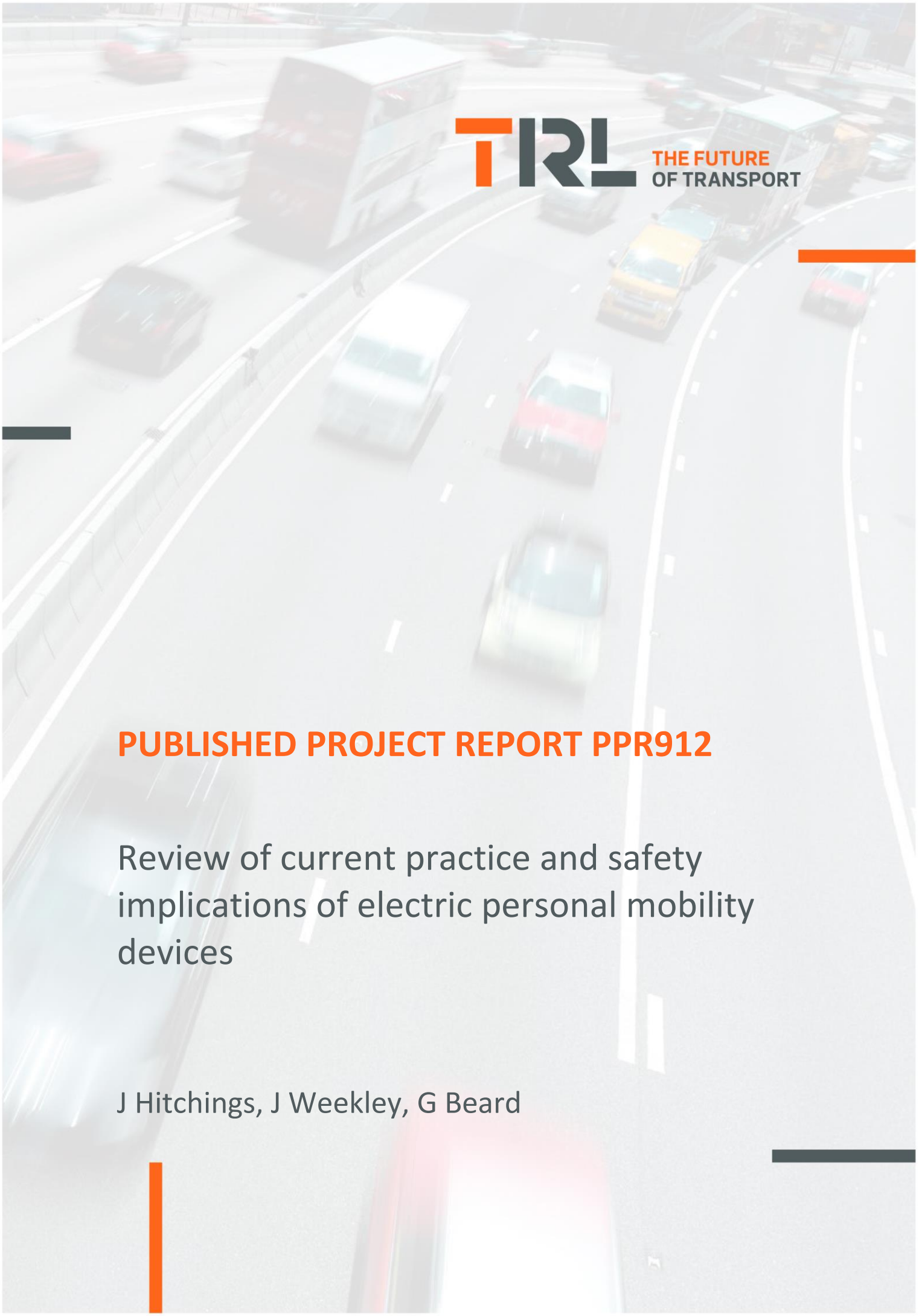

THE FUTURE OF TRANSPORT

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Review of current practice and safety implications of electric personal mobility devices

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Executive summary

Devices such as electric scooters (e-scooters), Segways, hoverboards, u-wheels, powered mini scooters (go-peds), and powered unicycles are emerging around the world as new and innovative forms of personal transport. Such devices may be classified as 'Powered transporters' - "novel personal transport devices which are mechanically propelled (propelled by a motor) as well as or instead of being manually propelled."[1].

Currently within Ireland, because powered transporters are considered to be mechanically propelled vehicles, they therefore require registration, motor tax, a driving licence and insurance when used on a public road. As powered transporters fail to meet the criteria for vehicle registration (i.e. minimum required safety standards), they are therefore not permitted for use on public roads in Ireland.

This project was commissioned to review current practice and the safety implications of these devices. The aim of this work was to inform considerations for future policy and regulatory framework options with regards to operation of powered transporters in Ireland.

In order to address this aim, a literature review was first undertaken to meet the following objectives:

- Understand the policy and legislation relevant to the use of powered transporters on roads, cycle paths and footways, nationally and internationally.
- Establish current state of knowledge with regards to the safety of powered transporter users, including the risks associated with interactions between powered transporters and other vehicles (including vulnerable road users), and the potential benefits associated with such vehicles.

The rationale behind the review was to identify evidence on which to establish a robust basis for recommendations for policy and legislation around use of powered transporters in Ireland. This was then followed by a case study investigation to identify the existing legislative context and current practice in a number of selected countries, and to use this to further inform the next steps towards future policy and regulatory framework updates.

The literature review showed that, whilst there is a lack of robust evidence available, there is some support for developing policy and legislation which:

- Encourages the use of personal protective equipment (PPE, e.g. helmets), possibly through targeted public awareness campaigns and by placing responsibility with powered transporter sharing companies to promote safety;
- Provides (or prescribes) training for operators of powered transporters prior to their use in public;

[1] https://www.gov.uk/government/publications/powered-transporters

- Creates clear safety standards that powered transporters are required to meet (e.g. weight or size restrictions, or minimum lighting/conspicuity standards), and possibly enforcing these standards through a type-approval system or certification process;
- Clarifies who exactly is permitted to use different devices (e.g. age limits and licence requirements); and
- Provides clear guidance on how and where different devices can be used (e.g. footways vs. cycle lanes vs. roads, and the rules that apply to each).

It is worth noting however that there is little evidence on which to base the details of such guidance, either from the safety perspective or from an infrastructure or engineering perspective.

Despite the limited direct evidence, it is clear these devices have potential benefits for active travel and possibly for improving air quality and reducing traffic congestion. In most countries there is increased uptake by users, regardless of the legal situation, and little enforcement of any regulations that exist and hence an outright ban would be both counterintuitive and impractical. Prohibition without justification is generally held to be unsustainable. There are also limited data available regarding the potential impact on serious injuries; anecdotal evidence suggests that scooter-related injuries increase with increased scooter use but that these are generally minor and a result of users falling off rather than interactions with other road users.

The key finding from the case study investigation was that there is no clear universal consensus – and much confusion - as to how to approach the issues surrounding powered transporters and there is significant variation in how different countries are regulating their use. In the absence of clear evidence on which to base detailed legislation, it is recommended that powered transporters should be allowed for use in certain circumstances, with a controlled and considered roll out to mitigate against potential negative safety implications.

Based on this review the following is therefore recommended:

1. Agree clear terms for vehicle classification. The classification must be able to accommodate different powered transporter types in order to future-proof against further technology innovation. Further, classifications should be based on considerations of safety, not (for example) on specifics of vehicle design such as starting mechanism, or size.
2. Promote the use of helmets and other protective equipment. This could take the form of an awareness campaign for educating the public and also engagement with sharing scheme providers, manufacturers and retailers.
3. Consider issuing a set of advisory guidelines for both individual users and users of sharing schemes. Whilst there is little robust evidence from which to develop specific restrictions there are several basic principles on which guidelines can be based:
    - Guidelines should minimise the likelihood of high-speed interactions, for example prohibiting powered transporters from high-speed roads

- Guidelines should consider other road users (including pedestrians), for example if powered transporters are allowed on pavements, there could be a maximum speed of 6 km/h to protect pedestrians.
- Allow flexibility for local authorities to implement these guidelines as appropriate for their jurisdictions.

If possible, these guidelines should be created in consultation with sharing scheme providers, local authorities and the Police.

4. Promote the need for safe use of powered transporters amongst the public and if possible encourage opportunities for training or familiarisation prior to use in public. This could be carried out alongside recommendations 2 and 3.
5. Consider methods of implementing minimum safety standards for the powered transporters themselves. One option would be to use the draft European Standard as the basis for a voluntary certification scheme.
6. Carry out further research into the safety features which should be mandatory, how powered transporter riders are likely to interact with other road users, and what operational guidelines should be produced to minimise risk.

1 Introduction

Electric personal mobility devices are an emerging vehicle category and are becoming more common around the world. Such devices include electric scooters (e-scooters), Segways, hoverboards, u-wheels, powered mini scooters (go-peds), and powered unicycles. , and is the term that will be used in this report hereafter. Varying terms are used in the literature to describe these technologies, including 'personal light electric vehicle', 'personal mobility device', 'recreational transport device', 'non-registered motorised vehicle', 'micro-mobility device' and 'alternative private passenger vehicle'. For consistency, this report utilises the collective term 'powered transporters', defined as "a variety of novel personal transport devices which are mechanically propelled (propelled by a motor) as well as or instead of being manually propelled."[2].

Currently within the Ireland, because powered transporters are considered to be mechanically propelled vehicles, they therefore require registration, motor tax, a driving licence and insurance when used on a public road. As powered transporters fail to meet the criteria for vehicle registration (i.e. minimum required safety standards), they are therefore not permitted for use on public roads in Ireland.

The project was commissioned by the Road Safety Authority in Ireland to review current practice and the safety implications of powered transporters. Specifically, this report details work conducted to understand: the application of legislation and rules of the road relevant to the use of powered transporters across Ireland, the UK and internationally; the potential risks associated with the interaction of powered transporters with other road users (including vulnerable road users), and; the potential safety, environmental, and operational benefits of this type of mobility device. The aim of this work was to inform considerations for future policy and regulatory framework updates by RSA with regards to operation of powered transporters in Ireland.

The remainder of the report is structured as follows:

- Section 2 presents a literature review, which includes details on the methodology used and a discussion of the findings.
- Section 3 presents a case study investigation, which details the current state of play with regards to operation of powered transporters in selected countries.
- Section 4 presents conclusions and recommendations for Ireland, based on the evidence identified from the literature review and case study investigation.

[2] https://www.gov.uk/government/publications/powered-transporters

2 Literature review

2.1 Introduction

As well as literature focused on powered transporters, this review also sought literature related to electric bicycles (e-bikes). Currently, e-bikes do not fall within the category of powered transporter; however, parallels can be drawn in that e-bikes are powered mechanically and manually, so it was considered that literature on e-bikes may provide useful insights on the potential benefits of powered transporters as well as safety and legislation considerations.

This section of the report details the in-depth literature review undertaken to meet the following objectives:

- Understand the policy and legislation relevant to the use of powered transporters on roads, cycle paths and footways, nationally and internationally.
- Establish current state of knowledge with regards to the safety of powered transporter users, including the risks associated with interactions between powered transporters and other vehicles (including vulnerable road users), and the potential benefits associated with such vehicles.

Garnering an understanding of well-evaluated legislation in place in other countries – as well as the benefits associated with powered transporters – will provide Ireland with an evidence base to make any necessary developments to their current policy and legislation for this emerging vehicle category.

2.2 Method

A list of search terms (see Appendix A) relevant to the research questions was generated to run the literature search. These search terms were tested and applied in a number of research databases (Google Scholar, ScienceDirect, TRID[3]) as Boolean search expressions. Other research databases were tested (BASE[4], CORE[5]) and found to not be useful sources for this review as they failed to produce any literature relevant to the current investigation. Multiple searches were conducted within each database through an iterative process, wherein search terms were tested individually and in combination with each other to identify which terms generated relevant results. Once the terms had been tested, those that generated relevant results were merged into a Boolean search expression. This allowed the output to be refined to the most manageable number of relevant texts. Additional filters

[3] Transport Research International Documentation Database that covers a million records of references to books, technical reports, conference proceedings and journal articles within the field of transport research.

[4] Bielefeld Academic Search Engine is one of the world's most voluminous search engines especially for academic resources, providing more than 120 million documents from more than 6,000 sources.

[5] Connecting Repositories is a research search engine built for the purpose of aggregating all open access research outputs from repositories and journals worldwide.

were applied where necessary to limit the search output to research conducted within the past ten years to ensure that the most up to date information was being used.

After conducting and refining the literature search, literature was then compiled in a spreadsheet for a full review. Search output that was clearly irrelevant based on the title was removed at this stage. The completed spreadsheet included 79 pieces of literature. The abstracts of this initial list of literature were reviewed and scored using a set of inclusion criteria (see Appendix B). After scoring, 45 pieces of literature were taken forward for full text review.

Literature was reviewed in full with findings recorded systematically in the review spreadsheet. Each individual text was presented in a row, with summaries of the research goals, methods and findings detailed in columns. Conclusions relating to the research questions of the current project were drawn, where possible, from each reference. The 34 texts originally excluded were reviewed in brief to ensure no major evidence had been missed through application of the inclusion criteria. No major findings had been missed, though nine papers were found to provide additional support for findings identified within the full text review and were included accordingly.

2.3 Results

This section presents the main findings relating to the objectives of the literature review. Around two thirds of the reviewed literature focused on a single specific device, most commonly either e-bikes or Segways. In these instances, findings are discussed with consideration given to other forms of powered transporter where possible. Additionally, there were some papers that considered powered transporters as part of a broader vehicle category, which included devices such as skateboards, mobility scooters and electric golf carts. As these kinds of devices do not fall within the scope of the current investigation, findings associated with them are not considered as part of the review. That is unless they could be directly applied to the powered transporters within the scope of this review.

With this in mind, this section breaks down the key findings into the following topic areas that emerged from the literature review:

- The need for appropriate legislation
- Safety and training needs
- Benefits of powered transporters
- Recommendations made by other road safety authorities

2.3.1 The need for appropriate legislation

To successfully manage the adoption of powered transporters it is important that legislation is appropriately designed to accommodate them. This review has raised a number of factors that highlight the need for countries to give more consideration to this emerging vehicle category. These include the growing interest in powered transporters as they continue to become more common and their usage worldwide increases, as well as current legislation showing a lack of understanding of required needs. Spear (2017) wrote a short thought-

piece discussing whether powered transporters such as e-scooters, Segways and hoverboards are a passing fad or an important part of our future transport network. The article highlights Singapore as a world leader in permitting and regulating powered transporters in public spaces, evidencing the increasing usage and ownership of such powered transporters within the country and elsewhere in the world. Spear concluded that these devices will likely form a part of future transport networks around the world, especially if their uptake is promoted to demonstrate their numerous potential benefits such as offering an effective and sustainable first- and last-mile travel solution.

The increasing use of powered transporters within other countries has been discussed within other research. The US Department of Transportation (Landis, Petritsch & Huang, 2004) noted that as a result of the aging American population there was an increase in the number of people using devices such as powered mobility scooters. In terms of the current review, this particular paper is now quite dated having been written only a short time after the invention of the Segway. However, it raises awareness of the aging population which may be more likely to consider powered transporters, in some form, as this emerging technology continues to be developed to meet growing mobility needs. The Korea Transport Institute estimates that sales of powered transporters in South Korea will increase by more than three times by the year 2022 (Kim, Park, Cho, Hyun and Lee, 2018). The market size of powered transporters in South Korea was over 60,000 units in 2016, which was estimated to increase by 20% in 2017 at the time of Kim et al.'s (2018) report. In Australia, approximately 80,000 Segways were purchased from the company's US manufacturer up to 2012 (Department of Transport and Main Roads, Queensland, 2012); this figure did not account for Segways being purchased from any other seller, nor did it include any other forms of powered transporter. These figures are still small when compared with sales of bicycles (Australia sold over one million bicycles in 2012[6]), however, what the figures do show is an upward trend in powered transporter purchases.

Many cities across North America saw a boom in the use of e-scooters in 2017 as a number of shared active transportation companies (e.g. Bird, Lyft) began operation. As these companies launched without appropriate permits or business licences, a number of cities and local authorities have since banned the use of these devices on public streets until appropriate policy is put in place to effectively manage them (National Association of City Transportation Officials, New York, 2018). However, Fang, Agrawal, Steele, Hunter and Hooper (2018) highlight how these scooter sharing companies attracted significant interest and investment capital. Evidently interest in such devices is certainly high and the act of banning the use of e-scooters outright would appear to have been conducted without full consideration to their potential. With this in mind, it is clear that legislation is therefore needed to control and prescribe how powered transporters should be used in a public environment.

The focus of Fang et al.'s (2018) article was to highlight the lack of infrastructure that currently exists to allow for the use of powered transporters. If and when powered transporters are incorporated into a country's transport system, it is necessary that steps

[6] https://www.statista.com/statistics/788362/australia-bicycle-sales/

are taken to appropriately accommodate them. It is likely that this would require funding for infrastructure that supports the use of powered transporters, such as parking and charging facilities. Although it was identified that within the city of San José, California, most users of shared dockless e-scooters parked these devices in sensible locations (e.g. alongside existing street furniture) largely out of the way of pedestrian traffic (Fang et al., 2018), this finding is likely not applicable to all other cities around the world and there still exists a risk of these devices being left in inappropriate locations (e.g. on the carriageway). To minimise this risk, appropriate parking infrastructure (e.g. specific facilities that allow for shared or private devices to be parked and charged), along with accompanying legislation or policy to enforce or promote the use of such facilities (e.g. penalties for failing to use appropriate parking facilities), could minimise the occurrence of powered transporters such as e-scooters being left in potentially hazardous locations.

A small trial of powered transporters conducted on Macquarie University campus in Australia found that 90% of those who participated in the trial found the devices to be an enjoyable and comfortable means of transport, while also identifying it as a good means of travel for short journeys (Dowling, Irwin, Faulks & Howitt, 2015). Albeit the sample of participants in this trial was small (17 riders) and usage was restricted to a university campus, it presents some insight into the positive perceptions and potential usage of powered transporters. Furthermore, qualitative feedback collected from this trial also highlighted individual concerns around the lack of infrastructure to adequately accommodate powered transporters. This point is further supported in a report by the National Transport Commission in Australia (2019), which notes that the current regulatory framework regarding the use of powered transporters is outdated, and the current transport infrastructure in Australia is being increasingly put under strain as it is not designed or able to accommodate the increased demand created by new vehicle categories. For example, infrastructure would likely need to incorporate appropriate parking facilities and pathways that allow for the safe use of powered transporters without creating conflicts with other path users.

Further concerns surrounding existing legislation were raised in a report by Fang, Agrawal and Hooper (2018), who discussed the wide variety of regulations that exist on e-scooters and other powered transporters between North American states. Different states regulate different forms of powered transporter to different levels of detail, with inconsistencies existing between states in terms of where they can operate. For example, a Segway is regulated as a vehicle in Nebraska, whereas in Idaho it is regulated as a pedestrian; and only six states (Virginia, California, Oregon, New Jersey, Utah, and Washington) have regulation that specifically addresses e-scooters. Policies need to be constructed based on evidence which considers the environment they are being enforced in, and the current variations in policy across the US would suggest that this has not been the case. They conclude by proposing a set of key principles that should be addressed when constructing effective regulations. This includes the need to protect public safety, clarify who has the right to operate on different shared spaces (e.g. footpaths), and having easily understood rules based on evidenced facts, not perceptions. Furthermore, regulation that makes the use of powered transporters illegal should be avoided, and new regulations should be designed to accommodate future device types. As such, regulators may prefer to design a class system for different powered transporters with appropriate rules assigned to each class. Litman

(2006) provided an early discussion exploring appropriate means of managing powered transporters as they grow in popularity and use. He drew attention to the importance of managing shared spaces to avoid conflicts between pedestrians, cyclists and powered transporter users. He raised an important point that any legislation that is created to manage new transport options should be made to deal with actual problems that exist. For instance, it would not be necessary to ban the use of powered transporters from public footpaths if they do not create a problem in that space. Litman argues that in cases where prohibition is not really justified, the rules are likely to be ignored by users; instead it is more effective for governing bodies to develop clear policies that promote responsible and appropriate behaviour. Legislation that is created on the use of powered transporters should consider the environment in which they are going to be used (both the type of road/pathway, as well as geographical location), as legislation that governs their use on a more general level may not be applicable to all regions where they are used.

Hyvönen, Repo and Lammi (2016) conducted an investigation into consumer perceptions of Light Electric Vehicles, such as e-bikes, electric skateboards and Segways. Data were collected and analysed from a representative sample of the Finnish population. The results showed that consumers perceive these kinds of devices (with the e-bike being a possible exception) as 'technological niches' (i.e. novel devices that are still seeking wide and accepted use), though they do show interest in them. They suggest that interest will only continue to grow, providing a further argument for the need to adopt appropriate legislation to accommodate this emerging vehicle category. With regards to e-bikes, Edge and Goodfield (2017) conducted a qualitative investigation on stakeholder perceptions towards e-bike adoption. Similar to Hyvönen et al.'s findings, e-bikes were seen as a promising technology – ideal for first- and last-mile travel – that encourages active travel and a modal shift away from private automobiles. Edge and Goodfield conclude their study by highlighting the need to investigate how much emerging vehicle types are likely to displace traditional transport options (e.g. car, bus) and a need to design policy to facilitate this shift.

The points discussed within this section have highlighted the increasing interest and adoption of alternative transport options such as e-scooters, Segways and other powered transporters. It would appear that powered transporters have great potential as an innovative transport solution, with early evidence suggesting they are perceived positively. However, more work is required to encourage and facilitate their continued uptake. In particular, an appropriate regulatory framework needs to be designed to ensure the devices are used in a safe way. This point will continue to be discussed in the next section which raises the argument for incorporating the wearing of protective gear and appropriate user training within a regulatory framework.

2.3.2 Safety and training needs

From the evidence identified in the literature review, two key factors emerged:

1) There is a need to encourage the wearing of appropriate protective gear (e.g. helmet, elbow/knee guards) while riding specific powered transporters, and;
2) There is a need to ensure users are sufficiently trained and familiar with how to operate a device.

The first of these factors stems from evidence examining the injury risk when using powered transporters such as Segways and hoverboards. The second became apparent from the literature investigating poor user behaviour, and differences between novice and experienced riders. These factors are discussed further below.

Kim et al. (2018) conducted a two-year study of patients administered to the emergency department of a hospital in Korea for injuries incurred from using a powered transporter (specifically e-scooters, electric unicycles and Segways). Sixty-five patients were identified during the study period (January 2016 to December 2017). The number of total incidents was over three times larger in the second year compared with the first, which suggests there is growing uptake of these powered transporters; however, further evidence over a longer period would be required to support this point. The most common injuries were sustained to the head and neck, resulting from the user falling over as opposed to a collision with another road user or infrastructure. Of note is that six of the 50 adult patients within this study admitted to alcohol consumption at the time of the injury. This raises some concerns about these powered transporters being used inappropriately while under the influence of drugs and alcohol, and presents an argument for considering this within the construction of appropriate legislation.

In Canada, 35 cases of various hoverboard-related injuries were recorded in the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) in 2016 (Do et al., 2016). The majority of these injuries involved fractures to the arm (wrist, forearm, elbow and upper arm), with other injuries occurring to the head, back and legs. These injuries ranged in nature from sprains, dislocations, tissue damage and concussion. A concerning finding from this investigation was that over two thirds of the reported injuries occurred in the home. Due to the enclosed nature of indoor environments that could potentially contain a great number of obstacles and hazards (e.g. furniture, stairs, pets), injuries sustained in an indoor environment have the potential to be serious, as they could be when used outdoors. Similar to the analysis by Kattan et al. (2017), these findings only represent a very small sample. A broader analysis of injury records across a range of different locations would create a better idea of the most common injuries, and the types of protective gear which would be most suitable for reducing injury risk. Over a ten month period in 2016, 13 cases of Seymour fractures (fractures to the end of the finger) were identified in a paediatric ward at a tertiary hospital in Saudi Arabia (Kattan et al., 2017). Injuries were found to be a result of improper use, where a child was sitting on the device (as opposed to standing) or getting their finger caught in the wheel mechanism. Appropriate awareness of the dangers of improper use of powered transporters could prevent such injuries. Protective gloves could also minimise injury to the hands if a rider were to fall from any form of powered transporter. It is important to note that the sample of these cases is relatively small, so enforcement of wearing gloves while operating powered transporters would not be justified but their use could be encouraged to minimise the risk of injury. Further investigation into how common this kind of injury is elsewhere in the world would be useful and could provide a means of raising public awareness on the safe use of powered transporters.

In 2018, the Portland Bureau of Transportation carried out their E-Scooter Pilot Program (PBOT, 2019), designed to assess whether e-scooters have an effect on congestion, fatalities and injuries, air pollution and mobility. They found that, during the pilot period, scooter-related injuries increased however most of these were relatively minor. Only 3% of these

injuries were the result of a collision with a pedestrian, with 84% being the result of an individual falling off their scooter, perhaps emphasising the need for training or awareness of safe use. It is worth noting that 34% of scooter riders in the pilot stated that they had replaced car trips with e-scooter trips; since there is a link between serious injuries and fatalities and vehicle miles, a replacement of vehicle journeys with e-scooter use may contribute to an overall decrease in injury risk. However, more data are needed to quantify this effect.

Mikkelsen, Morup-Petersen and Hvolris (2014) reported on two cases of hip associated fractures in elderly riders of Segways. Both were travelling on Segways at walking pace as part of a guided sightseeing tour, a common use of the device, and had received five minutes of introduction on how to operate it prior to taking part in the tour. Another case reported by Ashurst and Wagner (2015) saw an elderly rider suffer a femur fracture after falling from his own personal Segway while riding it intoxicated. Though these reports only detail a total of three cases, they demonstrate the severity of injuries that can occur while operating these devices. It is difficult to ascertain whether protective gear would have reduced the severity of injuries in these specific cases.

Xu et al. (2016a; 2016b) conducted two investigations of powered transporter safety using computer-simulated vehicle crash accidents. Their first study focused on rider injury resulting from impact with different motor vehicles (e.g. sedan, pick-up, SUV), and a second study focussed on head injuries resulting from subsequent impacts with the ground following a vehicle collision. Using simulated crash scenarios, they identified rider height as a key factor in the resulting injury severity. The simulations suggested that pedestrians had greater risk of their head colliding with the bonnet of the vehicle, whereas powered transporter riders were more likely to have their head collide with the windshield due to their higher centre of gravity. Due to the strength of the bonnet, pedestrian collisions therefore had a greater estimated injury severity than powered transporter collisions, where head impact with the windshield would likely result in comparatively less trauma. Devices like e-scooters and Segways were found to offer a small degree of impact protection, a benefit that pedestrians are not subject to. That is to say that at the point of collision, the device itself absorbs some of the impact from the vehicle rather than the full impact being put on the person. As a result pedestrians were found to be thrown a greater distance, further increasing the risk of more serious injuries. Although Xu et al.'s studies considered different vehicle types, speeds and angles of collision, their focus on head injuries resulting from collision impacts meant injuries to other parts of the body were not accounted for. Furthermore, it was not considered how the devices in question may have resulted in further injuries; for example, if the device is thrown into the rider as a result of the collision.

It is possible that protective gear (such as helmets, elbow pads, and knee pads) could prevent or reduce the severity of injuries sustained through use of powered transporters. Due to the self-balancing nature of devices like Segways and hoverboards, there is a risk of users falling from the device (Kim et al., 2018). In such an event, protective gear should aid in minimising the severity and risk of serious injuries such as bone fractures to the protected regions (Kim et al., 2018). Similar conclusions were drawn by Li et al. (2017) with regard to e-bike collisions. Consideration should be given to encourage the wearing of protective equipment such as helmets, elbow pads, and knee pads while operating any form of powered transporter. This could be driven by government policy or legislation, or by the

industry itself. For example, analysis of social media activity suggested that Bird, a leading e-scooter sharing company, did not actively promote the wearing of protective gear on their social media channels, particularly Instagram (Allem & Majmundar, 2019). Leading manufacturers, suppliers and governing bodies could work in combination to encourage good safety practices.

With regards to training needs, Rodier, Shaheen and Chung (2003) reviewed the safety of different low-speed travel modes in pedestrian environments, as part of a larger research project intended to trial the use of Segways within employment centres in Northern California. The low-speed modes in question included walking, cycling, riding scooters, and riding Segways; however, other powered transporters (hoverboards, e-scooters, and electric unicycles) also travel at similar low speeds. From an extensive risk assessment of these different modes, the authors identified user error as the major cause of collisions in this vehicle category. As the intention was to pilot the use of Segways in a later project, they recommended administering training to participants before use to minimise the risk of user error leading to collisions with others and the environment.

Miller et al. (2010) found experienced Segway riders (those who had used a Segway for a minimum of once per week for a period of 6 months) travel at moderately faster speeds than novice riders, but have greater control of the device and are more able to brake safely for both planned and unplanned events. A similar study by Nishiuci, Shiomi and Todoroki (2015) found experienced Segway riders to have better control over the device than novice riders, in terms of completion of a slalom obstacle course, being able to decelerate more smoothly. However, this study may not accurately reflect what would happen in a real-world scenario due to the highly artificial and low-risk testing environment that was used. Further research is required to draw robust conclusions; however, initial evidence suggests that experienced riders demonstrate better control over powered transporters than novice riders. As improved control should minimise risk of user error and the potential for collisions, this supports a need for providing suitable training prior to using powered transporters (Castonguay and Binwa, 2006).

Evidence from the literature on e-bikes raises some concerns about rider behaviour. Studies in China and Germany have reported on the frequency of riders travelling at unnecessarily fast speeds and travelling through red lights at signalised junctions and intersections (Bai, Liu, Guo, & Yu, 2015; Schleinitz, Petzoldt, Franke-Bertholdt, Krems, & Gehlert, 2017; Wang, Xu, Xia, & Qian, 2018; Yang et al., 2018). Injuries sustained from collisions at faster speeds are shown to be more serious than at slower speeds (e.g. Li et al., 2016; Siman-Tova, Radomislenskya, & Pelega, 2018). Riders in China in particular have demonstrated a lack of common safety practices, including failure to wear appropriate protective gear and frequent erroneous and dangerous behaviour (e.g. red-light running) (Du et al., 2013). Although this evidence is limited in how well it can apply to powered transporters, it does raise some points that should be considered when designing a regulatory framework to manage them. E-bike riders have been found to travel at unnecessarily fast speeds and engaging in dangerous riding behaviours, so it is therefore necessary to identify whether powered transporter riders are prone to engaging in similar behaviours. If research can identify what dangerous behaviours powered transporter riders are prone to doing (if any), then legislation can be specifically designed to address these problem behaviours. This may involve enforcing restrictive speed limits and other road rules.

This section has raised the argument for encouraging the wearing of personal protective equipment while riding powered transporters, as well as highlighted a need for training users on how to operate powered transporters such as Segways and hoverboards to reduce the likelihood of user error for novice riders. It is important to note that some of this evidence has been taken from other fields. Ultimately this means that the strongest conclusion that can be drawn is that more research is required to clarify whether there is an improvement to individual safety from undergoing user training and wearing protective equipment. Furthermore, this research would need to be conducted before any legislative changes are made.

2.3.3 Benefits of powered transporters

The literature review has identified a number of benefits that are offered by powered transporters, such as having a positive environmental impact and improving mobility. If the evidence demonstrates that powered transporters do indeed have a positive impact, then these benefits should be made clear to the user as this may encourage uptake of powered transporters. This could be done through public awareness campaigns, managed by local authorities or service providers. If uptake of powered transporters is to be encouraged, then it would be necessary to ensure that a regulatory framework is in place to manage their increasing numbers on the network.

One of the most practical benefits of powered transporters is that they offer a first- and last-mile transport solution that is useful for short journeys. Smith and Schwierterman (2018) conducted a series of analyses, each exploring a unique aspect of travel, with the overall goal of understanding how an e-scooter sharing system could meet mobility needs of commuters in Chicago. The analysis focused on the potential monetary and travel time savings of individuals who had access to e-scooters. They concluded that e-scooters offer a cheaper and quicker alternative when compared with more conventional travel means (e.g. private automobiles, public transit) for trips between half a mile and two miles, particularly in urban environments where parking constraints may exist. This came down to factors such as time saved in finding and walking to, and from, a parking spot (approximately six minutes in total), money saved per trip and per mile (estimated to be around $1.10 and $1.33 respectively), and e-scooters offering travel from locations void of public transport options. Smith and Schwierterman admit to making some significant assumptions in their analyses and fail to consider how a significant increase in alternative travel options could impact congestion and collision risks – a concern also raised by Litman (2006), who notes that powered transporters pose a moderate collision risk to other path and road users. Nevertheless the study provides a good introduction to the benefits that an e-scooter sharing service can offer to individuals. Providing such services are well-managed and regulated appropriately, congestion and safety issues should be minimised for both publicly available and privately-owned powered transporters (Lieswyn, Fowler, Koorey, Wilke, & Crimp, 2017). Shaheen, Rodier and Eaken (2005) provide similar evidence on the benefits of Segways and other low-speed mobility options (e-bikes and conventional bicycles) in California. In particular, they noted benefits in commuter travel time in dense employment hubs by connecting public transport stations with surrounding businesses.

Using alternative travel means such as powered transporters for shorter journeys should reduce reliance on cars. Providing these alternative travel means are sustainable, they will ultimately reduce carbon emissions and provide a benefit to the environment. Rose and Richardson (2009) undertook a systematic assessment of various personal mobility options to understand their impacts. This included assessing safety and environmental impacts, how they are likely to affect efficiency of transport systems, as well as facilitate accessibility and mobility. Their assessment demonstrated that powered transporters such as the Segway offer a slight positive impact on these factors. This is likely due to their use being focused on shorter journeys (up to two miles), as was mentioned in Smith and Schwierterman's (2018) study. When used for longer journeys, powered transporters are likely to be less efficient in certain aspects, such as overall travel time. E-bikes have already been shown to be suitable for substituting shorter journeys typically taken by cars or public transport (Kroesen, 2017; Lin, Wells, & Sovacool, 2017), which helps to reduce carbon emissions, improve air quality, and are overall beneficial for the environment (Cherry, 2007; Lieswyn & Wilke, 2016; Fyhri, Sundfør, & Weber, 2016). If powered transporters can achieve the same shift then they will bring about similar benefits. Rose and Richardson (2009) concluded that authorities need to be proactive in promoting the benefits of powered transporters in order to capitalise on the opportunities they present, as they have the potential to enhance transport system efficiency, while lowering the environmental impacts and ensuring safety outcomes are not compromised. This could be achieved through well-designed public awareness campaigns or incentive schemes that could be managed by governing bodies or service providers.

Beyond the environmental benefits, powered transporters have potential to offer health benefits to riders. Compared with travelling by car, which is entirely sedentary and requires little physical exertion from the driver, powered transporters offer a more active travel solution, although some contest just how active users need to be (Lieswyn et al., 2017). When compared with walking and cycling, using a device such as an e-scooter or Segway – which largely only requires the user to be standing on to operate it – is arguably not very active. Evidence suggests the joy of riding an e-bike has a positive effect on mental wellbeing (Jones, Harms & Heinen, 2016), though it is unclear whether this same effect would be seen in powered transporters. No strong evidence was identified in relation to the potential health benefits from using powered transporters. However, if one considers the reduction of air pollution that would be seen if powered transporters begin to substitute a large number of car journeys in highly congested city environments, this environmental benefit would likely have a positive impact on public health. Future research is needed to quantify the extent of the health benefits offered by powered transporters; if benefits are shown then these should be used as part of public awareness campaigns to further encourage their uptake (Lieswyn and Wilke, 2016).

For individuals with disabilities, powered transporters have the potential to improve mobility. Sawatzky et al. (2007) trained 23 subjects with a range of disabilities (e.g. multiple sclerosis, spinal cord injury, amputation) in how to operate a Segway. In spite of some elements of the Segway's design (weight and size), subjects found the device easy to use and were excited about the potential it offered as an assistive technology due to it offering improvements over other mobility aids (e.g. walkers, wheelchairs, leg/knee braces, crutches, canes). Further research should continue the work conducted by Sawatzky et al. to better

understand how powered transporters can benefit those who are less able. One idea would be to investigate whether similar benefits are offered to the elderly.

As discussed earlier, evidence from the pilot program carried out by the Portland Bureau of Transportation in 2018 showed that e-scooters replaced personal car and ride-hailing trips, with 34% of survey respondents saying that their last scooter trip had replaced driving a car or hailing a taxi (PBOT, 2019). This percentage was higher (at 48%) for tourists and visitors. Whilst this provides some evidence of modal shift, it was not clear from the pilot whether e-scooter used had contributed to a reduction in air pollution.

Similar to the evidence discussed on safety and training needs, the evidence on the beneficial aspects of powered transporters is lacking. It has suggested that there are potential mobility, environmental, and health benefits associated with powered transporters; however, the limited evidence is not sufficient to quantify the extent of these effects. It is clear that further research is therefore required, as having a stronger evidence base may give confidence to those encouraging the use of powered transporters, to help the benefits be realised.

2.3.4 Recommendations made by other road safety authorities

A number of authorities have undertaken their own investigations into what appropriate policy should look like. These investigations have sought to understand existing policy on powered transporters in order to make their own recommendations to governing bodies on how to best regulate their use. Looking at other work like this will raise points worth considering for the recommendations provided as part of the current review.

The Royal Automobile Club of Victoria, Australia (Pratt et al., 2016) conducted a study which reviewed existing legislation across Australia and internationally, while assessing the safety impacts of different powered transporters. They highlighted from their review that a clear definition of this emerging vehicle category needs to be established, as well as an appropriate legal framework. This would help address the inconsistencies that exist between different powered transporters within the current regulations in Australia. Public awareness of any changes to existing legislation also needs to be ensured. Pratt et al. also provide a series of points for further consideration. This includes making arrangements for the registration and insurance of powered transporters, rider testing and licensing, and the development of regulations that provide a minimum performance standard and encourage the use of appropriate safety equipment. Similar recommendations were also given in an earlier report from the Parliament of New South Wales (Joint Standing Committee on Road Safety, 2014), though they raised some additional points for consideration as well; namely that powered transporters need to be factored into the design of future public infrastructure. This is related to the considerations made by Fang et al. (2018) who suggest some cities may wish to adopt specific policy to mandate parking facilities for shared e-scooter services.

Continuing the research undertaken in Australia, the Justice and Community Safety Directorate (2016) carried out a review of Segways and similar powered transporters used within the Australian Capital Territory (ACT). This review was carried out to assess how these vehicles can be safely introduced into the current transport system. Categorisation as a motorcycle type vehicle would effectively ban them outright within the ACT, since they do

not meet the requirements for registration or insurance. They argued that there would be no justification for this decision as Segways have been operating relatively safely in the ACT and other jurisdictions since 2011. It is therefore reasoned that Segways would be better categorised as bicycles or pedestrians due to their similar speed and control capabilities. Bicyclists in Australia are subject to speed limits, and they are required to wear a helmet, but bicycles do not need to be licenced or registered. As bicycles are allowed on roads, there is an argument that Segways should be permitted to operate there as well under the same conditions. However, the Justice and Community Safety Directorate note that the Segway was not intended to be used on the road or to interact with motor vehicles, instead it was purposely designed to be used within pedestrianised areas. This investigation did not conclude with any recommendations, but instead raised a number of questions to consider when categorising different powered transporters, and how such categorisations should impact their use. For example, if Segways are to be treated as bicycles should they be allowed on shared or segregated paths? Or, if they are to be treated as pedestrians, should they be required to wear a helmet? Should they be subject to speed limits in certain areas? And what areas should they be allowed to operate in? Answering these questions would ultimately require further investigation. A trial could therefore be designed to understand how Segways – and other powered transporters – interact with others in different environments.

Castonguay and Binwa (2006), in a report prepared for the Transportation Development Centre in Canada, argue that the positive environmental qualities of Segways outweigh the possible inconvenience they may cause on footways, and as such they should therefore be permitted on urban pathways. This conclusion could reasonably be extended to powered transporters such as e-scooters and hoverboards as well. Of course, the safety of pedestrians on footways and in pedestrian spaces must also be considered since the use of powered transporters in these areas brings about the potential for collisions with pedestrians. Some models of e-scooter, for example, have maximum speeds of 25km/h (see section 3) - considerably faster than walking speeds and somewhat faster than an average casual cyclist. Such speed differentials mean that collisions between pedestrians and e-scooter riders could have potential to cause serious injury. Nevertheless, collisions with motor vehicles are likely to involve higher speeds and greater impact forces, and so use of e-scooters on roads may lead to higher injury risk. In the absence of clear evidence therefore, a reasoned risk assessment might conclude that the overall risk to road users would be lower if powered transporters are used in off-road areas like footways compared with being used on roads with motor vehicles. Therefore if one considers the alternatives of either banning their use outright, allowing their use on roads, or allowing their use on footways, this latter option could be considered most favourable as it encourages the uptake of a sustainable transport mode whilst controlling use to minimise risk. It is clear however that more evidence is needed to inform these risk assessments. As more robust evidence on safety risk emerges, alterations to operational restrictions could be made, as appropriate, such as speed limiting in busy pedestrian areas.

Castonguay and Binwa continue their list of recommendations by raising points that would support the safe use and management of these powered transporters in shared spaces. They highlight the need for public awareness campaigns to allay apprehensions towards emerging vehicle types among pedestrians, as well as promote the environmental benefits

of their use. Furthermore, clear rules for users need to be established to encourage and ensure the safe use of powered transporters. They recommend the need to monitor the use of Segways and other powered transporters and adjust standards accordingly. As powered transporters are still in their infancy, it is important that continued investigations are made to ensure the legislation that governs them is appropriate.

Daniel, Chien, Fleischer and Liu (2005), on behalf of the New Jersey Department of Transportation, completed a report on motorised scooters (scooters that operate either on a petrol or electric motor), assessing how these devices are legislated across US states and abroad in order to identify best practice. From their literature review and analysis of safety statistics they reached a number of conclusions. They suggest that minimum age should be comparable to that of motorised bicycles (around 16 years of age); however this is not based on any evidence and is suggested largely because they assume it would bring greater safety outcomes. Helmet use is recommended to be a requirement while operating a motorised scooter, which is supported by the discussion in section 2.3.2. They also recommend that, as registration of these vehicles with current classification system may not be possible since they lack required minimum safety standards, an alternative would be to maintain a list of approved manufacturers and model numbers that meet desired safety standards. This option would ensure that only powered transporters which are safe for public use are sold. Lastly, they discuss the operation of motorised scooters on roadways and footways, recommending that they should be restricted to roadways with designated speed limits not exceeding 30mph. However, other research discussed here (Castonguay and Binwa, 2006) has highlighted safety concerns around introducing such powered transporters alongside fast moving traffic, and further research would be required to ensure such speed limits are appropriate for maximising safety outcomes.

Lieswyn et al. (2017) argue that low-powered vehicles such as e-bikes and powered transporters should be regulated based on their speed capabilities. A maximum speed and size for vehicles could then be introduced for footpaths, shared and segregated pathways, and roadways; though they argue roadways should likely be restricted to e-bikes. Powered transporters capable of higher speeds could also be restricted to older age groups (for example, those who are over the age of 18). They also argue that helmet use could be dependent on the speed capabilities of the device as well. Although prior evidence that was discussed in section 2.3.2 has shown individual cases where helmet use may have minimised injury, further investigation would be required to understand the safety benefits provided by a helmet while riding a powered transporter, and whether this is related to the speed of the device.

The studies discussed in this section had similar objectives to that of the current review. They have carried out their own investigations in order to provide a series of recommendations on how to appropriately manage and legislate emerging vehicle types such as powered transporters. This has highlighted important points worth considering such as how to manage different powered transporters in different environments, introducing age restrictions for different powered transporters and enforcing mandatory helmet use. The recommendations provided by these studies will feed into the conclusions drawn by the current review, which will be discussed within section 4; however, it is important to note that they are limited in how well they can be applied. Some could be considered dated by

today's standards while others are not based on reliable evidence. Once again we are presented with a clear need for robust research studies to investigate this area.

2.4 Implications

It is clear from the literature review that there is currently a lack of strong evidence that addresses how best to regulate the use of powered transporters. Based on the evidence that was identified, there is some to support encouraging the use of personal protective equipment (PPE, e.g. helmets) while operating any form of powered transporter. Similarly, there is some evidence that would suggest a benefit from administering user training prior to operating powered transporters, in particular self-balancing devices such as Segways and hoverboards. Unfortunately, sufficient research has not been undertaken to assess and, in particular, quantify the benefits of PPE or implementing training programmes.

The benefits of powered transporters, such as improvements to traffic congestion, air quality, and individual health, are reasonably assumed and there exists some evidence that suggests as much. However, the extent of these benefits is not yet fully understood or quantified. As such there is potential that current estimates are exaggerated. If the benefits of powered transporters become better established, then these benefits should be promoted through effective public awareness campaigns to encourage uptake.

Some relevant recommendations for policy and legislation have been offered in past research; these provide some insight into key areas that need to be addressed and raise points worth consideration by RSA in their own policy making. This includes creating clear safety standards that powered transporters are required to meet (e.g. must be within certain weight and size constraints, must have sufficient lighting/conspicuity, etc.) so that only approved models are permitted; clarifying who exactly is permitted to use different powered transporters (e.g. restricted to those over the age of 16); and providing clear guidance on how and where different powered transporters can be used (e.g. required to wear appropriate protective equipment, used only on shared pathways, restricted to appropriate speed limits, etc.). These points would require further investigation and robust research trials to understand what safety features should be mandatory on powered transporters, as well as how powered transporters interact with other road users. Once sufficient evidence exists then clear and appropriate legislation can be created to answer questions surrounding where powered transporters can be used, who can use them, and how fast they should be allowed to go.

2.5 Limitations

There were a number of limitations that were identified during the course of the literature review process that should be highlighted.

One limitation that was identified was to do with the terminology used for the vehicle category in question. Throughout this report the term 'powered transporter' has been used to refer to devices such as e-scooters, Segways, hoverboards, etc. During the literature search, terms such as 'personal light electric vehicle' were also used. However, it was identified during the review that other terms have also been used for this vehicle category, including 'recreational transport devices', 'non-registered motorised vehicles', 'micro-

mobility' and 'alternative private passenger vehicles'. No additional searches were run with these alternative terms, therefore it is possible that some literature which utilised only these terms may have been missed. Moreover, there may be other terms used to describe this vehicle category that were not identified during the review.

The definition of the various terms also differed between articles. In some cases, the term 'personal mobility device' would refer only to e-scooters, Segways and hoverboards, whereas in other articles this same term also included e-bikes, powered wheelchairs and mobility scooters within its definition. Similarly, the terms 'e-scooter' and 'e-bike' were often used to refer to different devices; for example, within some articles the term 'e-scooter' was used to refer to both a motorised kick scooter as well as a moped. Such inconsistencies with terminology created difficulty in appropriately interpreting the findings.

Finally, the overall pool of literature which directly contributed to meeting the research objectives was lacking. Specifically, few papers assessed the use of different forms of powered transporter in shared spaces such as foot and cycle paths, or how these devices interacted with other road users. Papers that did provide more of a direct insight were largely focused on e-bikes, which do not directly fall within the definition of powered transporters. There was a small number of papers on Segways from the mid-2000s when this device was first introduced to the market, though little literature focussing specifically on Segways has been conducted within the past ten years. Unfortunately this meant the usable literature on this particular device is arguably quite dated. Furthermore, the majority of research that was found on hoverboards largely focused on cases of injury associated with their use. Though these are useful at building an argument for encouraging users to wear appropriate safety gear, it does not provide great insight into how to appropriately legislate them on public walkways and shared spaces. All in all, these points demonstrate that the evidence pulled from the literature review is limited.

These limitations should be considered alongside the conclusions drawn in this report.

3 Case study investigation

3.1 Introduction

The aim of the case study investigation was to identify the existing legislative context and current practice in a number of case study countries, and to use this to inform the recommendations for future policy and regulatory framework updates by the RSA.

The case studies sought to summarise each country's approach to the operation of powered transporters on roads, cycle paths and footways. As far as possible, this has included identifying relevant current legislation, identification of any policy or guidance on safety (e.g. use of helmets, limitations of operation to specific roads, minimum age or licence requirements), and considering any recent or proposed changes to the national approach.

3.2 Method

The countries were selected according to defined criteria aimed at identifying the most relevant cases. The criteria for selection were:

- Countries where powered transporters are in frequent operation
- Countries where legislation or policy on use of these vehicles is more developed
- Countries where there have been recent developments in this area

Preference was given to countries with good safety records and with a similar legislative culture to the Ireland. The list of countries resulting from these criteria is shown below. A high-level investigation in each of these countries was carried out to ascertain the current 'state of play'.

- Ireland
- UK
- Germany
- France
- Switzerland
- Spain
- Israel
- US
- New Zealand
- Belgium
- Netherlands
- Australia

The investigation highlighted the difficulties that regulators, policy makers and the general public face when considering these vehicles – notably that there is a lot of uncertainty; not only in relation to how these vehicles should be dealt with in the future but also for how they should be dealt with currently. This is due largely to two factors: firstly, there is a lack of consistency in how different types of powered transporters are defined and named. The same make and model of vehicle can have a different name in different countries, the same names are used to refer to very different vehicles in different countries and vehicles that differ only by non-safety critical elements can be classified and dealt with in very different ways. The second factor leading to uncertainty is the pace at which changes in this area are being implemented. Technology is developing rapidly, powered transporters are in the news across the world, countries are being forced to react rapidly in response to incidents and

demands and, as a result, the legislative context and practice is changing on an almost weekly basis, leading to a great deal of conflicting information.

Therefore, in each of the subsections below, we present a short summary of the information obtained for each country at the present time and any points of particular interest, along with a summary of the key themes drawn from all countries and the implications of these for the recommendations. In many cases, this information has been drawn from news articles and the best existing knowledge of those practitioners within the country. There is generally a lack of official sources addressing this area, supporting the limitations of the literature review discussed above, as direct regulation and legislation are either non-existent or in the process of revision. Except where it would cause confusion, the terminology used in the following sections has been kept consistent with that used in each country.

3.3 Results

3.3.1 Europe (general)

The European Committee for Standardization (CEN) is in the process of defining a standard for powered transporters[7], referred to as 'personal light electric vehicles' (PLEV). This standard has been published as a draft for consultation and has a current status of 'pending' at the time of writing. Within the standard, the definition of PLEV used is "a wheeled vehicle partially or totally motorized used for the transportation of one person in a public and /or private space".

The draft standard is stated as applying to:

- Personal light electric vehicles totally or partially electrically powered from self-contained power sources with or without self-balancing system
- Having battery voltages up to 100VDC, and/or an integrated battery charger with up to a 240VAC input

The draft standard similarly states that it does NOT apply to:

- Vehicles that are considered as toys
- Vehicles without a self-balancing system with a seat
- Vehicles intended for competition
- Electrically powered assisted cycles (EPAC)
- Vehicles and/or devices intended for use under medical care
- Electric vehicles having a maximum speed above 25 km/h

[7] CEN – PREN 17128 (Status: pending) Non-approved light motorized vehicles for the transportation of persons and goods and related facilities – Personal light electric vehicles (PLEV) – Safety requirements and test methods.

- Vehicles having a rated voltage of more than 100 VDC or 240 VAC

These definitions and scope provide much-needed clarity as to which vehicles will be classified as PLEVs if and when the standard is mandated into law. In addition, the draft standard further groups PLEVs into four classes by key design elements, as shown in Table 1.

Table 1: Classification of PLEVs by design elements according to CEN – PREN 17128

Types	Maximum design speed (km/h)	Seating position	With self-balanced system
Class 1	Up to 6 km/h	No	No
Class 2	Up to 25km/h	No	No
Class 3	Up to 6 km/h	Optional	Yes
Class 4	Up to 25 km/h	Optional	Yes

The aim of the standard is to specify "safety requirements, test methods, marking and information relating to personal light electric vehicles to reduce the risk of injuries to both third parties and the user during intended use". Elements that are addressed within the draft version of requirements are:

- Speed limiters should ensure the maximum speed limit (depending on Class) is not exceeded. Vehicles of Class 2 and 4 should also have a 'pedestrian mode' limiting speed to 6 km/h.
- All vehicles should be fitted with front, side and rear retro-reflectors. Vehicles of Class 2 and 4 should be fitted with active front and rear lights.
- Audible warnings devices (e.g. bells or horns) should be mandatory for Class 2 and 4 and optional (but recommended) for Class 1 and 3.

3.3.2 Ireland

The Road Traffic Act 1961[8] defines a mechanically propelled vehicle as: "a vehicle intended or adapted for propulsion by mechanical means, including: (a) a bicycle or tricycle with an attachment for propelling it by mechanical power, whether or not the attachment is being used, (b) a vehicle the means of propulsion of which is electrical or partly electrical and partly mechanical, but not including a tramcar or other vehicle running on permanent rails."

[8] Section 3(1) (a) and (b), http://www.irishstatutebook.ie/eli/1961/act/24/enacted/en/html

Under existing legislation, if a mechanically propelled vehicle (MPV) is used in a public place it is subject to all the regulatory controls that apply to other motor vehicles. Therefore, it must be roadworthy, registered, taxed and insured and comply with all road traffic laws as any motor vehicle, including being prohibited on public footpaths. The driver of the vehicle must hold the appropriate driving licence and is obliged to wear a crash helmet[9].

The key factor for regulation therefore is whether a powered transporter is classified as an MPV or not. If it can be powered by mechanical or electrical power alone (i.e. if it can continue without the user pedalling or scooting it) then it is considered to be an MPV. This means that e-scooters, for example, are legally considered MPVs and subject to the requirements above, regardless of whether they require an initial push or kick-start.

If a powered transporter is not considered an MPV then it is considered equivalent to a bicycle and does not require licence or insurance. However, this classification is made by exclusion rather than directly, and as such has implications that may not be appropriate. For example, classifying a battery e-scooter as a bicycle suggests that they are legal to use in bike lanes, which is not the case. Section 3 RTA 1961 defines a pedal cycle as “a bicycle which is intended or adapted for propulsion solely by the physical exertion of a person or persons seated thereon”.

3.3.3 Belgium

In Belgium, legislation was recently updated to include these types of new mobility. Electric scooters will generally fall under the definition of "motorized propulsion device" which is defined[10] as any motor vehicle with one or more wheels with a maximum design speed of 18 km/h. The legislation explicitly states that, provided the design speed remains capped at 18 km/h, motorised propulsion devices are not treated as motor vehicles.

Within this definition, devices are further classified in the legislation[11] as follows:

- Users of motorised propulsion devices that do not travel faster than walking pace are treated as pedestrians.
- Users of motorised propulsion devices that drive faster than walking pace are treated as cyclists.

The requirements with which pedestrians and cyclists must comply therefore also apply to users of powered transporters. In practice this means that devices with a max speed of 18

[9] http://rsa.ie/Documents/VS_Information_Notes/Two_Three_Wheeled_Vehicles/FAQs%20on%20E%20Bikes%20and%20Pedelecs%20and%20battery%20Scooters.pdf

http://www.rsa.ie/Documents/VS_Information_Notes/Two_Three_Wheeled_Vehicles/FAQs%20on%20Segways%20or%20Powered%20Transporters.pdf

[10] https://wegcode.be/wetteksten/secties/kb/wegcode Royal decree concerning general regulations on the police of road traffic and the use of public roads. [BS 09.12.1975] Title I: Introductory provisions Art 2.15.2.

[11] https://wegcode.be/wetteksten/secties/kb/wegcode Royal decree concerning general regulations on the police of road traffic and the use of public roads Title II: Rules for the use of public Art 7a

km/h can be used on cycle paths, and on pavements at speeds less than or equal to walking pace. Anything faster will be classified a motor vehicle and will be subject to all the requirements that any motor vehicle must comply with, however a reform of these rules is being considered which would raise the maximum speed to 25 km/h, equivalent to that of e-bikes.

Brussels requires scooter sharing schemes to register and abide by local rules. There are currently three electric scooter sharing schemes in Brussels. For all three, riders must be over 18 years old and in possession of a valid driving licence. The companies require riders to wear a helmet and to ride in bike lanes, not on pavements. The maximum speed varies between the three providers from 18 km/h to 25 km/h.

3.3.4 France

In France the legal framework is currently in the process of change. In the absence of any specific regulation, the default position is to assume that users of electric scooters and similar devices should follow the existing Highway Code which suggests that they are subject to a max speed of 6 km/h on pavements and up to 25 km/h in cycle lanes[12]. There is no specific law that formally prohibits driving on the road.

However, in October 2018, guidance was issued on a government website[13] clarifying that use of electric scooters and other electric mobility devices is currently illegal. According to this information, the rules governing a 'trottinette avec moteur' (electric scooter) are:

- Its use is prohibited on public roads (pavements and traffic lanes).
- Use is permitted on private roads
- Any dangerous behaviour deliberately putting the life of others in danger can be punished with 1 year of imprisonment and a €15,000 fine.

The law does not currently require helmets, high-visibility clothing or insurance but they are all recommended, as is using an electric scooter which has been CE certified[14]. In practice, as in many other countries, this legislation is rarely enforced and such devices are seen often in cities.

In order to address the uncertainty, new legislation is imminently expected. In October 2018, the Minister of Transport made an announcement suggesting that the government was moving towards legislation that would:

- Create a new category of vehicles in the Highway Code to take into account electric scooters and other new means of urban transport
- Allow these devices on tracks, bike lanes and on road in 30 km/h zones

[12] https://trottinette-lab.fr/reglementation-loi/

[13] https://www.service-public.fr/particuliers/vosdroits/F308

[14] https://urbanmobilitydaily.com/la-legislation-sur-les-trottinettes-electriques-en-france/

- Prohibit their use on pavements

Another idea being considered is a new law requiring users of scooters that can travel faster than 25 km/h to have a category A1 licence[15].

In addition, the government intends to give power to the local authorities governing French cities to decide where electric scooters and similar devices will be allowed within their municipalities. As in many other cities, scooter sharing schemes are being introduced and regulation is being demanded to ensure these are implemented safely.

3.3.5 Germany

In Germany, the government has recently voted to approve the use of e-scooters on roads and cycle paths[16], via the introduction of a new 'Light Electric Vehicle Bill'[17].

The law, expected to come into effect in June 2019, will legalise the use of small electric vehicles without a seat, such as e-scooters and self-balancing vehicles (e.g. Segway), on public roads in Germany for users aged 14 or over. The law applies to electric vehicles without a seat (if self-balancing, they can be with or without a seat), with a handlebar, and with:

- Maximum speed: 20 km/h
- Maximum power: up to 500 W (up to 1,400 W in case of self-balancing vehicles)
- Maximum dimensions: 700 x 1,400 x 2,000 mm
- Maximum mass (without rider): 55 kg

The vehicles need to fulfil certain basic roadworthiness requirements (including brake performance, lights, audible signals/horn, and basic vehicle dynamics requirements) and have to be type-approved. There is no requirement to register the vehicles, but they need to be insured (with a badge as proof of insurance applied to the vehicle). No licence is required for these vehicles.

There will be usage restrictions for the vehicles as follows:

- Users must be 14 years or older.
- Vehicles may not be used on footpaths, shared foot-/cycle paths, or pedestrian precincts.
- Vehicles may only be used on cycle paths (if available) or on the road.
- Cities can, however, permit use of e-scooters in other areas if desired, and by erecting traffic signing as shown below:

[15] http://www.assemblee-nationale.fr/15/propositions/pion1348.asp

[16] https://europe.autonews.com/automakers/germany-votes-legalize-electric-scooters

[17] https://www.bmvi.de/SharedDocs/DE/Anlage/G/Gesetze-19/II-15-referentenentwurf-ekfv-enorm.pdf?__blob=publicationFile

Figure 1: German traffic sign used to indicate that e-scooters are permitted for use

There are certain other restrictions, including a requirement for the vehicles to travel in a line (rather than abreast), users must not hold on to other vehicles, users must not ride hands-free, and users are recommended to wear a helmet.

3.3.6 Netherlands

In the Netherlands, an electric scooter that runs on rechargeable batteries is only permitted if it has been approved and designated by the minister as a "bijzondere bromfiets (special moped)[18]". Other electric scooters are not permitted on public roads.

If the scooter has been so approved and designated, then it can be driven on public roads; the following traffic rules apply[19]:

- Rider must be at least 16 years old
- No licence required
- No licence plate / registration required, although the vehicle must be insured, have an insurance plate and a vehicle identification number
- No helmet required
- Maximum speed of 25 km/h
- Keep to the right as much as possible
- Lighting is required at night and in poor visibility, red and white / yellow reflectors required at all times
- If a designated lane is available, it must be used

[18] Electric scooter https://www.rijksoverheid.nl/onderwerpen/bijzondere-voertuigen/vraag-en-antwoord/wat-zijn-de-verkeersregels-voor-een-motorstep

[19] https://www.rijksoverheid.nl/onderwerpen/bijzondere-voertuigen/vraag-en-antwoord/welke-regels-gelden-er-voor-een-segway

In practice however, despite interest, few electric scooters have been approved for use on public roads though both Amsterdam and Rotterdam are considering authorisations for scooter sharing companies. Due to an incident in October 2018, changes in regulation have been slower than expected. Many scooter sharing companies have established bases in Amsterdam but none have yet received a permit[20]. Results from the investigation into the incident, and therefore any new regulations, are not expected until the end of the year.

3.3.7 Spain

In Spain, as in many other countries, electric scooters proliferated rapidly in cities in the summer of 2018. Existing legislation – that was intended for non-motorised scooters – allowed their use on pavements and as a result they were subsequently banned in many places. In Madrid, they were prohibited and fines were imposed for unauthorised scooters. In November, Spain's Director General for Traffic announced new measures to ban e-scooters from being ridden on pavements and that a maximum speed limit of 25 kilometres per hour was to be introduced[21].

In February however, local authorities in Madrid granted licences for 18 companies to operate within the city provided they comply with the local rules. Electric scooters in the city are banned from pavements, bus lanes, and multi-lane roads. They are allowed to ride in cycle lanes and on cycle paths, and on roads where the maximum speed is 30 km/h or less[22].

3.3.8 Switzerland

Most sources state that all vehicles – including a 'trottinette' – with an electric motor are subject to type-approval in Switzerland and may only be sold with a registration plate[23]. Non-type-tested vehicles are therefore illegal and cannot be insured. Approved vehicles require an annual tax to be paid, which also provides liability insurance. To ride an electric scooter, a test for a specific driving licence (or a higher licence) is required. Other sources however suggest that neither a driving licence, registration nor insurance are required, due to confusion as to how such devices are classified[24].

Electric scooters are seemingly considered as motorcycles (mopeds) with respect to traffic rules. The definition allows up to a maximum design speed of 20 km/h (may provide electric support up to 25 km/h) and up to 500W motor. Rules include:

- Minimum age for an electric scooter is 14 years

[20] https://newmobility.news/2019/02/06/netherlands-still-free-of-e-scooters-after-stint-accident/

[21] https://www.politico.eu/article/e-scooters-test-europe-antiquated-traffic-rules/

[22] https://elpais.com/elpais/2019/04/09/inenglish/1554797032_434337.html

[23] http://www.swissroller.ch/swissroller info gesetze.htm

[24] https://www.englishforum.ch/transportation-driving/264738-electric-scooter-rules.html

- There is no helmet required for vehicles up to a maximum speed of 20 km/h
- Electric scooters are allowed on the road, cycle lanes and cycle paths; cycle lanes and paths MUST be used when available next to a road
- Electric scooters are not allowed on pavements or footpaths

The key element is that all electric scooters must be approved, but in practice very few types and models seem to be at present.

3.3.9 United Kingdom

In the UK, there is clear guidance[25] provided by the Department for Transport laying out both the definition of "powered transporters" and their legal position. The term covers "personal transport devices which are mechanically propelled (propelled by a motor) as well as or instead of being manually propelled. It includes e-scooters, Segways, hoverboards, go-peds (combustion engine-powered kick-scooters), powered unicycles, and u-wheels". There is a specific exclusion of e-bikes – or electrically-assisted pedal cycles (EAPCs) - which have their own regulatory framework.

There is no specific legislation dealing with powered transporters; similar to other countries the current legal context is a result of retroactively applying existing legislation to this new technology. Unlike other countries however, the existing legal definitions and classifications result in a clear, albeit restrictive, position.

The definition of "motor vehicle" as set out in the Road Traffic Act 1988 is "any mechanically propelled vehicle intended or adapted for use on roads" which covers powered transporters. As a result of this definition, the laws governing other motor vehicles also govern the use of powered transporters, meaning that:

- Powered transporters are prohibited on the pavement or other pedestrian-only area (by section 72, Highway Act 1835)
- Powered transporters are prohibited from using footpaths, bridleways or restricted byways (by section 34 Road Traffic Act 1988)
- Powered transporters are prohibited from using cycle tracks, cycle lanes on roads, or other spaces dedicated to pedal cycle use only (by section 21(1), Road Traffic Act 1988)

In principle, as for any other type of motor vehicle, it is legal to use powered transporters on public roads if the usual requirements for motor vehicles are met. These requirements include valid insurance, licence, payment of vehicle tax, registration, compliance with technical standards, driver testing and licensing. In practice however, these requirements are very difficult, potentially impossible, to fulfil in the current regulatory framework, meaning that to all intents and purposes powered transporters cannot be used on UK roads.

[25] https://www.gov.uk/government/publications/powered-transporters/information-sheet-guidance-on-powered-transporters

It is worth noting that these laws governing motor vehicles on pavements have specific legal exemptions – and precedents - for mobility scooters and wheelchairs.

3.3.10 Israel

In Israel, electric scooter sharing companies have been operating since August 2018, with the largest uptake observed outside of the United States. Until January 2019, electric scooters were restricted to bicycle paths where available, but were allowed on roads where there were no bicycle paths present. Previous Israeli laws considered electric scooters a type of bicycle and therefore they were subject to laws for bikes and e-bikes.

Since 1st January 2019 however new regulations have been technically in place. These state:

- No e-bikes or electric scooters can be used by riders under 16 years old
- Riders over 16 years old require either a drivers licence, or a specific e-bike licence, obtainable after doing a course in school or test centres
- Helmets are required at all times and a reflective vest in darkness

In practice this legislation is yet to be widely enforced, however additional regulations are expected allowing strict penalties for contravention[26]. These penalties – approved by the government but not yet finalised - allow:

- The possibility of postponing the attainment of a driver's licence by a year for a person who is caught riding an electric bicycle or scooter under the age of 16
- The possibility of confiscating or destroying an electric bicycle or scooter that is found to be unfit for the road, driving while intoxicated, the rider is under 16, riding with an additional person against the law, and failing to obey a red light
- Heavy fines for traffic violations with electric bicycles or scooters ranging from NIS 250 for minor offenses to NIS 1,000 for serious offenses such as not wearing a helmet

3.3.11 United States

There are many scooter sharing schemes in existence in the United States. Normally US federal law that governs electric bikes is applied to electric scooters as well. This means that electric scooters are often allowed on roads. However laws vary state by state, and local authorities within states can regulate their own municipalities, meaning that there may be significant differences between jurisdictions.

In California, the Vehicle Code[27] states a number of requirements and restrictions for motorised scooters, including:

[26] https://www.theyeshivaworld.com/news/israel-news/1654985/electric-bike-riders-in-israel-require-a-license-beginning-january-1-2019.html

[27] https://www.dmv.ca.gov/portal/dmv/detail/vr/scooters

- A motorised scooter does not require registration, licence plates or insurance, but the rider must have a valid drivers' licence (any class)
- Riders under the age of 18 must wear a helmet
- A motorised scooter can be operated on roads that have a speed limit of 25 mph (or up to 35 mph if local authorities allow) but the scooters themselves cannot exceed 15 mph
- A motorised scooter may be operated on a bicycle path, trail or bike lane, but not on a footway (sidewalk). If the bike lane is on-road (protected or non-protected) then the scooter is allowed regardless of the road's speed limit but still cannot go faster than 15 mph

A motorised scooter in this context is defined as "a two-wheeled device that has handlebars, a floorboard designed to be stood upon when riding, and is powered by a motor". It is clear that the Code is aimed at the 'Vespa-style' motorised scooter, however the definition does also cover the electric kick-scooter style. In major cities like San Francisco, newly-introduced rules[28] for the electric kick-scooter style align with the Vehicle Code, illustrating that these are applicable to both styles.

In Michigan, there are clear rules governing electric scooters. This is due to the fact that Michigan has previously existing electric skateboard legislation – this legislation came into force in September 2018 following an incident in 2016 – and the definition within this also covers electric scooters. The definition under Michigan law is:

> "A wheeled device that has a floorboard designed to be stood upon when riding that is no more than 60 inches long and 18 inches wide, is designed to transport only one person at a time, has an electrical propulsion system with power of no more than 2,500 W, and has a maximum speed on a paved level surface of not more than 25 mph."

This means that the law for the use of electric scooters is as follows[29]:

- Scooters are only allowed on streets or highways with speed limits of less than 25 mph, except when crossing
- Must be ridden as near to the right side of the roadway as is practicable
- Operators must ride no more than two abreast (side-by-side)
- Cannot pass other vehicles between lanes of traffic
- Cannot operate on a roadway between one-half hour after sunset and one-half hour before sunrise unless scooter is equipped with:
    - white light on the front that is visible from at least 500 feet away

[28] https://bayareabicyclelaw.com/new-e-scooter-laws-2019/

[29] https://sinasdramis.com/michigan-personal-injury-attorney/electric-scooter-laws

- reflector on the rear that's visible from up to 600 feet when in low beam headlights from a motor vehicle
- optional use of a red light in addition to the reflector

- May only be occupied by one rider at a time
- Riders under 12 are not able to operate scooters on roadways, streets, or the highway
- Using scooters on footways (sidewalks) is legal under electric scooter laws in Michigan. However, riders must yield the right-of-way to pedestrians and give an audible signal before passing

In some states self-balancing devices such as Segways or the larger type of motorised scooter have been associated with assisted mobility and are therefore exempt from restrictions that may apply to other types of device.

In Washington, DC, motorized scooters are classified as Personal Mobility Devices[30], and are therefore not considered motor vehicles. This means there is no inspection, licence, insurance, or registration required, although riders must be over 16 years old. Additionally, this means that motorized scooters are allowed on the footways (sidewalks) and in bike lanes, and helmets are not required.

In Atlanta, motorized scooters are considered Electric Personal Assistive Mobility Devices, meaning they can be used on footways (sidewalks) and highways where the speed limit is at most 35 mph, or in bike lanes.

3.3.12 Australia

In Australia, a national approach to dealing with such vehicles is currently being discussed; however in the absence of specific provision in existing legislation, there are differences in the way each state has chosen to apply existing laws[31]. For example, in Victoria e-scooters that travel faster than 10 km/h are considered motor vehicles and therefore must be registered and licensed as any other motor vehicle; whilst in New South Wales e-scooters are prohibited except on private land.

There is, as in many countries, increasing interest from companies wishing to implement scooter sharing schemes in major cities; where current state rules currently prohibit such schemes, trials are on-going on private land such as university campuses.

[30] https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/DMV_May%2017%202013%20Non-traditional%20Motor%20Vehicle%20chart_0.pdf Personal Mobility Devices in the US context are specifically for assisted mobility for the elderly or those with disabilities rather than the more general use of the term used in other sections of this report; this illustrates the inconsistency of the definitions and terms used throughout the world.

[31] https://www.abc.net.au/news/2018-12-23/the-rules-around-scooter-sharing-in-australia/10639170

In December 2018, Queensland introduced state-specific rules governing e-scooters; these rules state that:

- Riders must be at least 16 years old; if between 12-16 years riders must be accompanied by an adult
- No licence is needed
- E-scooters can have a maximum speed of up to 25 km/h, but must be able to stop quickly to avoid a collision
- Helmets and lights are required
- E-scooters are only allowed on paths, not roads or road cycle lanes
- Riders must not use mobile phones or drink alcohol whilst using an e-scooter

3.3.13 New Zealand

The New Zealand Transport Agency provides official guidance[32] for "low-powered vehicles" which covers a number of personal mobility devices. Low-powered vehicles are those that do not meet the definition of a motor vehicle, or have been declared not to be a motor vehicle and they can be used without registration or a driver's licence.

The key definition for the purposes of this review is that: "an electric scooter is designed in the style of a traditional push scooter, with a footboard, two or three wheels, a long steering handle and an electric auxiliary propulsion motor. In order to meet the requirements for a low-powered vehicle, the wheels must not exceed 355 mm and the motor must have a maximum power output not exceeding 300 W."

According to the guidance, such e-scooters can be used on the footpath or the road – except in designated cycle lanes that are part of the road (which were designed for the sole use of cyclists). When on the footpath the user must:

- Operate the device in a careful and considerate manner
- Operate the device at a speed that does not put other footpath users at risk
- Give way to both pedestrians and drivers of mobility devices.

On the road, e-scooters must be operated as near as practicable to the edge of the roadway. A helmet is not legally required to be worn when using an e-scooter, but it is recommended.

The guidance also specifies that mobility devices (with a motor of up to 1500 W) and power-assisted cycles (up to 300 W and designed to be propelled primarily by the rider) are also classified as low-powered vehicles. For the latter, the usual rules for bicycles apply. All other powered vehicles require registration, an appropriate driver licence and must meet appropriate equipment and safety standards for the appropriate class of vehicle. This includes Segways and e-scooters over 300 W.

[32] https://www.nzta.govt.nz/vehicles/vehicle-types/low-powered-vehicles/

It is interesting to note that, despite the credibility of the source, the guidance itself urges caution and emphasises the inconsistency and uncertainty surrounding these devices. The guidance emphasises that the responsibility for determining the legal classification of a device - and hence ensuring lawful use - lies with the user and suggests consultation of the full legal definitions of "vehicle and motor vehicle in the interpretation section of the Land Transport Act 1998".

3.4 Summary

The current state of play in these case study countries varies from those who have implemented new legislation to govern personal mobility devices, those where new legislation is pending or in process, to those where they are covered in some form by existing legislation or where there is no regulation at all.

In many of the countries, where legislation exists it is often a result of the criteria used in the definitions covering new devices by default rather than design; if these devices are not clearly specified then their classification is often by a process of exclusion. This results in their classification varying by country to a considerable extent – sometimes existing criteria mean that they are classified along with e-bikes or electric motorcycles, sometimes they are classified as pedestrians or non-electric bicycles, and sometimes they are treated as any other motor vehicle. In some countries, similar devices are classified differently depending on factors such as top speed, starting mechanism, or motor power.

This unintentional 'by exclusion' approach results in, at best, an inconsistent position country by country and, at worst, in unsafe practice. For example, an electric scooter defined as a motor vehicle may therefore be technically legal on high-speed roads but the increased potential for interactions with other high-speed vehicles means that it would not be recommended from a safety perspective.

As discussed previously, there is also a great deal of variation in the terminology used in different countries, as well as variation in classification. A solution for this issue is provided by the classification used in the draft European Standard (see Section 3.3.1) which uses key design elements as criteria.

There is also variation in the detail of any requirements that are imposed – for example, some countries state an age limit for use of these devices but this ranges from 12 years to 16 years. A few countries mandate helmets – notably Germany (in the new legislation) and Israel – but most do not, perhaps because helmets are not mandated for cyclists in many countries.

In all case study countries where legislation is in place, whether by default or not, there is very little evidence of enforcement of any requirements. Even where existing legislation means these devices are illegal, their use appears to be increasing and few, if any, prosecutions are taking place. This is assumed to be a result of both policing priorities and, in many cases, confusion about the legislative context even amongst those authorities. In some countries, the requirement for insurance and/or type-approval or registration of these devices appears to be being used as a proxy for an outright ban, perhaps whilst the safety implications are still unknown.

Another key theme found in all countries considered is that, regardless of the presence of national legislation or guidance, many local authorities – particularly in cities – are responding to the influx of these devices (usually in the form of sharing schemes) by producing their own guidance or regulations within the existing laws. This is likely a response to the timescales required for national legislation and the need to be proactive in addressing this issue.

4 Recommendations and conclusions

This report set out to review current practice and the safety implications of powered transporters. An in-depth literature review, and a case study investigation of selected countries, was undertaken to understand: the application of legislation and rules of the road relevant to the use of powered transporters across Ireland, the UK and internationally; the potential risks associated with the interaction of such devices with other road users (including vulnerable road users), and; the potential safety, environmental, and operational benefits of this type of mobility device.

This work has important implications for RSA's development of future policy and regulatory framework updates with regards to operation of powered transporters in Ireland.

Firstly, from the literature review, it is clear that evidence is currently lacking to inform best practice in powered transporter regulation. However, of the evidence identified, there is some support for developing policy and legislation which:

- Encourages the use of personal protective equipment (PPE, e.g. helmets), possibly through targeted public awareness campaigns and by placing responsibility with powered transporter sharing companies to promote safety;
- Provides (or prescribes) training for operators of powered transporters prior to their use in public;
- Creates clear safety standards that powered transporters are required to meet (e.g. weight or size restrictions, or minimum lighting/conspicuity standards), and possibly enforcing these standards through a type-approval system or certification process;
- Clarifies who exactly is permitted to use different devices (e.g. age limits and licence requirements); and
- Provides clear guidance on how and where different devices can be used (e.g. footways vs. cycle lanes vs. roads, and the rules which apply to each).

Refinement of the details of these points should be based on clear evidence from further investigation and robust research trials. Specifically, evidence is needed to understand what safety features should be mandatory on powered transporters and how powered transporters riders are likely to interact with other road users.

Whilst direct evidence of the benefits of powered transporters is limited, it is clear that they have potential to reduce traffic congestion, improve air quality, and promote active travel if they are used in the right ways in place of less sustainable modes of transport such as the private motor vehicle. Since, for most governing bodies, there are clear local, national and international targets to reduce greenhouse gas emissions and improve air quality, an outright ban on powered transporters would seem counterintuitive. Whilst definitive legislation is developed, it is instead recommended that such devices should be allowed for use in certain circumstances, with a controlled and considered roll out to mitigate against potential negative safety implications. For example, restricting use away from high-speed roads where potential accident severity will be greater may be advisable in the absence of any further evidence. Likewise, setting guidelines for use in other settings may also mitigate

against incidents, such as speed restrictions in areas where interactions with pedestrians are likely.

Finally, it is clear from the case study investigation that no universal consensus on how best to approach these issues has been reached. Of particular note is the varied definition and classification of powered transporters; such uncertainty in how these types of devices should be treated from a legislative perspective is highly detrimental to their safe operation and wider rollout.

As a first step in developing policy and legislation the following recommendations are therefore made:

1. Agree clear terms for vehicle classification. The classification must be able to accommodate different scooter (and other vehicle) types in order to future-proof against further technology innovation. Further, classifications should be based on considerations of safety, not (for example) on specifics of vehicle design such as starting mechanism, or size.
2. Promote the use of helmets and other protective equipment. This could take the form of an awareness campaign for educating the public and also engagement with sharing scheme providers, manufacturers and retailers.
3. Consider issuing a set of advisory guidelines for both individual users and users of sharing schemes. Whilst there is little robust evidence from which to develop specific restrictions there are several basic principles on which guidelines can be based:
    - Guidelines should minimise the likelihood of high-speed interactions, for example prohibiting devices from high-speed roads
    - Guidelines should consider other road users, for example if devices are allowed on pavements, there could be a maximum speed of 6 km/h to protect pedestrians.
    - Allow flexibility for local authorities to implement these guidelines as appropriate for their jurisdictions, whilst avoiding inconsistency and confusion.

    If possible, these guidelines should be created in consultation with sharing scheme providers, local authorities and the Police.
4. Promote the need for safe use of these devices amongst the public and if possible encourage opportunities for training or familiarisation prior to use in public. This could be carried out alongside recommendations 2 and 3.
5. Consider methods of implementing minimum safety standards for the vehicles themselves. One option would be to use the draft European Standard as the basis for a voluntary certification scheme.
6. Carry out further research into the safety features which should be mandatory, how powered transporter riders are likely to interact with other road users, and what operational guidelines should be produced to minimise risk.

5 References

Allem, J. P., & Majmundar, A. (2019). Are electric scooters promoted on social media with safety in mind? A case study on Bird's Instagram. *Preventive Medicine Reports, 13*, 62-63, 10.1016/j.pmedr.2018.11.013.

Ashurst, J., & Wagner, B. (2015). Injuries following Segway personal transporter accidents: Case report and review of the literature. *Western Journal of Emergency Medicine, 16,* 693-695, 10.5811/westjem.2015.7.26549.

Bai, L., Liu, P., Guo, Y., & Yu, H. (2015). Comparative analysis of risky behaviours of electric bicycles at signalised intersections. *Traffic Injury Prevention, 16,* 424-428, 10.1080/15389588.2014.952724.

Castonguay, S., & Binwa, P. (2006). *Pilot Project for Evaluating the Segway™ HT Motorised Personal Transportation Device in Real Conditions*. Quebec: Centre for Electric Vehicle Experimentation in Quebec (CEVEQ).

Cherry, C. (2007). *Electric bike use in China and their impacts on the environment, safety, mobility and accessibility*. UC Berkeley Centre for Future Urban Transport: A Volvo Centre of Excellence.

Daniel, J., Chien, S., Fleischer, D., & Liu, R. (2005). *Motorised Scooters/Go-Peds*. New Jersey: New Jersey Institute of Technology.

Department of Transportation and Main Roads (2012). Segway PT Safety: A review of the legislative and safety implications of Segway PT use on or around the road network. Queensland: Department of Transport and Main Roads. Retrieved from: https://www.parliament.qld.gov.au/documents/tableOffice/TabledPapers/2013/5413T3276.pdf

Do, M. T., McFaull, S., Cheesman, J., Mersereau, T., Rao, D. P., Crain, J., & Thompson, W. (2016). Emergency department presentations for hoverboard-related injuries: The electronic Canadian Hospitals Injury Reporting and Prevention Program, 2015 to 2016. *Research, Policy and Practice, 36*, 316-317.

Dowling, R., Irwin, J. D., Faulks, I. J., & Howitt, R. (2015). Use of personal mobility devices for first-and-last mile travel: The Macquarie-Ryde trial. *In: Proceedings of the 2015 Australasian Road Safety Conference, Gold Coast, Qld.*

Du, W., Yang, J., Powis, B., Zheng, X., Ozanne-Smith, J., Bilston, L., & Wu, M. (2013). Understanding on-road practices of electric bike riders: An observational study in a developed city of China. *Accident Analysis & Prevention, 59,* 319-326, 10.1016/j.aap.2013.06.011.

Edge, S., & Goodfield, J. (2017). Responses to electric bikes (e-bikes) amongst stakeholders and decision-makers with influence on transportation reform in Toronto, Canada. *In: Canadian Transportation Research Forum, May 28-31, Winnipeg*. Retrieved from: http://ctrf.ca/?page_id=4419

Fang, K., Agrawal, A. W., & Hooper, A. (2018). Electric kick scooters on sidewalks in Virginia but not in California? A review of how states regulate personal transportation

devices. Mineta Transportation Institute, San José State University, San José, United States.

Fang, K., Agrawal, A. W., Steele, J., Hunter, J. J., & Hooper, A. M. (2018). Where do riders park dockless, shared electric scooters? Findings from San José, California. Mineta Transportation Institute, San José State University, San José, United States.

Fyhri, A., Sundfør, H. B., & Weber, C. (2016). *Effect of subvention program for electric bicycle in Oslo on bicycle use, transport distribution and CO_2 emissions.* Oslo: Institute of Transport Economics.

Hyvönen, K., Repo, P., & Lammi, M. (2016). Light electric vehicles: Substitution and future uses. *Transportation Research Procedia, 19,* 258-268, 10.1016/j.trpro.2016.12.085.

Joint Standing Committee on Road Safety (Staysafe) (2014). *Report on Non-Registered Motorised Vehicles*. Report 3/55. Sydney, NSW: Parliament of New South Wales.

Jones, T., Harms, L., & Heinen, E. (2016). Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. *Journal of Transport Geography, 53,* 41-49, 10.1016/j.jtrangeo.2016.04.006.

Justice and Community Safety Directorate (2016). *Segway review discussion paper: A review of Segway and Segway type vehicles used in the Australian Capital Territory*. Canberra, ACT: Justice and Community Safety Directorate.

Kattan, A. E., AlShomer, F., Alhujayri, A. K., Alfozan, M., Murrad, K. A., & Alsajjan, H. (2017). A case series of pediatric Seymour fractures related to hoverboards: Increasing trend with changing lifestyle. *International Journal of Surgery Case Reports, 38,* 57-60, 10.1016/j.ijscr.2017.06.058.

Kim, Y. W., Park, W. B., Cho, J. S., Hyun, S. Y., & Lee, G. (2018). The new recreational transportation on the street: Personal mobility, is it safe? *Journal of Trauma and Injury, 31,* 125-134, 10.20408/jti.2018.040.

Kroesen, M. (2017). To what extent do e-bikes substitute travel by other modes? Evidence from the Netherlands. *Transportation Research Part D: Transport and Environment, 53,* 377-387, 10.1016/j.trd.2017.04.036.

Landis, B. W., Petritsch, T. A., & Huang, H. F. (2004). *Characteristics of Emerging Road Users and Their Safety*. McLean, VA, United States: Federal Highway Administration.

Li, X., Yun, Z., Li, X., Wang, Y., Yang, T., Zheng, L., & Qian, J. (2017). Orthopedic injury in electric bicycle-related collisions. *Traffic Injury Prevention, 18,* 437-440, 10.1080/15389588.2016.1218001.

Lieswyn, J., & Wilke, A. (2016). E-bikes: Legislation, policy and design considerations of an empowering technology. *In: Proceedings of 2Walk and Cycle Conference, Auckland, New Zealand, 6-8 July.*

Lieswyn, J., Fowler, M., Koorey, G., Wilke, A., & Crimp, S. (2017). Regulations and safety for electric bicycles and other low-powered vehicles. *NZ Transport Agency research report 621*. 182pp.

Lin, X., Wells, P., & Sovacool, B. K. (2017). Benign mobility? Electric bicycles, sustainable transport consumption behaviour and socio-technical transitions in Nanjing, China. *Transportation Research Part A: Policy and Practice., 103,* 223-234, 10.1016/j.tra.2017.06.014.

Litman, T. (2006). Managing diverse modes and activities on non-motorised facilities: Guidance for practitioners. *ITE Journal, 76*, 20-27.

Mikkelsen, R. K., Morup-Petersen, A., & Hvolris, J. (2014). Two cases of hip associated fractures after falls from the Segway Personal Transporter. *Emergency Medicine, 4,* 10.13140/RG.2.1.5061.7044.

Miller, S., Kennedy, J., Molino, J., Emo, A., Rousseau, G., Tan, C., & Do, A. (2010). *Operating Characteristics of the Segway™ Human Transporter*. McLean, VA, United States: Federal Highway Administration.

National Association of City Transportation Officials (2018). Guidelines for the Regulation and Management of Shared Active Transportation. Retrieved from: https://nacto.org/home/shared-active-transportation-guidelines/

National Transport Commission (2019). Barriers to the safe use of innovative vehicles and mobility devices. Melbourne: National Transport Commission. Retrieved from: https://www.ntc.gov.au/current-projects/barriers-to-the-safe-use-of-innovative-vehicles-and-mobility-devices/

Nishiuchi, H., Shiomi, Y., & Todoroki, T. (2015). Segway running behaviour focusing on riders' experience based on image-processing data. *Asian Transport Studies, 3,* 467-486.

Portland Bureau of Transportation (PBOT) (2019). 2018 E-Scooter Findings Report – The City of Portland, Oregon. Retrieved from: https://www.portlandoregon.gov/transportation/article/709719

Pratt, K., Makwasha, T., Cairney, P., Smith, R., & Jones, D. (2016). *Assessment of new recreational transport devices.* Report No. 16/02. Victoria: Royal Automobile Club of Victoria Ltd.

Rodier, C. J., Shaheen, S., & Novick, L. (2004). Improving Bay Area Rapid Transit (BART) district connectivity and access with the Segway Human Transporter and other low speed mobility devices. California PATH Research Report No. UCB-ITS-PRR-2004-27. Retrieved from: https://cloudfront.escholarship.org/dist/prd/content/qt6x0767zk/qt6x0767zk.pdf

Rodier, C., Shaheen, S. A., & Chung, S. (2003). Unsafe at any speed? What the literature says about low-speed modes. *In: Transportation Research Board 84th Annual Meeting, Washington, DC.*

Rose, G., & Richardson, M. (2009). Implications for road system management of emerging types of private passenger vehicles. *In: 32nd Australasian Transport Research Forum, 29 September-1 October, Auckland, New Zealand.*

Sawatzky, B., Denison, I., Langrish, S., Richardson, S., Hiller, K., & Slobogean, B. (2007). The Segway personal transporter as an alternative mobility device for people with

disabilities: A pilot study. *Archives of Physical Medicine and Rehabilitation, 88,* 1423-1428, 10.1016/j.apmr.2007.08.005.

Schleinitz, K., Petzoldt, T., Franke-Bartholdt, L., Krems, J. F., & Gehlert, T. (2017). The German Naturalistic Cycling Study – Comparing cycling speed of riders of different e-bikes and conventional bicycles. *Safety Science, 92,* 290-297, 10.1016/j.ssci.2015.07.027.

Siman-Tova, M., Radomislenskya, I., & Peleg, K. (2018). A look at electric bike casualties: Do they differ from the mechanical bicycle? *Journal of Transport & Health, 11,* 176-182, 10.1016/j.jth.2018.10.013.

Smith, C. S. & Schwieterman, J. P. (2018). *E-scooter scenarios: Evaluating the potential mobility benefits of shared dockless scooters in Chicago*. Chaddick Institute for Metropolitan Development, DePaul University, Chicago, United States.

Spear, J. (2017). Time to embrace scooters, Segways and hoverboards? *Transportation Professional*, 14 February, 24-26.

Wang, C., Xu, C., Xia, J., & Qian, Z. (2018). The effects of safety knowledge and psychological factors on self-reported risky behaviours including group violations for e-bike riders in China. *Transportation Research Part F: Traffic Psychology and Behaviour, 56,* 344-353, 10.1016/j.trf.2018.05.004.

Xu, J., Shang, S., Yu, G., Qi, H., Wang, Y., & Xu, S. (2016). Are electric self-balancing scooters safe in vehicle crash accidents? *Accident Analysis & Prevention, 87,* 102-116, 10.1016/j.aap.2015.10.022.

Xu. J., Shang, S., Qi, H., Yu, G., Wang, Y., & Chen, P. (2016). Simulative investigation on head injuries of electric self-balancing scooter riders subject to ground impact. *Accident Analysis & Prevention, 89,* 128-141, 10.1016/j.aap.2016.01.013.

Yang, H., Liu, X., Su, F., Cherry, C., Liu, Y., & Li, Y. (2018). Predicting e-bike users' intention to run the red light: An application and extension of the theory of planned behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour, 58,* 282-291, 10.1016/j.trf.2018.05.027.

Appendix A List of search terms

The search terms below were used for the literature search.

1st Level		2nd Level
e-scooter* OR		legislation OR
electric scooter* OR		regulation* OR
e-scooter*		standard* OR
e-bike* OR		restriction* OR
electric bike* OR		permit* OR
electric bicycle* OR		ban* OR
e-bike* OR		law OR
EAPC OR		rule* OR
electrically assisted pedal cycle OR		policy OR
electric pedal cycle OR		guidance OR
Segway OR		best practice OR
hoverboard* OR		guideline* OR
go-ped OR		risk* OR
personal mobility device* OR		hazard* OR
powered mobility device* OR		benefit* OR
powered transporter* OR		vulnerable road user* OR
powered unicycle* OR		safe* OR
powered monocycle* OR	AND	accident* OR
personal electric vehicle* OR		collision* OR
personal light electric vehicle* OR		adoption OR
PLEV* OR		uptake OR
personal transporter* OR		usage OR
motorised scooter* OR		use* OR
motorized scooter*		rate* OR
		environment* OR
		operation*
		cycle lane OR
		cycle track OR
		cycle path OR
		road OR
		highway OR
		pavement OR
		footpath OR
		footway OR
		sidewalk

Appendix B Inclusion criteria and scoring

The inclusion criteria below were used for scoring the literature.

	Score = 1	Score = 2	Score = 3
Relevance	Not relevant to the objectives of the project	Some indirect relevance to the objectives of the review	Directly relevant to the objectives of the review
Quality	Non-scientific article (e.g. online source, newspaper or magazine article)	Non-peer reviewed scientific article	Peer-reviewed scientific article (e.g. journal paper or conference procedure)

Review of current practice and safety implications of electric personal mobility devices

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