dependent upon broader social trends in urban development and lifestyle. • There is insufficient data to determine the existing and potential demand for other LPVs. Current ambiguity in the legislation may be limiting demand. • Lightweight e-scooters with a seat are being purchased as a lower cost alternative to mobility devices, and like many other LPVs can complement public transportation as a first/last kilometre solution or support increased mobility in urban areas.

Topic	Findings and recommendations
Safety	• Studies on LPVs other than e-bikes are device-specific (ie Segways, mobility scooters). Although limited by poor reporting and classification, the safety record of other LPVs does not seem to be substantially different than for pedestrians or cyclists. • A significant drawback with the existing crash reporting system is there is no easy way to differentiate a powered device/vehicle from an unpowered one. • One study modelled Segways, e-unicycles, pedestrians and cyclists and predicted that because LPV riders are higher off the ground, they fare better than pedestrians in motor vehicle collisions. *Recommendation 19: Consider the addition of a factor code in CAS to record whether relevant wheeled devices (cycle, skateboard, scooter, wheelchair) were powered devices.* • Pedestrian advocates are concerned about any increase in the number of LPVs on footpaths. Rather than prohibiting devices and therefore limiting transport and recreation choices, the key appears to be in consumer education at the point of sale, targeted campaigns and device-specific literature published in print and online. *Recommendation 20: Continue educational efforts and consider enhanced materials such as a safety information leaflet template for supplier and retailer adoption and distribution.* • The design of footpaths and streets can also be improved to help minimise injuries due to pedestrian or driveway conflicts, tipping, obstructions, or poor surface quality. *Recommendation 21: Consider further means of improving local transport infrastructure.*
Vehicle class	• The New Zealand rules for mobility scooters are clearer and more flexible than the rules in some Australian states. There seems to be little benefit in the UK's three class system for mobility devices, although some UK rules and guidance add clarity, may improve safety and merit consideration. • Austroads is conducting research to inform policy and rules on personal electric transportation devices (PETDs). • Administratively, the simplest solution is to refine definitions of the existing classes as appropriate or to add a PETD class, leaving wheeled recreational devices to unpowered devices. Differences in the rules for any other criteria would be associated with the class definitions. Suppliers and consumers will benefit by harmonising the Australian and New Zealand markets for other LPVs. • From a consumer standpoint, the simplest approach is a single class such as personal mobility devices PMDs) or personal transport devices (PTDs) covering most or all low-speed electric devices and vehicles. Differences in the rules for any other criteria would be administered without the benefit of classes. *Recommendation 22: Consider consultation with Australian authorities to maximise the consistency in vehicle classes, standards and rules, which will likely result in the explicit permissibility of other LPVs.*
Maximum motor-assisted speed	• 15 km/h is currently stipulated in the standard for powered mobility devices. For other LPVs, values below 25 km/h will severely restrict product choices and will be difficult to enforce. • 25 km/h is consistent with those countries that have set a device speed limit and with the current Austroads research proposal. • Values above 25 km/h will provide more product choices than 25 km/h, but are not supported based on the safety analysis. *Recommendation 23: Consider a maximum motor-assisted speed for LPVs other than mobility scooters.*
Speed limits	• Footpaths: there is justification for the establishment of a maximum operating speed on footpaths to address pedestrian interactions; this research considered 6, 10 and 15 km/h. • 15 km/h is consistent with the typical maximum speed of runners, unpowered scooter riders and mobility scooters under AS/NZS 3695. Speeds lower than that are unlikely to be enforceable or respected, while higher speeds increase the probability and severity of injuries (especially in driveway conflicts with motor vehicles). • Shared paths: as per e-bike conclusions. *Recommendation 24: Consider including a maximum speed of 15 km/h for use of LPVs on footpaths in the Road User Rule.*

Topic	Findings and recommendations
Power	• Many LPV manufacturers do not publish continuous power ratings. For self-balancing devices, peak power is often rated because higher power levels help the device maintain stability and therefore improve safety. • Removing the power limit would be consistent with most other countries and would eliminate uncertainty for suppliers and consumers (given that manufacturers generally do not publish continuous rated power specifications for other LPVs). *Recommendation 25: Contingent on adoption of the maximum device speed, consider removal of the 300 W power limit for wheeled recreational devices and any other LPV class to be introduced.*
Dimensions and weight	• For LPVs permitted on footpaths, a width of 70 cm encompasses the majority of reviewed vehicles. • Either consultation with Austroads or further primary research could be undertaken to confirm the safety and comfort impacts of various LPV dimensions and weights. *Recommendation 26: Consider consultation with Australian authorities on the establishment of a harmonised maximum dimension and weight for other LPVs/PETDs.*
Braking	• There is no current means for roadside enforcement to asses deficient braking of a homebuilt or low-quality non-conforming production device. *Recommendation 27: Add the requirement that an LPV 'must have an effective stopping system including brakes and/or motor control' to the legislation and/or rules.*
Standards	• Manufacturers and/or importers already must declare compliance with applicable electrical, product, and vehicle safety standards. As the category of LPVs covered in this research is relatively new, there are no up-to-date standards that cover all aspects of these devices. • A new EU standard *CEN/TC 354 Light electric vehicles and self-balancing vehicles* is in development. *Recommendation 28: Consider referencing the upcoming EU PLEV safety standard and/or advocating that Standards NZ develop a harmonised standard.*
Certification and registration	• Unless an LPV that can travel at speeds similar to motor vehicles is permitted, then there would appear to be no need for certification to a vehicle standard. • Registration could provide a means for data collection on the types of LPVs, information dissemination to owners, enforcement and communications in the event of product recalls. Disadvantages include added administrative burden, cost for the consumer, and potential barriers to uptake. *Recommendation 29: Retain the status quo (ie no registration requirement) for mobility devices and other LPVs.*
Mobility impairment	• The research found that mobility-impaired persons are adopting e-scooters and Segways as alternatives to mobility scooters. If these devices are not permitted for the general public, they might be added to the definition of a mobility device, in which case it may be necessary to explicitly require proof or assurance of disability for those using a mobility device. *Recommendation 30: If e-scooters and/or Segways are prohibited for the general public, then consider permitting them for mobility impaired persons and establishing a means of confirming bona fide use.*

<table>
<tr><th>Topic</th><th>Findings and recommendations</th></tr>
<tr><td>Age</td><td>For mobility devices, some countries have set a minimum age for the use of mobility scooters (eg 14 years in the UK). This denies mobility-impaired children who have the maturity and physical ability as determined by their parents and/or doctors to access an important means of travel and engagement with their environment.
Recommendation 31: Consider retaining the status quo no minimum age for mobility devices.
A minimum age regardless of speed capability or usage location would achieve a safety improvement but is overly restrictive given that some LPVs are specifically designed for children (e.g. low speed hoverboards and e-scooters).
For LPVs limited to 15 km/h or less, no minimum age is considered appropriate because children are already using footpaths on unpowered kick scooters at these speeds.
For LPVs capable of speeds greater than 15 km/h, the selection of a minimum age depends on where the devices are permitted to be operated and should take into account the minimum age for e-bikes.
Recommendation 32: Consider no minimum age for LPVs capable of up to 15 km/h and alignment of a minimum age for faster LPVs to match the minimum age for e-bikes.</td></tr>
<tr><td>Driver licensing</td><td>As with e-bikes, the need for driver licensing is dependent on whether LPVs that can keep up with urban motor traffic are permitted. With the top speed of most LPVs ranging from 6 km/h to 25 km/h, a driver licence requirement is not considered necessary.
Recommendation 33: Consider requiring a driver licence only for users of those devices that are permitted to use the road and have a maximum motor-assisted speed above the value adopted for class AB e-bikes.</td></tr>
<tr><td>Helmets</td><td>Helmets are mandated for riders of wheeled recreational devices and LPVs (eg Segways) in some countries.
In New Zealand, there have been calls for mandatory helmets for children riding wheeled recreational devices.
Although some researchers have undertaken cost/benefit analyses of mandatory helmet laws (MHLs) for cyclists or other road users, there is no expert or social consensus on the merits of MHLs.
Recommendation 34: Consider retaining the status quo that helmets are not required for riders of mobility scooters.

Recommendation 35: Consider the efficacy of mandatory helmet legislation in the first instance. Then, consider whether LPVs permitted to use the road should be subject to the same helmet wearing requirement as pedal cyclists. The issues to be taken into consideration could include user age, device stability, and speed capability.</td></tr>
<tr><td>Usage locations</td><td>This research found a variety of views on where LPVs should be operated, largely dependent upon speed. As many LPVs have a top speed that is on the threshold of footpath or road use, it is difficult to develop a blanket solution.
Footpaths: the least restrictive approach would allow all LPVs to use the footpath where the motor assistance ceases to propel at no more than the adopted footpath speed limit, OR it is equipped with at least one of the following features: adjustable speed control (‘turtle’ or ‘footpath’ mode, low power or low speed setting) that is engaged while on the footpath, active speed feedback system, or autonomous speed control OR it is operated without motor assistance.
Recommendation 36: Consider allowing all LPVs to use footpaths if a listed speed reduction measure is engaged or the motor assistance is off, subject to all other adopted requirements and RUR 11.1.
Shared paths: it is generally acknowledged that the use of LPVs on shared paths is acceptable; the existing RUR 11.1 provides behavioural rules for footpaths and roads.
Roads: the minimum speed to be considered a road vehicle is 4 mph (6 km/h) in the UK and 10 km/h in some Australian states. This research suggests that the value should be at least 10 km/h for mobility scooters and at least 15 km/h for all other LPVs.
Recommendation 37: Consider a minimum road speed for all other LPVs.</td></tr>
</table>

Appendix B: LPV specification tables

In order to help inform a potential device/vehicle list for compliance purposes, this appendix provides key specifications for a selection of various LPVs. Power ratings are continuous as stated by the manufacturer. The information in this table has been extracted from a separate spreadsheet with other data such as weight capacity, braking type and sources. E-bike specifications are a small sample; there is a very large number of manufacturers. This sample is not representative of the market in general.

Table B.1 Selected LPV specifications

Device type	Brand	Model	Max speed (km/h)	Continuous power (W)	Width (cm)	Weight (kg)
e-kick scooter	Zumaround	Zum	32	250	-	16.0
e-kick scooter	Zumaround	MiniZum	29	250	-	13.5
e-kick scooter	Zumaround	MaxiZum	34	250	-	20.0
e-kick scooter	INU		25	500	55	25.0
e-kick scooter	Inokim	Quick 3 Hero	25	350	-	15.0
e-kick scooter	Inokim	Quick 3 Super	29	400	-	16.5
e-kick scooter	Inokim	Light Super	25	300	47	13.0
e-kick scooter	E-Twow	S2	30	500	13.5	10.8
e-skateboard	Z-board	II	32	1,000	24.1	8.6
e-skateboard	Yuneec	E-Go cruiser	20	400	27.5	6.3
e-skateboard	Boosted board	Dual	32	1,500	19	7.0
e-skateboard	Leif eSnowboard	Fulton	37	1,295	82	4.4
e-skateboard	Evolve	Carbon series street	38	350	96	8.0
e-skateboard	Marbel		32	2,000	25	4.5
e-skateboard	STARY		30	-	-	5.2
e-skateboard	Monolith	M1	39	1,600	26	6.6
Hoverboard 2.0	Razor	Hovertrax 2.0	10	135	22.9	12.2
Hoverboard	Glyro		13	-	-	-
Hoverboard	Swagtron		13	-	-	9.9
Hoverboard	Hoverzon	S	13	-	58.4	10.0
Hoverboard	Swagway	X1	16	-	58.4	12.7
Hoverboard	Skque	Arrival	10	700	-	13.0
EUC	SBU		20	-	35.4	12.2
EUC	IPS	151	30	1,000	26.5	16.5
EUC	Airwheel	Q5	18	-	18.5	11.5
EUC	Ninebot	E+	22	500	22.9	12.8
Self-bal scooter	Airwheel	S6	17	-	50.3	14.0
Self-bal scooter	NineBot	Minipro	16	-	26.0	13.0
Self bal scooter	Segway	I2 SE PT	20	-	63.0	47.3
Mobility scooter	EV Rider	RiderXpress	8	450	58.4	62

Device type	Brand	Model	Max speed (km/h)	Continuous power (W)	Width (cm)	Weight (kg)
Mobility scooter	Golden Tech	BuzzAround XL	6.4	-	-	49
Mobility scooter	Horizon Mobility	Aztec 2	13	-	70	142
Mobility scooter	Invacare	Meteor	15	400	66	85
Mobility scooter	Invacare	Comet	15	250	61	136
Mobility scooter	Invacare	Lynx	8	-	50	49
Mobility scooter	Invacare	Auriga	10	230	61	66
Mobility scooter	Shoprider	889 SL	12	-	64	108
Mobility scooter	Drive Medical	Envoy 6	9.7	470	60	94
Mobility scooter	Drive Medical	Phoenix 3 wheel	6.4	350	57	55
Mobility scooter	EV Rider	Royale 4 Dual	15	1,300	91.5	198
Mobility scooter	EV Rider	Royale 3	15	1,300	74	184
Mobility scooter	Luggie	Luggie standard	6	-	51.5	25
Mobility scooter	Pride Mobility	Victory 9 3 wheel	8.4	-	56.515	59
Mobility scooter	Radical	Three wheel	10	600	53	88
Mobility scooter	Newage Vehicles	B4 Baby enclosed	15	1,400	71	260
Yike Bike	Yike Bike	Model C	23	200	64	11.4
E-bike	Smart Motion	eCity	*	300		
E-bike	Smart Motion	Essence	*	300		
E-bike	Smart Motion	Catalyst	*	350		
E-bike	Kinetic eZee	Sprint 7L	*	300		
E-bike	Merida	Big Tour	25	250		
E-bike	Pedego	Commuter	* (NZ) 32 (USA)	300 (NZ) 500 (USA)		
E-bike	Vintage	Tracker	58	750, 3,000		
E-bike	Marrs-cycles	M-2	48	1000		
E-bike	Cutler cycles	Fusion	51	1000		
E-bike	HPC	Supermundo	64	750		
E-bike	M1 Sporttechnik	Spitzing	47, 70	250, 500, 800		
E-bike	Nyx	X-Series	50, 95	3000		

* Top motor-assisted speed not stated.

Appendix C: Interview summaries

The scope of work included telephone interviews with industry and other key stakeholders to inform the assessment of potential regulatory options (chapter 9 of the research report). This appendix presents summaries of seven interviews:

1 E-bikes: Tony Arnold (Australian Bicycle Council), Phil May (Juiced Bikes NZ)

2 Mobility scooters: Jill Stansfield (Kapiti Older Person's Council), Keri McMullan (author, *Low vision and mobility scooters*), Roselle Thoreau (author, *Perceptions and experiences of mobility scooters by older adults experiencing a decline in mobility*)

3 Other LPVs: Kevin Grimes (E-unicycle owner)

4 Pedestrian advocacy: Andy Smith (Living Streets Aotearoa)

In addition to these persons, extensive email exchanges were conducted with Alistair Smith and Patrick Morgan (both of Cycle Action Network NZ). The email format of these communications precludes reproduction in a table format in this appendix. As with all the input received through this research, where appropriate their views have been reflected in the assessment of regulatory options.

Many other informal discussions were held during the course of the research, including visits with retailers and interaction with vendors and customers at the Positive Ageing Expo (26 September 2016, Christchurch) and the Motorhome Expo (4 November 2016, Christchurch).

The tables on the following pages include top motor assisted speed, whether or not throttles should be permitted (for respondents with an interest or opinion on e-bikes), and applications (where the device should be allowed to be used).

Name	Tony Arnold	**Focus area**	E-bikes
Organisation	Australian Bicycle Council (views are the interviewee's own)		
LPVs owned	None; although he has ridden a pedelec, throttle e-bike, cargo e-bike, Yike Bike and Segway.		
Speed	25 km/h seems to be safe level, idea of assistance rather than power bike. Attractiveness of higher speeds in terms of alternative to driving: I understand this, but if we can get suburban streets down to 30 km/h then you are looking at a more equal kind of environment. If you are riding on the road then 32 km/h is probably good. But what do you do on paths? The idea that you need to go 32 km/h to keep up with cycle traffic seems high to me. Riding slower shouldn't be a problem. More of a problem if 30 km/h becomes an expectation.		
Throttles	When you have hand control of the throttle, if you are standing still and activate it is more prone to accidental application of power. Whereas a pedal only, you are ready for the power to come on. It would seem that proportional assist would work better. Could be more of a problem with higher power. Our bikes are now a lot more 'polished' as they are EU standard - might be the evolution of e-bikes in general or could be the standard. Have no sense about whether the EU standard is being enforced at all. *Five years ago, I rode a throttle rental bike and thought it interesting that it wasn't a pedelec. More recently, I've seen the Dutch brands like Gazelle with pedal assist that are quite suitable for the purpose of transportation.*		
Applications	Shared paths: substandard shared paths with trail e-bikes, power bikes, scooter style bikes are not a good idea. Six out of eight states allow adults to ride on the footpath. Only Victoria and New South Wales do not allow cycling on the footpath. In Australia, as cycles including pedelecs can go on footpaths in most states, then it would be hard to say that a e-kick scooter cannot go on the footpath. The main difference would be throttles versus pedalling.		
Other	When the vehicle is more like a motorbike, then it should be registered. The barriers to riding bikes is not whether you can do 32 km/h, it is more about safety, rain, hills, and self-identification. Regarding other LPVs: by having more options, then people don't have to drive and park cars everywhere. However, in Australia we tend to be fairly risk averse, as exemplified by the MHL. There are concerns that users will hit a pedestrian or injure themselves by falling off.		

Name	Phil May	**Focus area**	E-bikes
Organisation	Thortech – importers of Juiced Bikes		
LPVs owned	ODK utility e-bike		
Speed	Californian regulations are pragmatic. 32 km/h for class 1 e-bikes (allowed a throttle, share all bike lanes) with 45 km/h for S-pedelecs/class 3 (share some bike lanes). When sharing the road you need the speed to take the lane. Posted speed limit on some dedicated facilities		
Power	Current NZ Transport Agency regulations which are great from a traditional cyclist perspective but lacking vision and understanding of electric bike reality. That 300 W maximum output is not only inadequate for meaningful assistance with New Zealand geography but is also effectively surpassed by every single electric bike motor in use in New Zealand even those advertised as 250 W.		
Throttles	Some sort of throttle (start assist to 6 km/h or open) is necessary for utility e-bikes at low speeds. Riders can't even turn the pedal to start moving on a steep gradient and most torque sensors are not instantaneous. A smooth and quick start at traffic signals is important to get ahead of traffic. The sort of bikes that are going to get people out of cars are going to be those that are affordable $2500 sweet spot; if you start to make them too expensive due to regulatory requirements and component costs you are limiting adoption.		
Applications	S-pedelecs operated at their higher speeds should use the road, not bike lanes.		
Other	Not comfortable with legislating behavioural issues. About to get in a shipment of Cross Current S-Pedelecs, as part of this sale, will be providing an educational leaflet that retailers need to get signed by all customers; mandating such information leaflets and levying each e-bike to pay for education regime would be the best way to address safety. Perhaps additions to the road code that are targeted at the issues for e-bikes.		

Name	Jill Stansfield	**Focus areas**	Pedestrians/mobility scooters
Organisation	Kapiti Older Person's Council		
Speed	Neighbour who uses a mobility scooter says she travels at 19 km/h on a narrow footpath with shrubs impeding view of pedestrians (and other vehicles) emerging from properties. Regarding stopping distance, neighbour stated that as soon as she took her hand off the throttle it would stop – no appreciation of the actual distance it could travel during this time.		
Applications	There is no real alternative to using the footpath, but rider behaviour is a concern; some riders don't seem to want to deviate from their path of travel, forcing pedestrians off the path at times		
Other	Path design needs to be improved, the standards are there but the funding doesn't seem to be. There is a need to improve education messaging		

Name	Keri McMullan	**Focus area**	Mobility scooters
Organisation	Researcher and author: McMullan, K (2016) *Low vision and mobility scooters*. Bachelor of Occupational Therapy, Otago Polytechnic, Dunedin.		
Speed	For vision-impaired study participants, they tend to go walking speed or slower in most situations. In wide-open spaces, they do tend to increase speed. Participants do use the footpath speed mode (for those that have them).		
Applications	None of the participants would 'happily' go in the road, but sometimes they must. They do ride indoors in shops, but this is self-determined by the shop layout, eg aisle widths.		
Other	Safety features such as flags – participants have a mixed opinion on this. Mirrors are useful for the people that have them. Vision impaired scooter riders use them in spite of their vision, they have gone to them for autonomy. Safety seems to be self-regulating.		

Name	Roselle Thoreau	**Focus area**	Mobility scooters
Organisation	Engineering Partnership Manager, University of Auckland Researcher and author: Thoreau, R (2015) *Perceptions and experiences of mobility scooters by older adults experiencing a decline in mobility*. Doctor of Philosophy, University College London.		
Speed	No opinion offered		
Applications	Road going use is typically found in smaller communities where there are no footpaths and/or low traffic on the road. Users prefer the footpath where they can. Works fine in New Zealand.		
Other	UK registration – not all sellers inform buyers of this requirement; second hand buyers don't know. When insuring them, owners don't have all the required information. Regulation is stopping some people from using class 3 scooters. Educate public to (a) dispel perception of lazy overweight people, most users would otherwise be in a wheelchair or housebound and (b) address pedestrian concerns - scooters are seen as more of a danger than they really are. As soon as somebody on a scooter collides with a pedestrian, it is newsworthy, but scooter/pedestrian collisions are rare. Educate users: in UK, retailers required to offer instruction, but quality varies; comprehensive tuition is available but not widely; nobody wants to take responsibility. Safety features: Horns are standard, and should be used as required – perceptions that rider is being aggressive need to be addressed. Powered wheelchairs are more expensive because of the engineering; mobility scooters don't make their users look as disabled – it is a Catch-22.		

Name	Kevin Grimes	**Focus area**	E-Unicycles (EUCs)
Organisation	NZ Post (views are the interviewee's own)		
LPVs owned	IPS 191 electric unicycle (EUC). Owned since April 2016, used for the 4 km trip to work in Lower Hutt; there is no parking at workplace. Considered e-bikes, but found the EUC suited needs better. First EUC was underpowered for rider weight.		
Speed	Paraphrased quotes follow. *Depends on where it is regulated to be ridden. The one that I have can go 30 km/h. The larger wheel models can go faster. I think this is stupid fast, but some people would use it. For private land, should be no limit. Cycle lanes - 30-40 km/h would be max. Footpaths - nearer to 10-15 km/h.* *If you had a car that stopped at 100 km/h, nobody would buy it. A basic model goes 8-9 km, but nicer models have Bluetooth connection to smartphone. EUCs have audible warnings when you reach certain speeds.* *Perhaps the rule could be 10 km/h on footpath, cycle lane 25 km/h, private road unlimited.* *My EUC is currently set to 25 because that is as fast as I like to go. You can tell how fast you are going. Very easy to modify your speed.* *It isn't about limiting the power to limit the speed, it should be limiting the speed electronically. For EUCs, the only practical approach is a user adjustable speed limit.* *I lean forward to accelerate and move forward, and the wheel moves forward to stay underneath me. As it hits a user set speed threshold the wheel tips backwards. Need it to be more powerful than I want it to be, because the problems come from those that don't have enough power to manage all situations.*		
Throttles	N/A		
Applications	*Good question. These devices are new. If someone invented a pushbike today, we'd be going through all the same questions. A big advantage of a unicycle is the larger wheel size. The larger diameter makes it more practical - it is the transition between surfaces that is the usual problem. So, they are capable of easily changing between facility types. From a rider perspective, it is simpler if you have a smoother surface. Excellent for protected bike lanes* *I can ride it slower than I can walk. You don't have a minimum speed. It is really down to user behaviour though. The most practical place is a cycle lane, then mixed traffic, then footpath. If it is a cycle lane, you might say it should be 25 - 30 km/h. Need to ensure that it can keep up with cyclists.*		
Other	*Most people who ride these aren't riding them for the adrenaline rush; most people ride them for enjoyment, relaxing, unusual feeling of gliding. It's to get around much quicker than a car. Really valuable because it is a public transport first mile/last mile solution. One of the few LPVs that is small and light enough to easily carry on the train, store it under my desk at work. Makes public transport accessible.* *The MHL should apply as long as it applies to bikes, although there is the argument that encouraging more use will lead to mode shift and better safety outcomes for everyone.* *Other safety gear - different to a pushbike compared to how you are positioned. Knee pads, elbow pads are a good idea and recommended.* *Regarding the rider's awareness of their speed; Other than the "generic" wheels, which can't go over 12km/h anyway, all wheels that I know of have Bluetooth connectivity. And that isn't just to a smartphone, but also to smart watches. I know a couple of riders in the USA that use their watches to know the route they are going - as it means they aren't holding their phones in-hand.* *The other relevant topic, that we didn't touch on, is insurance... One of the biggest issues overseas is that powered vehicles require insurance, but it is hard to get for e-unicycles.* *Over here, insurance isn't compulsory like it is in some places, but I understand that our insurance companies are working toward policies (or endorsements) for LPV. I don't currently have insurance, but would like to have some (indemnity). And I will be working on this, when I have some time.* *I do know though that insurance companies in NZ are working on e-vehicle options, so it shouldn't be an issue if a level of insurance is required.*		

Name	Andy Smith	**Focus area**	Pedestrians
Organisation	Living Streets		
LPVs owned	Don't own one, but have ridden a Segway and an e-bike		
Speed	E-bikes: 25 km/h and 45 km/h classes seem appropriate		
Throttles	Don't see the point in limiting throttles, they are a transport machine. Whether you restrict throttles or not, the potential to startle a pedestrian remains.		
Applications	Interviewee did not appear to have a formed opinion as yet. Other LPVs on footpaths: *I would like to think that if active people are going to use them (other LPVs) as a recreational device they shouldn't be allowed on the footpath because they are not for recreation, they are for transport. If allowed, should be limited to 7 km/h or so. On the other hand, perhaps the RUR is sufficient and we could leave it to case law. If someone gets run down, precedent will be set. There are going to be more of these vehicles, people are going to use them, and we need to be adaptive.* Other LPVs on shared paths and cycleways: they should be allowed if they want to. Mobility scooters: they should not be allowed on major roads without facilities for their operation; increasing their visibility should be a focus.		
Other	Mobility scooters should have a flag; the existing regulations on them seem adequate. Segways should be a mobility device if the user is mobility impaired.		

Appendix D: Sample safety information sheet

CROSSCURRENT SAFETY INFORMATION SHEET

We love our bikes, they are well made, affordable and fast. We got into e-bikes to get our cities moving, but we want you to keep safe when you're on the roads. Please read this Safety Information Sheet to become familiar with the issues that power assisted cycle riders face.

You will know most of this already but **please read, tick each line and sign**, we're all in this together!

- ❑ Cars don't expect you to be travelling fast, they really don't. If you aren't dressed in lycra on a speedy looking road-bike then drivers **will underestimate** your speed, so:
  - ❑ Keep alert
  - ❑ Meet driver's eyes
  - ❑ Keep your eyes open and scanning left and right
  - ❑ Expect drivers to pull out or turn in front of you, especially when undertaking to the left of stationary queues
  - ❑ Do not ride in the "door zone", expect car doors to open without warning
- ❑ Pedestrians are the most vulnerable road users; they are top of the food chain when it comes to safety and consideration:
  - ❑ Look out for pedestrians, they will underestimate your speed too
  - ❑ Be extra vigilant around crossings and intersections
  - ❑ Give way to pedestrians at pedestrian crossings
  - ❑ Better to assume someone will step onto the road when you are unsure, slow down, you'll soon get back up to speed
  - ❑ On cycle lanes separated from the footpath by a paint stripe, don't go over 30 km/h in cycle lanes to protect pedestrian wanders into your lane, if you need to go faster then go onto the road
  - ❑ When passing pedestrians on shared paths, slow down, provide plenty of space, and give a friendly hello, warning or ring your bell so you don't startle them
- ❑ Your fellow cyclists are vulnerable too. We have the capability to keep up with traffic in many situations where *they* don't so we need to ride accordingly:
  - ❑ Don't go over 30 km/h in cycle lanes, try using a lower assist level
  - ❑ Keep a safe following distance
  - ❑ Use a bell or a friendly verbal warning when overtaking, overtake on the right
  - ❑ On narrow bike lanes wait until you get to the next stop light and position yourself to go in front at the next green light. Hey, you're on a bike, you can politely ask!
  - ❑ Many cyclists will also underestimate your speed, follow the same safety guidelines as per cars
- ❑ Last but certainly not least, obey all road rules, ride defensively and have yourself a whole lot of FUN!

Keep up to date on the Cyclist Road Code: https://www.nzta.govt.nz/resources/roadcode/cyclist-code/

Phil and the Juiced Bikes NZ Team   Signed:______________________________

Appendix E: Survey

This appendix presents charts and information from the survey. The full response database is available separately for more information and/or further analysis.

E1 Aims and distribution

The purpose of the survey was to gather information from an identified range of key informants who have valuable experience and knowledge related to the future of low-powered vehicles in New Zealand. Purposive sampling was used to identify and include important stakeholder groups, including:

- e-bike, mobility scooter and other LPV manufacturers, importers and retailers
- transport researchers
- elderly advocacy groups (including Age Concern and Grey Power)
- Disabled Persons Assembly (DPA)
- pedestrian and cycling advocacy groups (Living Streets Aotearoa and Cycling Action Network)
- government agency staff
- transport writers for blogs and traditional media outlets.

The survey was open to the general public, with specific advertising being made through the NZ Transport Agency *Cycle life* e-newsletter and social media (eg Facebook and Twitter).

E2 Development

A draft survey was developed and distributed to the project steering committee, wider project team and key stakeholders. Some changes were made in response to feedback received and the survey was made publicly available at 4pm on Friday, 2 September 2016.

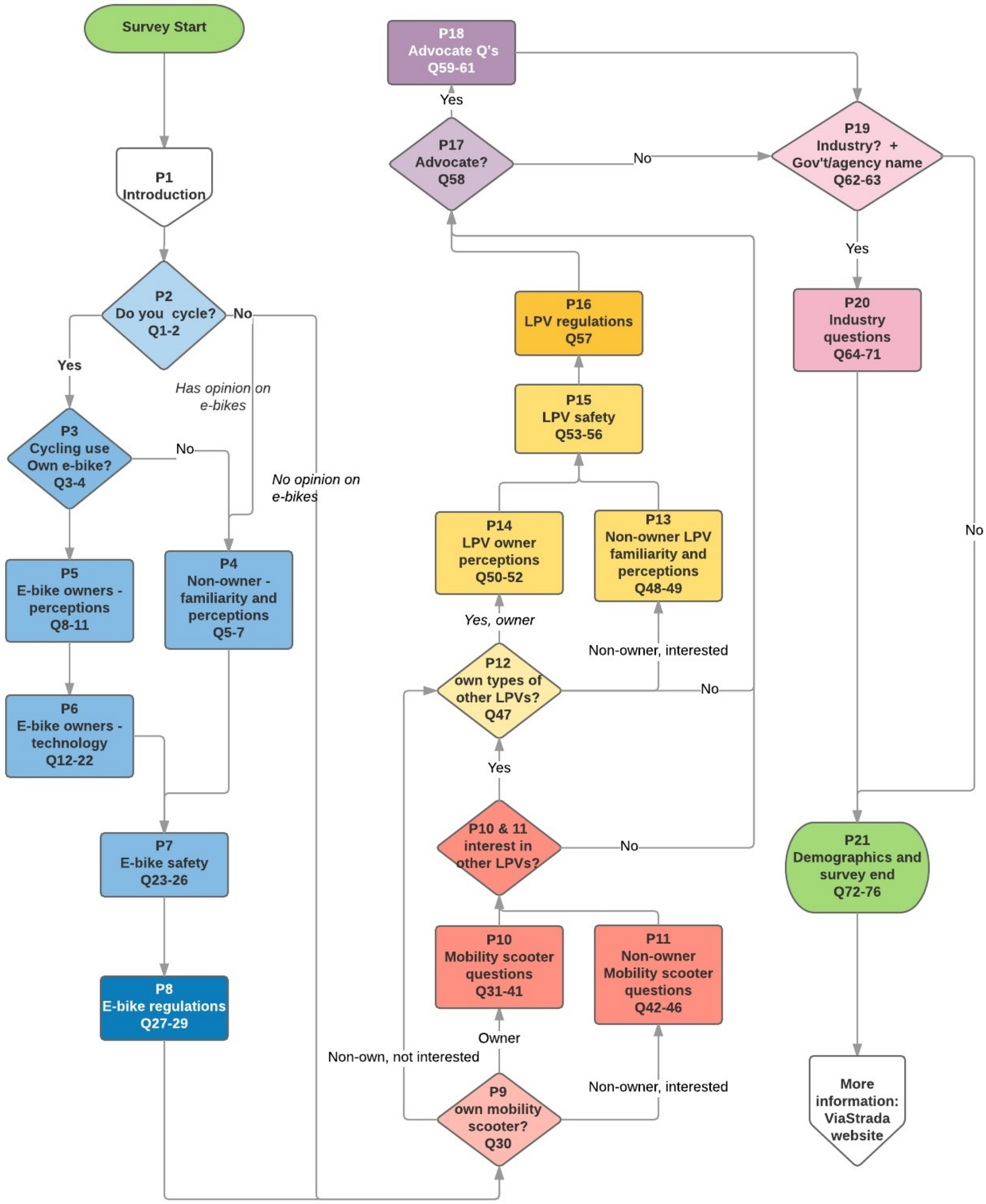
Feedback from survey participants was monitored throughout the duration of the survey. Two modifications were made on 8 September in response to comments from one particular participant; these changes were made to improve the clarity and logic of the survey but are not considered to have affected the overall results before and after. Question 2 on Page 2 was added to give people who don't cycle the option of skipping straight to mobility scooters and Page 11 was added to give people who don't have a mobility scooter the option of commenting on their use. When these modifications were made, 750 survey responses had already been received; it is not considered that these modifications have had any significant influence on the survey results.

After initial testing, the survey was officially opened to the public on 2 September 2016. The part 1 report, which was used to inform the workshops, included summary information from the first 10 days that the survey was open, a total of 1,025 responses. The survey was closed on 15 November 2016, ie after a period of 75 days. In total, 1,356 responses were received.

E3 Survey logic

Figure E.1 illustrates the structure that determines which questions each person answers based on their responses to key questions. Each box refers to a page, some of which include multiple questions. Note that this includes the two minor modifications (to questions 2 and 30) made on 8 September.

Figure E.1 Survey logic map



E4 Survey questions

The survey comprised the following questions. Note that the response options are not detailed, but the broad nature of the responses available is given in brackets after each question – for most questions there was also an open field for comments. The numbers correspond to the question numbers cited in the survey logic map. Survey response data analyses and data has been provided separate from this report.

1 Typically, I cycle: (frequency)

2 I don't cycle. Here's what I want to do next: (survey navigation)

3 Regarding cycling (whether powered or otherwise), in general I: (riding environments)

4 Regarding e-bikes, I: (ownership)

5 How familiar are you with e-bikes? Select all that apply. (familiarity)

6 Please indicate your level of agreement regarding the following statements. (properties of e-bikes)

7 If you have a negative perception of e-bikes, please indicate anything that has contributed to that perception. (opinions / experiences)

8 Please indicate your level of agreement regarding the following statements. (potential benefits of e-bikes)

9 I had or have the following concerns about e-bikes: (concerns)

10 If you own an un-assisted bike as well, what proportion of cycling time do you use your e-bike? (proportion)

11 Why did you buy an e-bike? Select all that apply: (reasons for buying)

12 How many bikes do you own? (number of unpowered bikes and e-bikes)

13 My e-bike is a (specify brand and model)

14 The type of my e-bike is: (types / styles)

15 (Explanation of throttles and pedal assistance sensors). My e-bike motor is activated by: (means of motor activation)

16 E-bikes with throttles: (opinion)

17 My e-bike motor maximum continuous power is:

18 (Explanation of motor power). Assuming that the current legislation actually means continuous power rating as is common in the e-bike industry, is the New Zealand motor power limit of 300 watts: (adequacy rating)

19 Does your e-bike provide enough assistance to get you over hills? (select all that apply) (opinion)

20 My e-bike motor: (cut-out speed)

21 What are your typical average and top speeds on level (flat) ground? (speeds)

22 My e-bike battery is a: (type of battery)

23 Have you ever been involved in a crash involving an e-bike (while driving, cycling, or walking)? (No / type of crash)

24 Have you ever been involved in a near-miss involving an e-bike (while driving, cycling, or walking)? A near miss can range from strongly flinching due to another road user nearly colliding with you through to a situation where you had to take strong evasive action (heavy braking / steering / sudden stopping / jumping out of the way). (No / type of crash)

25 Have you ever felt threatened by the presence of e-bike users (while driving, cycling or walking)? (yes/ no)

26 In terms of safety, compared to regular un-assisted bicycles, do you think e-bikes are: (comparison)

27 If regulated, how fast should e-bikes be permitted to go when on the road? This question refers to the "motor cut-out speed". Higher speeds may still be possible on downhills or through muscular energy alone. (speed)

28 Where should e-bikes be permitted? Select any of: (road / path locations)

29 Is there anything else you'd like to say on the subject of regulating e-bikes and/or use in New Zealand? (open)

30 Regarding mobility scooters: (ownership)

31 The main reason that I (or my immediate family member) got a mobility scooter was: (select all that apply) (reasons for buying)

32 For what purposes is the mobility scooter used? (purposes)

33 The mobility scooter is used in the following locations (travel environment)

34 I (or my immediate family member) have experienced the following incidents while using the mobility scooter: (crash types)

35 The following factors contributed to the incident(s): (contributing factors)

36 If there has been an injury while using the mobility scooter: (injury severity)

37 Mobility scooters range from models that can go 6 km/h to 16 km/h (or more). Should they be electronically speed restricted? (speed)

38 The following scooter features should be made mandatory: (features)

39 Have you (or your immediate family member who uses the scooter) had any scooter safety training? (yes/no)

40 Australia requires mobility scooters capable of more than 10 km/h to be equipped and registered as a road vehicle. Should this, or something similar, be considered in New Zealand? (yes/no)

41 Regarding other low-powered vehicles (Segways, e-kick scooters, etc): (survey navigation)

42 Mobility scooters range from models that can go 6 km/h to 16 km/h (or more). Should they be electronically speed restricted? (speeds)

43 The following scooter features should be made mandatory: (features)

44 Do you believe scooter safety training: (mandatory / voluntary etc)

45 Australia requires mobility scooters capable of more than 10 km/h to be equipped and registered as a road vehicle. Should this, or something similar, be considered in New Zealand (yes/no)

46 Regarding other low-powered vehicles (Segways, e-kick scooters, etc): (survey navigation)

47 I own the following (select as many as applicable): (other LPV types)

48 How familiar are you with the following? Select all that apply. (other LPV types and familiarity)

49 Please indicate your perceptions of these devices / vehicles: (other LPV types and opinions)

50 Please indicate your perceptions of these devices / vehicles: (other LPV types and opinions)

51 Why did you buy it? Select all that apply: (reasons for buying)

52 How much do you use it? (frequency)

53 Have you ever been involved in a crash involving a LPV (other than e-bike or mobility scooter)? (no / crash type)

54 Have you ever been involved in a near-miss involving a LPV (other than e-bike or mobility scooter) (no / crash type)

55 Have you ever felt threatened by the presence of one of these devices (while driving, cycling or walking)? (yes / no)

56 Please indicate any concerns with these devices / vehicles: (concerns)

57 I believe these devices / vehicles: (opinions regarding regulations / use)

58 Are you a member of an advocacy organisation? Examples (not an exhaustive list): CAN, Living Streets, Grey Power, DPA, AA, BIANZ (yes / no)

59 Advocacy organisations I am a member of: (organisation)

60 My role: (open)

61 Does your organisation have an official position or policy on e-bikes or other low-powered vehicles? If so, please describe it below. (open)

62 Are you involved in the bicycle or small wheel vehicle industry? This includes the manufacture, importation, and/or retailing of any type of cycles, skateboards, scooters, mobility scooters, etc. (yes / no)

63 Do you work for government? (yes / no)

64 My business is a (select all that apply): (manufacturer / retailer etc)

65 Regarding products that are available in un-powered and powered (or power-assisted) versions, my product mix includes (select all that apply): (type of device)

66 Regarding powered products, my product mix includes (select all that apply): (type of LPV)

67 If your business deals in both unpowered and powered (or power-assisted) bicycles: (proportions)

68 Please indicate the approximate number of units you sold in the last 12 months: (sales figures)

69 Please indicate the approximate number of units you anticipate selling in the next 12 months: (sales predictions)

70 For your most popular units, how easy is it to adjust the maximum motor cut-out speed? (level of ease)

71 How often do end-users / customers seek to over-ride controller settings? (type of setting and frequencies)

72 Would you like to participate in a workshop on e-bike / other low-powered vehicle technology and regulation (tentatively 26 October in Christchurch and 15 November in Wellington or Tauranga)? Note that space will be limited and transport is at participants own cost. (yes / no)

73 What is your age? (optional) (age range)

74 Respondent gender (optional) (gender)

75 Address (optional) (address)

76 Any other thoughts?

Appendix F: Glossary

ACC	Accident Compensation Corporation
ACT	Australian Capital Territories
ADA	Americans with Disabilities Act
BDCM	brushless direct current motor
BPSA	Bicycle Product Suppliers Association (USA industry group)
BSEB	bicycle-style electric bicycle
CAS	Crash Analysis System (NZ Transport Agency)
cc	cubic centimetres
CE	Conformité Européenne (European Conformity)
CNG	NZ Transport Agency's *Cycling network guidance* online resource
CONEBI	Confederation of the European Bicycle Industry
CPSC	Consumer Product Safety Commission (USA)
CVC	California Vehicle Code
DIY	do it yourself
DTMR	Department of Transport and Main Roads (Queensland)
EAPC	electrically-assisted power cycle (UK)
e-bike	electric bicycle; synonymous with EAPC and EPAC, includes all variants of BSEBs and SSEBs
EBWR	Electric Bicycle World Report
EC	European Commission
EPAC	electrically power assisted cycle (EU, AU)
EPAMD	electric personal assistive mobility device
e-scooter	electric kick scooter
EU	European Union
EUC	electric unicycle
EV	electric vehicle
GPS	global positioning system
Li-Ion	lithium-ion (battery)
LPV	low-power vehicle
LSEV	low-speed electric vehicle
LSV	low-speed vehicle
LTA	Land Transport Authority (Singapore)

MoT	Ministry of Transport (New Zealand)
nd	no date
NEV	Neighborhood Electric Vehicle (USA)
NHTSA	National Highway Traffic Safety Administration
OECD	Organisation for Economic Cooperation and Development
OEM	original equipment manufacturer
OPDMD	other power-driven mobility device (US)
PAB	power-assisted bicycle
PAS	pedal assist sensor
Pedalec	pedal-electric bicycle (AU) – an e-bike where the motor only functions if the rider pedals
Pedelec	pedal-electric bicycle (EU) – an e-bike where the motor only functions if the rider pedals
PETD	personal electronic transportation device
PMD	powered mobility device (various countries) or personal mobility device (Singapore)
PTD	personal transportation device
RUR	Road User Rule (also more formally known as the ‘Land Transport (Road User) Rule’)
S-pedelec	speed pedal-electric bicycle (EU)
SSEB	scooter-style electric bicycle
UL	Underwriter’s Laboratories – a US product safety and standards certification company
US	United States
USA	United States of America
W	watt
Wh	watt-hour
WRD	wheeled-recreational device (New Zealand legal term)