E-bikes: legislation, policy and design considerations of an empowering technology

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ABSTRACT

With improving batteries and economies of scale driving lower prices, electric bicycles (e-bikes) are becoming more popular worldwide. Specialty retailers are opening across New Zealand to cater for demand. However, in contrast to most countries, New Zealand legislation regulates motor power and is silent on motor assistance cut-out speed. More powerful batteries and controllers supplying high amperage can enable any otherwise legal motor to propel an e-bike to speeds well in excess of 40 km/h. Legislators must respond quickly to keep pace with technological and marketplace changes, minimise harm to road and path users, and support the positive benefits of e-bikes. To help inform any legislative change, this paper clarifies e-bike definitions, discusses the range of technologies including motor types and electric cargo bicycles, and describes regulatory criteria commonly used overseas. Finally, e-bikes increase the variance in operating speeds and the prevalence of larger bicycles that can carry people, pets, and cargo. This paper suggests aspects of cycleway design that should be updated to better accommodate e-bikes.

INTRODUCTION

Structure of this paper

This paper presents a classification of e-bikes and reviews current legislative approaches from selected international jurisdictions in contrast with current New Zealand law. Existing research on e-bike rider speed and behaviour is summarised, showing that e-bikes may not be faster than a road bike but the technology is likely to increase the variance in operating speeds and the prevalence of larger bicycles that can carry people, pets, and cargo. Therefore, aspects of cycleway design that should be updated to better accommodate e-bikes are discussed. This paper concludes with thoughts on educational needs and suggests further research topics.

Growth in e-bikes

Electric bikes ("e-bikes") are the most widely used form of electric transportation in the world [1]. China is the world's largest e-bike market, as sales of lead-acid battery scooter style e-bikes have been driven by environmental policies restricting petrol powered two-wheelers (ibid). Lithium-ion battery bicycle style e-bikes are the mainstay of current sales in western countries. With rapid advances in battery technology and manufacturing economies of scale, weight and prices are dropping while range is increasing. These factors are helping propel sales growth. Data are not readily available on e-bike sales in New Zealand, however a useful comparison can be made between the similarly car-oriented United States with Western European countries. Between 2011 and 2014, e-bike sales increased 71% in the USA and 59% in Europe [2, 3]. Market adoption figures suggest that e-bikes are more popular in Western Europe than in the USA, as shown in Table 1.

Table 1: E-bike sales comparison between top 3 EU e-bike countries and USA

Location	E-bike sales, 2014 (1,000s)[1]	Population, 2016 (1,000s)[2]	E-bikes sold / 1,000 population
Germany	480	80,682	5.9
The Netherlands	223	16,980	13.1
Belgium	130	11,372	11.4
Top 3 EU consumers	832	109,034	7.6
USA	193	321,369	0.6

Notes: 1. EU data: CONEBI [2] USA data: EBWR [3]
2. Population source: www.worldometers.info

The e-bike market is maturing faster in Europe due to the general cultural attitudes towards cycling – in Europe e-bikes are seen as an enabler of utility cycling[1], so retailers already used to catering to the utility market had no problem selling them [4]. In English speaking countries, cycling is more commonly associated with sport. Electric assistance is anecdotally seen as "cheating" by staff working in traditional bicycle shops, and so there have been limited opportunities to see or purchase e-bikes.

This is now changing, as New Zealand-based e-bike specialist retailers are setting up physical and online stores. Two physical stores opened in Christchurch just in the last year. In comparison to sport-oriented bicycle shops, e-bike retailers have no compunctions about electric assistance.

[1] Including the Copenhagen bike share scheme "Bycyklen" that since 2014 utilises e-bikes.

The opportunity

The NZ Transport Agency has committed to increasing cycling trips by 10 million per annum by 2019, and is largely aiming to achieve this through the Urban Cycleway Programme [5]. In 2014/15, there are currently 32 million bike trips per annum in New Zealand in the three reference cities of Auckland, Wellington, Christchurch [6]. If we are to increase by one-third, cycling would become much more normal. If such a cultural shift is achieved, we would be moving away from cycling mostly as a sport, and closing the gap to where Europe is today. E-bikes address many of the common objections to cycling, such as minimum fitness requirement, hills, distance, or inability to carry items. On the other hand, they can't overcome weather issues and safety concerns, though, but safety can (and should) be addressed through better infrastructure, and e-bikes handle headwinds well. Therefore, e-bikes should be seen not as something cheaters use but as something that appeals to a much broader cohort of the public.

The problem

On 30 November 2015, Palmerston North City councillor Rachel Bowen was riding an e-bike when Yu-Chien Cheng overtook her and turned left, cutting her off. Bowen received a broken elbow. Ms. Cheng was given a lesser licence disqualification than usual, after pleading guilty to careless driving causing injury, because she hit a person riding an electric bike. According to media reports [7]:

> *Bowen told police she thought she was going at the "average cyclist speed", while a witness said nothing about the speed. Police accepted the electric bike could travel faster, but there was no evidence that had happened in this case… The judge said the crash was partly because of the electric bike, but Cheng was clearly at fault.*

A New Zealand territorial authority has recently posted signs explicitly banning e-bikes from reserve trails, based on existing policy excluding motorised bikes[2]. However, regulated factory e-bikes and kits are quieter and slower than the petrol kits which precipitated the original policy.

These cases demonstrate the tendency to assume that an e-bike can travel faster than a standard bicycle, despite the fact that most factory-produced e-bikes do not provide assistance above 25 km/h or 32 km/h and many fit road cyclists can achieve 50 km/h or more. Without a legislated maximum speed, this assumption may continue to result in misallocations of crash responsibility and exclusions of e-bikes from various locations by local authorities. Then again, throttle control bikes do not even require the user to pedal, and this may well catch out a driver.

Policy should be set quickly, because the more e-bike users who comply with a certain aspect of potential policy, the easier it will be to introduce. For example, if New Zealand were to adopt the EU standard prohibition on throttles, this will need to happen before the e-bike fleet grows to the point where grandfathering in non-compliant bikes is judged to be infeasible.

[2] The authors are aware that the same territorial authority's new draft policy is much more permissive, but a 25kph speed cut-out is suggested as a requirement.

DEFINITIONS

MacArthur and Kobel [8] define e-bikes in two broad categories: bicycle-style electric bikes (BSEB, Figure 1) and scooter-style electric bikes (SSEB, Figure 2).

Figure 1: BSEB (image: Richard Masoner)

Figure 2: SSEB (image: UCLA Transportation)

SSEBs are the most common e-bike type in China, but are closer in design to a motor scooter than to a bicycle [9]. In many jurisdictions including California, a SSEB is classified as a motor scooter and must be registered and insured in order to be operated on a public roadway [8]. Although vestigial pedals are provided (presumably to meet legal requirements), these are located too far apart and behind the rider's knees to be useful. Accordingly the pedals are often removed at the point of sale or quickly bent[3] and SSEBs are generally operated by throttle only. As this paper focuses on electric bicycles that are primarily designed to be human powered, the authors consider that SSEBs are bicycles by technicality only and they will not be further discussed.

In the BSEB category, there are two primary sub-types: **pedal assist** or pedal electric (known in Europe as a pedelec), and **throttle control** or throttle operated. On pedal assist e-bikes, the electric motor engages when a torque sensor detects pressure on the pedals, and cuts out when the user stops pedalling. The harder that the user pedals, the more assist is provided. On throttle control e-bikes, the electric motor engages when the user operates a handlebar-mounted throttle. Therefore, the user does not need to pedal at all. Whether pedal or throttle-activated, BSEBs are generally propelled by motors located in the front hub, rear hub, or mid-drive (crankset).

Some e-bike kits that are designed for pedelecs and are primarily to be activated by the torque sensor may also have a throttle control (e.g. the Canadian Bion-X kit). These throttles may be electronically managed to comply with the rules of various export markets such as the European Union, as will be discussed later in this paper.

There are other possible variations on e-bikes, such as the Twike or the Organic Transit ELF. These are similar to velomobiles in that they are enclosed for weather protection like a car, but they have ergonomic pedals like a recumbent bicycle. The Twike can top out at over 80 km/h, so it is designed to be used like a motor vehicle on most urban and rural roads. The ELF's motor stops providing assistance above 25 mph (40 km/h) to meet US standards for low speed electric bicycle as defined by the Consumer Product Safety Commission and the low speed vehicle (LSV) as defined by the Code of Federal Regulations. As these e-bikes are not geometrically similar to a bicycle and are not anticipated to be imported in any large numbers into New Zealand in the foreseeable future, they will not be further discussed here.

[3] The lead author is a former bicycle store owner with SSEB experience. The pedal crank arms must be located more than twice as far apart (a dimension called the Q-factor that affects ergonomic usability) as a normal bicycle and as such are both difficult to efficiently operate and susceptible to damage if the scooter is dropped on its side. Due to the weight of a SSEB (typically 50 kg), the incidence of owners dropping the scooter is high.

LEGISLATION

Existing New Zealand legislation

The legal definitions of "cycle" and "power-assisted cycle" are contained in the Road User Rule (RUR) [10]. A cycle is to be "designed primarily to be propelled by the muscular energy of the rider". When the RUR came into effect in February 2005, power output of a power-assisted cycle was restricted to 200 Watt, but this was raised to 300 Watt only four months later [11]. A "mobility device", which was also introduced by the RUR, is "for use by persons who require mobility assistance due to a physical or neurological impairment" and, at 1,500 Watt, can have a significantly higher power output.

The original 200 W limit may have been chosen for consistency with Australia[4], however manufacturers have generally developed three motor input power levels: 250 W (common in Europe), 350 W (common in North America), and 500 W (a much smaller number of motors). More discussion on the limitations of using power as a regulatory criterion is provided later in this paper.

Overseas legislation

In Europe, the EU directive 2002/24/EC and the assessment standard EN15194:2009 exempts e-bikes from motor vehicle-type approval requirements as long as the cycle has a maximum continuous rated power of no more than 250 W, "of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h (16 mph) or if the cyclist stops pedaling" [12]. The standard refers to EPACs, the acronym for electrically power assisted cycles. The common synonym for EPAC in Europe is "pedelec". While the focus is on pedal assistance, throttles are allowed on EU market e-bikes as long as they only provide "start-up" assistance and cut out at 6 km/h.

In the USA, the U.S. Consumer Product Safety Act authorises the Consumer Product Safety Commission (CPSC) to promulgate rules governing e-bikes and lodge these rules in the Code of Federal Regulations. The CPSC defines "low speed electric" bicycles as a two or three-wheeled vehicle with fully operable pedals, a top speed when powered solely by the motor under 20 mph (32 km/h) and an electric motor that produces less than 750 W [13]. This simple standard has been widely adopted at the state level, but does not cover the many nuances of the rapidly evolving e-bike marketplace.

California's recent rulemaking provides an interesting case study. The lead author of this paper was a stakeholder during the rule development and observed a number of possible approaches (such as a weight limit) dropped from the final regulations. As the most recent US state law in the most populous state in the nation, it sets a precedent that will likely be emulated elsewhere. Key features of the law include the establishment of three classes of e-bikes [14]:

- Class 1: "low-speed pedal-assisted electric bicycle," has no throttle and the motor cuts out at 20 mph (32 km/h)
- Class 2: "low-speed throttle-assisted electric bicycle," has a throttle and the motor cuts out at 20 mph (32 km/h)
- Class 3: "speed pedal-assisted electric bicycle," has no throttle, the motor cuts out at 28 mph (45 km/h), and a speedometer, minimum age of 16, use of a helmet, and a prohibition on shared path or protected cycleway use (unless local ordinances authorise such use)

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[4] Note that the Australians have since adopted the EU standard, but with a 250 W limit.

The Californian regulations include labelling requirement, prohibition on tampering with or modifying an e-bike to change its speed capability (unless the owner then appropriately replaces the classification label), and stipulates that a person operating any class of e-bike is not subject to financial responsibility (insurance), licensing, registration, or license plate requirements. Also, the California regulations continue to define a SSEB as a moped with a maximum speed of 30 mph (50 km/h) and treat such vehicles as completely separate from e-bikes.

A selection of overseas regulations and the key regulatory criteria of labelling, allowance for throttle control, motor cut-out speed in km/h, stated input power (generally continuous rating rather than peak), total maximum bike weight, and age restrictions is summarised in Table 2. Following the table, each of the criteria are discussed in turn.

Table 2: Selected overseas e-bike regulations

Place	Terms / Notes	Label	Throt.	Km/h	Watts	Kg	Age
Australia	Power Assisted Bicycle Pedelec	-	Yes No	- 25	200 250	- -	- -
Canada	Type label required	Yes	-	32	500	-	-
China		-	-	20	-	40	-
EU	Pedelec (EN15194 Kits are exempt	Yes	Up to 6 km/h	25	250	40	-
Germany Switz.	Pedelec (as per EU) S-Pedelec	Yes Yes	No No	25 45	250 400	- -	- -
Israel		-	-	25	250	30	14
Japan	Max. assist ratio 2:1	-	-	-	-	-	-
NZ	Class AB	-	-	-	300	-	-
UK	Bicycle Tricycle, tandem	Yes Yes	- -	24 24	200 250	40 60	14
USA CA	Low speed vehicle Class 1 Class 2 Class 3	- Yes Yes Yes	- No Yes No	32 32 32 45	750 750 750 750	- - - -	Var[1]. - - 16

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

Given the multiple classes of e-bikes, labelling is a key part of the EU and California rules. According to the EU standard EN15194 (soon to be superseded by a new ISO standard) the frame must be visibly and durably marked with the word "EPAC" (electrically power-assisted cycle), the cut-off speed of the motor in km/h, and the electric motor maximum continuous rated power in Watts [12, 15]. A generic sample (Figure 3) of labelling compliant with Californian Assembly Bill 1096 outlines the class number, power rating of the motor, and motor cut-out speed [16].

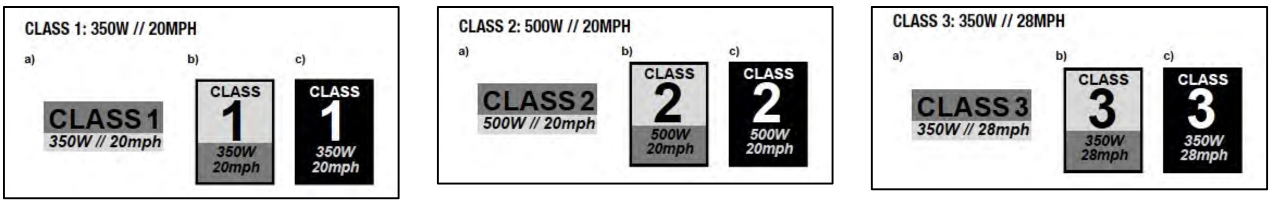

Figure 3: Example of generic class labels in compliance with California Vehicle Code

Throttle controls are restricted to 6 km/h on pedelecs in Europe, restricted to Class II e-bikes in California (providing for a means to retrospectively apply further rulemaking if data supports it), and are not regulated in New Zealand. The Cycling Action Network's policy development paper suggests that throttles “can be safer, more economical, and more convenient” [17] however no data or further justification is provided. It is obvious that battery life is reduced if the throttle alone is used for motor engagement and no human power is supplied, so this policy statement may have a different kind of economy in mind rather than the typical consideration of range. For example, a BionX pedal-assist e-bike kit has a torque sensor for motor engagement and an auxiliary throttle button. In contrast to the EU’s approach to pedelec throttles as a “start-up” aid, the BionX throttle does not activate the motor from a dead stop – one must be travelling at least 2 or 3 km/h. The authors found no published data on the safety or other implications of throttles, other than throttle-controlled e-bikes are considered less of a bicycle than pedal-assist bikes by existing bicyclists [18]. Another consideration is that pedal-assist requires more human power than throttle-control, and therefore the health benefits of the former are likely to be greater.

Speed, or more accurately motor cut-out speed, is used in numerous countries to regulate e-bikes. The range of limits is from 20 km/h to 45 km/h, with lower values common in Asia and the highest values accorded only to a limited and more regulated class of e-bikes. The two most common values in western countries are 25 km/h (Europe including UK, Australia) and 32 km/h (North America). There are competing objectives when setting the cut-out speed. Lower values may be more appropriate for shared paths, cycle lanes or narrow pathways (if overtaking is difficult), and uphill gradients exacerbate the issues. Higher values can be advantageous where e-bike riders need to achieve more equitable speeds with motorists in mixed traffic conditions, e.g. roundabouts that are designed for free-flow rather than safety. A further nuance of the EU standard is that the motor must provide progressively less assistance as the rider nears the cut-out speed. A benefit of California’s Class 3 or Europe’s S-Pedelec type is that a wider range of rider needs can be met[5] while still providing rulemaking flexibility; the same may be achieved by bringing this type under moped rules. However, the Californian legislation recognises that a Class 3 e-bike is still a bicycle in the traditional sense (as opposed to a moped), and cannot be operated by throttle only. Class 3 e-bikes are not subject to registration requirements and therefore are more accessible than mopeds.

Opponents to blanket motor cut-out speeds for e-bikes that are to be used in mixed traffic environments may suggest that unsafe speed behaviour is a matter of road use appropriate to the conditions and capabilities of the vehicle. For example, most cars can easily travel 150 km/h but we expect drivers to only drive 10 km/h in Auckland’s shared space streets. This is the background to California’s requirement that Class 3 e-bikes must have speedometers.

Power may be rated as either input or output, and either peak or continuous. The peak (or instantaneous) watts used by a motor is equal to the battery voltage multiplied by the current (measured in amps) supplied to the motor by the controller [19]. Therefore, peak motor watt ratings are not dependent on the motor but on the other parts of the e-bike. Continuous input power is the more commonly used metric, and represents the number of watts that the motor can safely run at without overheating. This is also a difficult metric, because motors will overheat more easily in warmer climates. As noted previously, the current New Zealand legislation refers to output power, which is not a measure that manufacturers use. Aside from the issues of measuring power, a major problem with limiting e-bike motor power is that it may preclude innovation and adoption in the area of e-cargo bikes for carrying children, pets, and goods delivery. Finally, power limits are more likely to be an issue in hilly places like Wellington and Auckland, where 250 W is simply not enough assistance for heavier riders and/or laden bicycles.

[5] Rider needs vary depending on the location and trip needs; 25 km/h may be appropriate in dense and congested cities, 32 km/h in more suburban cities, and 45 km/h for trips between urban centres along rural roads

Weight is included in Israel and the UK on the basis of the physics of a collision between an e-bike rider and a pedestrian. A weight limit was dropped from initial drafts of the Californian legislation because the safety benefits were considered to be outweighed (no pun intended) by the disbenefits of excluding electric-assist cargo bikes and child-carrying trikes.

A minimum age of 16 years is a requirement for legal use in 19 American states [8], while 14 years is used in the UK and Israel. The merits of age restrictions and whether these should apply to all e-bikes or just faster classes of e-bikes appear to be subjective and/or related to other existing age restrictions (e.g. helmet use or driver licensing). This criterion could be related to motor cut-out speed, given that lower speeds such as 20 or 25 km/h are similar to what most teenagers are capable of attaining on human power alone.

Safety of e-bike riders and other non-motorised users

A key consideration in regulating the characteristics and/or use of e-bikes is whether performance characteristics affect road safety. As e-bikes are a relatively new and fast evolving technology, there is little in the way of relevant published research on the topic. In a brief literature review several recent publications are of interest.

The e-bikeSAFE study initiated in 2013 in Sweden has revealed that while the top speed of e-bikes is not significantly different from normal bicycles, the average speed of e-bike riders is 23 km/h while the average speed of unassisted bicycle riders is 14 km/h [20]. Further results of the study were not found in the literature review, but the published paper suggested that:

> *riding faster increases cyclists' attention demand as interaction with other road users, such as overtaking manoeuvres, becomes more frequent. Further, electrical bicycles are not always clearly distinguishable from traditional ones. As a consequence, it may not be obvious for other road users, (e.g. a driver at an intersection), to estimate their speed (e.g. when deciding to cross the bicycle path) (p.8)*

A study of bike sharing users in Knoxville, Tennessee found that in comparison to unassisted bike riders, e-bike riders travel slightly faster on road but slightly slower on shared use paths. Both groups exhibit nearly identical safety behaviour and have high rates of violations [21]. There are two transferability caveats: first, the Knoxville streets included in the study may not be sufficiently similar to the New Zealand context. Second, bike share system users may not be representative of the wider cohort of existing or potential people riding e-bikes.

Perceptions may be as important as actual safety outcomes. In a survey of 718 self-identified American bicyclists, McLeod [22] showed eight types of e-bikes and asked whether these bikes were bicycles. The results showed that lower motor speed cut-out tends to make people more likely to see e-bikes as bicycles; that the shape of the e-bike matters; and that throttle controlled e-bikes are less accepted. The author suggests that unless these characteristics are included in national legislation, then communities will regulate their use based on public perceptions.

A positive is that e-bikes often have continuous running lights, making users more visible in traffic. This is, however, not necessarily a benefit exclusive to e-bikes, as day-time running lights for bikes have been on the market since 2010 [23].

ENFORCING E-BIKE RULES

Enforcement of any new rules in New Zealand could occur at any one or more levels: importation, point of sale, or end-user (traffic behaviour). If one were to assume that a revision in the legislation established different classes as in Europe and California, then there will be a need to identify whether a rider was adhering to the specific requirements applicable to their class of e-bike. E-bike class / type labelling might be required of all businesses manufacturing or importing whole bikes, kits, or components. If a label is required, the question would be where it must be placed. A consistent place would make enforcement action easier.

Issues that may arise include the ability of end-users to "hack" controller software or override motor-cut out speed restrictions through simple hardware. Californian law prohibits such tampering, however it would be difficult to ascertain whether this had occurred absent a standardised testing protocol such as might be possible under a Warrant of Fitness scheme. The authors of this paper have talked to some e-bike retailers, who reported that such alterations are commonplace. Given that most jurisdictions have rejected the imposition of licensing and registration requirements on e-bike riders (in recognition of the benefits and limited differences of e-bikes compared to unassisted bikes), this will be an enforcement challenge.

Another consideration is that e-bike kits are available today that are completely hidden from view, and the first case of 'mechanical doping' in a professional bike race[6] was reported earlier in 2016. As batteries and motors continue to decrease in size and weight, any e-bike prohibitions would be difficult to enforce as officers would not be able to determine if the prohibition was being violated.

ENGINEERING FOR E-BIKES

From an engineering perspective, while e-bikes do not necessarily have a higher top speed than a road bike, it is likely that the variance in speeds among the cycling fleet will increase, particularly on climbs. Whilst the variance within the e-bike fleet is smaller as shown in Figure 4, when the two profiles are overlaid, it becomes clear that the higher the proportion of e-bikes, the higher the variance, as e-bikes are more likely to operate at the upper range of the speed distribution [20].

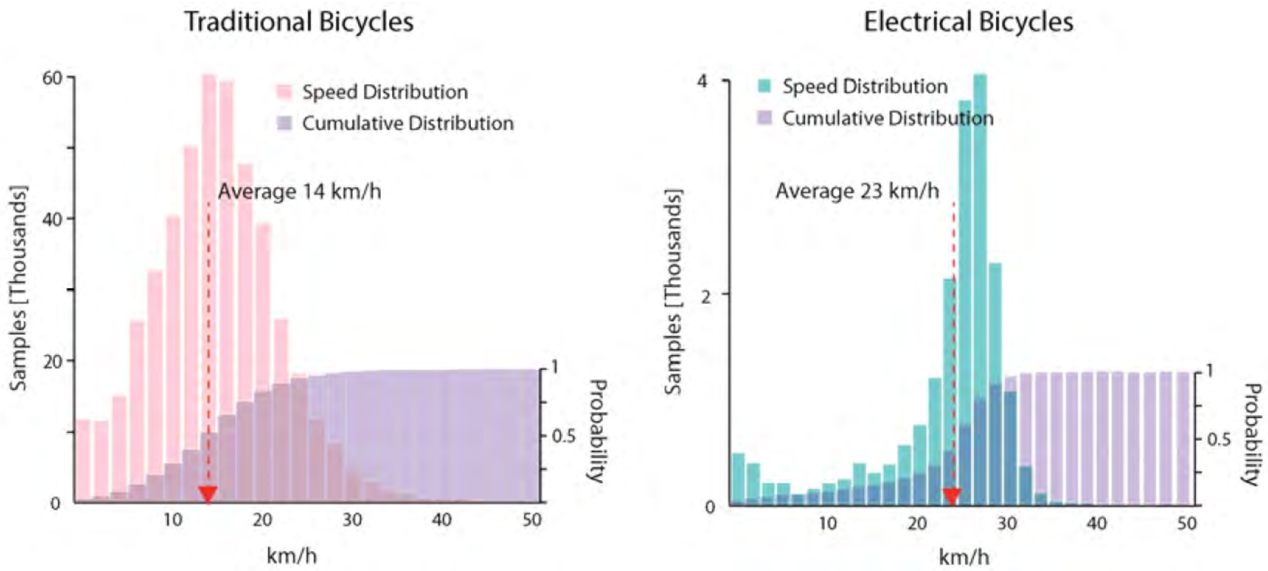

Figure 4: Comparison of traditional and e-bike speed profiles (Figure 3 in Dozza, 2013)

At present, New Zealand design advice is to increase the width of cycle lanes once cycle traffic flows exceed 150 in the peak hour; this is a function of limiting the number of required passing manoeuvres to within a given level of service. To achieve the same level of service when speed variance of the cycle fleet increases, the peak flow number will have to be reduced. Hence on average, cycle facilities will have to become wider if e-bike uptake increases. This will be

[6] At the 2016 UCI Cyclo-cross World Championships in Belgium, competitor Femke Van den Driessche was found to have a motor hidden in her bike frame.

especially prominent at intersections, where e-bikes are able to accelerate much quicker, but it is also the place within networks where demand on existing space is highest.

Austroads recommends that pathways that are to be used by bikes be designed for a speed of at least 30 km/h, and provides minimum horizontal curve radii tables for speeds between 20 km/h and 50 km/h [24]. Despite this guidance, many existing pathways have tighter curves that will be more noticeable for e-bike riders traveling at higher average speeds than traditional bike riders. There may be increasing calls to improve existing deficient path curves. The AASHTO guidance that is (indirectly) the original source for Austroads was updated in 2012 and includes a metric formula which may be easier to use than interpolating from the table in Austroads [25].

Sight lines at driveways are more important for e-bike users who are likely to have a slightly higher average speed. Being overlooked at driveways is the main mid-block crash type for pathways, and whilst sight line restrictions due to parking can be influenced by design guidance, this is much more of a given for intervisibility between drivers leaving a driveway due to existing boundary fences or building lines. Hence, the major variable that will influence crash data is the operating speed on pathways, and from a safety perspective, the lower the operating speed the better.

Some policy makers have considered dealing with some of the design issues by imposing a legal speed restriction on shared paths, i.e. even if an e-bike is capable of a higher speed, an operating speed limit would apply to overcome design deficiencies. As previously noted this approach is probably unworkable and unrealistic, as most bikes (including e-bikes) do not have a speedometer. In California, only their Class 3 e-bike (similar to a European S-Pedelec) must have a speedometer whilst Class 1 and 2 are excluded from this requirement.

One aspect of motive support by electric motors can be observed overseas, where the emergence of e-bikes results in larger bikes; either longer, or wider, or both. Some people make use of the motive support to transport goods, their pets, or their children, and the proportion of cycles that exceed standard dimensions increases accordingly.

Figure 5: The lead author’s e-assist cargo bike in Davis, California (image: A.Wilke)

Staggered barriers and cycle parking stands will need to be spaced further apart to accommodate these larger bikes, and refuge islands may have to be increased in width. The least critical of these issues are parking facilities, as it may be sufficient for some of the infrastructure to accommodate larger bikes. Staggered barriers may exclude some bikes when they physically cannot fit through the restriction, which would be a significant nuisance for their owners. Where long bikes overhang into the adjacent traffic lanes at refuge islands that are too narrow, this can present a safety issue. We know that the prevalence of wider and/or longer bikes will increase, and this raises the question as to when we should update our design guidance accordingly.

At path transitions from road to path or vice versa, it is more difficult to negotiate these with larger bikes. In the USA, 20º-45º ramps are typically used [25] but when piloting an e-assist cargo bike, the lead author could not stay in the cycle lane and line up for a path transition at speeds above about 10 km/h at ramps with sharp angles of intersection. The authors recommend to use ramps between 17º and 35º (see Figure 6 for an example), with a preference for the shallower end.

Figure 6: A shallow angle cycle ramp from shared path to carriageway, Davis, California (image: J. Lieswyn)

EDUCATION FOR E-BIKES

Why promote e-bikes?

As noted in the introduction to this paper, several arguments have been made in favour of greater uptake of e-bikes. These are generally along the line of attracting more people who would ride but have concerns about their physical ability to overcome factors such as hills or the ability to keep up with other people riding and general traffic [17]. Other key goals that could be achieved if e-bikes are used as a substitute for more polluting forms of transport include reductions in energy use, CO_2 emissions, and social costs [1, 26]. A European survey has found that 20% of the respondents were interested in pedelecs for environmental reasons [27]

Educational messages

If we accept that e-bikes should be promoted, there will be a need to educate the public about the different types of e-bikes, applicable legislation, and courteous behaviours. E-bike users have pointed out that unsafe riding behaviour is a wider issue. For example:

> *"I was riding my e-bike on a bike path the other day, only using the pedal-assist to get up the hills, when these two guys on regular bikes came zooming by like idiots. The bike is not the problem, it's the rider." - e-bike user in California [28]*

The authors of this paper are not aware of any evidence that electric-assist is a significant predictor of unsafe behaviour aside from the angst caused by delivery companies using SSEBs in New York City [8]. As previously noted, the only reviewed study comparing e-bike rider behaviour to unassisted cyclist behaviour found no significant difference in traffic violation rates [21].

Buyers of e-bikes or kits could be directly informed of requirements or safety tips through targeted disclosures at the point of sale. For example, California requires all manufacturers to include a single page disclosure with nothing else but a warning to seek advice on insurance.

It is likely that New Zealanders will have the same types of concerns about e-bike use on cycleways, shared paths, and mountain bike trails that Americans have. A survey of US bicyclists [22] showed that "endangerment" concerns borne of observations or perceptions around e-bike riders' failure to give way and overtaking manoeuvres where a perceived high speed differential startles the slower rider. Educational messages and special cycle skills training sessions could aim to reinforce courteous road user behaviour.

FURTHER RESEARCH NEEDS

This paper has outlined why the regulation of e-bike sales and use in New Zealand should be updated, and has described several alternative approaches employed overseas. The following questions remain to be answered, if possible:

1. Approximately how many e-bikes or e-bike users exist in New Zealand, and what are the characteristics of their owners and trips these bikes are used on?
2. What are the views of e-bike industry participants and other key stakeholders on regulation, enforcement, education, and encouragement?
3. Building on the work of e-bikeSAFE [20], what (if any) are performance characteristics and safety implications of e-bikes?
4. Common criteria used in the regulation of e-bike sales and use include (but are not limited to) motor power, motor cut-out speed, e-bike gross vehicle weight, e-bike geometry, and user age. If New Zealand's e-bike regulation were to be changed, which criteria and what values are most appropriate? Are there other criteria that should be considered?
5. What are the implications of any changes in regulation on existing e-bike owners?
6. Should New Zealand continue to permit throttle-controlled BSEBs, or restrict them as in the EU? What are the merits and safety implications of throttle-controlled BSEBs?
7. New Zealand could regulate e-bikes at the importation, point of sale, or the end-user level, or any combination of these. What are the best means of enforcing existing or potential new regulations on e-bike usage in New Zealand?
8. What educational and/or encouragement messages should New Zealand central, regional and/or local governments and agencies initiate or support regarding e-bikes?

CONCLUSIONS

E-bikes provide a non-polluting and low noise alternative to motor scooters and cars for more trips. They also enable a broader range of the public to try cycling, especially in hilly locations. Although there is no known research on the health benefits of e-bikes, it is apparent that if the pedal assist variant (as opposed to throttle control) were to replace more sedentary activities and travel mode choices, improved health outcomes would be realised.

E-bikes are likely to be sold in ever greater numbers in New Zealand. The current regulation of 300 W output power is insufficient to address the conflicts that will occur between road and path users. Legislators must respond quickly to keep pace with technological and marketplace changes, minimise harm to road and path users, and support the positive benefits of e-bikes. If we do not act, public perceptions may turn against e-bikes and limit adoption of a technology that will help improve mobility and environmental outcomes.

Classification methods and regulatory criteria including labelling requirements, throttle control, power, motor cut-out speed, weight, and age have been presented. Given the limitations of motor power ratings, it is suggested that the key criterion should be motor cut-out speed. Given the New Zealand context, a debate is needed on whether legislation should emulate the 25 km/h EU pedelec standard, the 32 km/h US standard, or some other speed. If 25 km/h or 32 km/h is selected, there will be greater choice as these two standards dominate the international marketplace. The authors support consideration of a separate 45 km/h class such as the EU's S-pedelec or California's Class 3, as it may be more appropriate for people who frequently travel longer distances on facilities with few driveways and intersections.

Now is also the time to consider how e-bikes fit with concurrent efforts to update design guidance and develop the urban cycleway network further. Providing wider facilities will be even more important to maintain an acceptable level of service with increased adoption of e-bikes.

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