Ref. Ares(2019)5349536 - 22/08/2019

European Commission

Study on the assistance factor (auxiliary propulsion power and actual pedal power) for cycles designed to pedal of vehicle sub-category L1e-B

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July – 2019

TRL

EUROPEAN COMMISSION

Directorate - General for Internal Market, Industry, Entrepreneurship and SMEs
Directorate C — *Industrial Transformation and Advanced Value Chains*
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2019

LEGAL NOTICE

Luxembourg: Publications Office of the European Union, 2019

ISBN 978-92-76-09364-0
doi:10.2873/085443

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1 EXECUTIVE SUMMARY

Regulation (EU) No 168/2013[1] created two new sub-categories within the L1e vehicle category (for light, powered, two-wheel vehicles) – L1e-A (Powered Cycle) and L1e-B (Two-wheel Moped). The Commission Delegated Regulation (EU) No 3/2014[2] then introduced a set of requirements for 'cycles designed to pedal' in L1e-B, which effectively created an additional sub-category within the L1e-B sub-category. Amongst the requirements specified in Annex XIX to Regulation (EU) No 3/2014 was the regulation of assistance factor, the ratio of power supplied by the electric motor to that supplied by the rider via the pedals. Regulation (EU) No 3/2014 specifies that assistance factor should be limited to a maximum value of four.

This study was created to establish whether any evidence exists that the regulation of assistance factor has an effect on the safety of cycles designed to pedal in L1e-B. The main methods employed in seeking this evidence was a search and review of publicly available information on this specific topic and the broader field of electrically assisted bicycles, and engagement with a range of stakeholders with interests in this area.

National regulations in many EU countries, including France, Germany, Belgium, the Netherlands, Spain and the U.K. treat cycles designed to pedal in L1e-B in the same way as other vehicles in that category, in that riders are required to hold third party insurance and wear an approved helmet and their vehicles are required to have a license plate and be licensed with the national authorities. Riders in all EU countries are required to hold a driving license. Cycles designed to pedal in L1e-B are usually prohibited from using cycle paths and thus must be ridden on the road.

The main practical implications of being categorised as a cycle designed to pedal, in accordance with Regulation (EU) 3/2014, therefore is that these machines are required to comply with the structural integrity standards for bicycles rather than mopeds, are restricted to a maximum mass of 35kg, are not required to undergo a range test and are required to have pedals that can be used as the sole means of propulsion for the vehicle and an adjustable seat to permit an optimum ergonomic pedalling position to be adopted.

A range of stakeholders were contacted during the preparation of this project. A spectrum of views were expressed regarding the appropriateness of regulating assistance factor. There seemed to be broad agreement that assistance factor was a useful metric for separating cycles designed to pedal from other vehicles in the L1e-B sub-category. Some stakeholders suggested that it might be useful to regulate assistance factor to ensure that the performance of the vehicle was matched to the strength of the rider. No stakeholder was able to point to any evidence that assistance factor has a direct effect on safety.

Currently cycles designed to pedal in L1e-B represent a small proportion (circa 1%) of electrically assisted bicycles in use in Europe. Only 69 type approvals for cycles designed to pedal in L1e-B were found. CONEBI estimate that of the approximately two million electrically assisted bicycles sold annually in the EU, only 20-25,000 are cycles designed to pedal in L1e-B. Collisions involving these vehicles are thus quite rare and research on

[1] Regulation (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles

[2] Commission Delegated Regulation (EU) No 3/2014 supplementing Regulation (EU) No 168/2013 of the European Parliament and of the Council with regard to vehicle functional safety requirements for the approval of two- or three-wheel vehicles and quadricycles

their use and behaviours is minimal. Currently only Germany and Belgium collect collision data on cycles designed to pedal in L1e-B in a separate category from other light two wheelers. The available collision data suggests that cycles designed to pedal in L1e-B may be involved in a disproportionate number of collisions for the size of their fleet, relative to electrically assisted bicycles outside the scope of type approval regulation and mopeds. However, extreme caution must be exercised in drawing any conclusions from these data as the absolute number of collisions involving cycles designed to pedal in L1e-B is still very small. In Germany cycles designed to pedal in L1e-B were involved in around 400 collisions per year, compared to around 70,000 collisions involving conventional bicycles and 4,000 involving electrically assisted bicycles outside the scope of the regulations.

The study of the effects of assistance factor in cycles designed to pedal in L1e-B is limited to two projects which drew conflicting conclusions. No studies were found that took a systematic approach to the evaluation of the effect of assistance factor on the safety of cycles designed to pedal in L1e-B. It is thus not possible at this time to provide definitive evidence to determine whether the regulation of assistance factor is having an effect on safety – either positive or negative.

A study in Germany by Schleinitz et al. (2015) found that the riders of the electrically assisted bicycles with assistance up to 45km/h rode at an average of 24.5km/h, compared to 17.4km/h for the electrically assisted bicycles with assistance up to 25km/h and 15.3km/h for the conventional bicycles. However, they noted that the difference in mean speeds between electrically assisted bicycles with assistance up to 25km/h and 45km/h was not statistically significant, i.e. the variation between riders was greater than the variation between bicycle types.

This report presents a commentary on the information currently available in this area and provides a summary of the views expressed by stakeholders during the course of the investigation.

2 INTRODUCTION

Regulation (EU) No 168/2013 made significant changes to the type approval of L category vehicles. The regulation introduced two new sub-categories of vehicle – L1e-A (powered cycle) and L1e-B (two-wheel moped) into the existing L1e (Light two-wheel powered vehicle) category (Table 2.1).

Table 2.1: Definitions of vehicles in the L1e category and electrically assisted bicycles which are outside the scope of type approval regulation (Adapted from European Commission, 2013 and 2014)

	Electrically assisted bicycles below the thresholds for type approval	L1e-A (Powered Cycle) (2, 3 or 4 wheels)	Cycles designed to pedal in L1e-B (Two-wheel moped)	Mopeds in L1e-B (Two-wheel mopeds)
Defining regulation	EN15194	Regulation EU No 168/2013	Regulation EU No 3/2014	Regulation EU No 168/2013
Maximum motor assisted speed	25km/h	25km/h	45km/h	45km/h
Maximum permitted motor power	250W	1,000W	4,000W	4,000W
Assistance factor limited	No	No (However, testing is a requirement for type approval)	Maximum motor power 4x human power	No
Pedalling required to move	Yes (Walk-assist allows electric drive up to 6km/h)	Yes (Walk-assist allows electric drive up to 6km/h)	Yes (Walk-assist allows electric drive up to 6km/h)	No

Electrically assisted bicycles with motors of more than 250W and assistance speeds above 25km/h were permitted under Regulation 2002/24/EC, which Regulation (EU) No 168/2013 replaced. However, the Delegated Regulation (EU) No 3/2014 supplemented Regulation (EU) No 168/2013 and introduced for the first time the concept of cycles designed to pedal in sub-category L1e-B, which would be subject to a separate set of requirements to the other vehicles type approved within L1e-B. In particular Annex XIX to Regulation (EU) No 3/2014 requires that 'cycles designed to pedal' in sub-category L1e-B should:

- Be designed and constructed in a manner that complies with EN 14764:2005 (now superseded by ISO 4210:2014).
- Have a mass in running order of 35kg or less.

- Be fitted with pedals that enable the vehicle to be propelled by the rider's muscular leg power alone.
- Have an adjustable seating position.
- Have a maximum assistance factor, the ratio of power provided by the motor to the power provided by the rider's pedalling, of four.

Commission Delegated Regulation (EU) 2016/1824[3], which amends Regulations (EU) No 4/2014 exempts cycles designed to pedal from the requirement to undergo a range test. Delegated Regulation (EU) 2016/1824 also specifies the tests of structural integrity, taken from ISO 4210:2014 that Powered Cycles in L1e-A and cycles designed to pedal in L1e-B must be subjected to (Table 2.2).

Table 2.2: Test and minimum forces or number of test cycles for vehicles of category L1e-A and cycles designed to pedal of vehicle category L1e-B (Adapted from European Commission, 2016)

Subject	Name of test	Reference of test which shall be used	Minimum value of the required test force or minimum number of test cycles
Handlebar and stem	Lateral bending test (static test)	ISO 4210-5:2014, test method 4.3	800 N
	Fatigue test (Stage 1 — Out of phase loading)	ISO 4210-5:2014, test method 4.9	270 N
	Fatigue test (Stage 2 — In phase loading)	ISO 4210-5:2014, test method 4.9	370 N
Frame	Fatigue test with pedalling forces	ISO 4210-6:2014, test method 4.3	1,000 N
	Fatigue test with horizontal forces	ISO 4210-6:2014, test method 4.4	Number of test cycles = 100,000
	Fatigue test with a vertical force	ISO 4210-6:2014, test method 4.5	1,100 N
Front fork	Static bending test	ISO 4210-6:2014, test method 5.3	1,500 N
Seat post	Stage 1, fatigue test	ISO 4210-9:2014, test method 4.5.2	1,100 N
	Stage 2, static strength test	ISO 4210-9:2014, test method 4.5.3	2,000 N

Recital (11) of Regulation (EU) No 3/2014 notes that the limitation of assistance factor to a value of four times the rider's muscular power should be subject to further scientific

[3] Commission Delegated Regulation (EU) 2016/1824 amending Delegated Regulation (EU) No 3/2014, Delegated Regulation (EU) No 44/2014 and Delegated Regulation (EU) No 134/2014 with regard, respectively, to vehicle functional safety requirements, to vehicle construction and general requirements and to environmental and propulsion unit performance requirements

research and possible revision in the future. This report will in part contribute to the development of the scientific basis for the potential revision to the regulation of assistance factor in cycles designed to pedal in L1e-B.

2.1 National regulations

While this investigation is intended to specifically address the type approval of cycles designed to pedal in L1e-B, the effect of national regulations on the way in which these vehicles are used cannot be entirely excluded. In broad terms national regulations treat cycles designed to pedal in the same way as all other vehicle in the L1e-B sub-category. The implications of this are that in many EU countries, including Austria, Belgium, France, Germany, the Netherlands, Spain and the U.K., the riders of cycles designed to pedal are required to hold a driving license and insurance, wear an approved helmet and ride on the road rather than cycle paths. Cycles designed to pedal in L1e-B must be registered with the appropriate national authority and carry an identification plate.

The effect of these national regulations is significant in that they may be creating some unintended consequences for the riders of cycles designed to pedal in L1e-B. Foremost amongst these is the fact that the requirement to use the road rather than specially designed cycle infrastructure brings the riders of cycles designed to pedal into conflict with cars and other road vehicles. Collisions between bicycles and cars are obviously much more likely to result in fatalities and serious injuries than those between bicycles or bicycles and pedestrians. Given the limited maximum speed of cycles designed to pedal in L1e-B, they also struggle to keep up with the flow of traffic, thus causing congestion and drawing hostility from drivers who are used to pedal cycles being segregated from motorised traffic.

3 TECHNICAL BACKGROUND

3.1 Power, torque, speed and angular velocity

It may be useful at this stage to briefly review the relationship between power, torque, speed and angular velocity, and the effects that these properties have on the behaviour of vehicles. 'Power', measured in Watts (W), is traditionally thought of as the rate of doing work. For our purposes here it is perhaps more useful to think of power as a composite measure of force and velocity.

i.e. power = force x velocity

The practical implication of this idea is that power is a speed dependent property. Thus a vehicle that is stationary, even if it is transmitting its maximum available torque, is transmitting no power. From the perspective of vehicle behaviour, the available power dictates the top speed that the vehicle is able to attain, but not its acceleration or the forces it is able to generate. 'Power' is thus not a useful measure when considering the behaviour of vehicles when starting off or at very low speeds.

The force acting on a vehicle due to aerodynamic drag increases as its speed increases. This increase is exponential in nature, i.e. doubling the forward speed quadruples the aerodynamic force. On a bicycle travelling at 45km/h, on a smooth flat road, the vast majority of the force resisting motion is the result of aerodynamic drag. The rider (or electric motor) thus has to do work to overcome this aerodynamic force. Since power is a composite of force and velocity, the faster the bicycle moves the higher will be its power requirement.

Torque is a measure of rotational force, usually measured in Newton Metres (Nm). 1Nm being the torque that would result from applying a one Newton (approximately 0.1kg) force to the end of a one metre long lever. Torque and force are effectively made interchangeable by the action of levers and cranks – the rider of a bicycle applies a linear force to the pedals, which is converted into a rotational torque by the pedal cranks, which is transmitted as a linear force by the chain, which is then converted back to a torque by the rear sprocket, which is then converted into a linear force at the point where the tyre meets the road.

Power can also be considered a composite of torque and angular velocity.

i.e. power = torque x angular velocity

Angular velocity being a measure of the rate at which something is rotating. Angular velocity is usually measured in radians per second (rad/s), 6.28rad/s being equivalent to one rotation per second. Power cannot be measured directly; it can only be calculated from other parameters. When the output power of a motor is measured it is done by measuring torque and angular velocity separately and multiplying the results. It is thus possible to have two motors of the same power but with completely different characteristics – one producing very high torque at very low angular velocity and another producing very low torque but at a high angular velocity.

When the rider of a bicycle sets off from stationary, they have to generate a high torque to accelerate themselves and the bicycle. They do this by pushing down hard on the pedals. This high force is strenuous to both the rider and the bicycle itself. Once the bicycle is travelling at a moderate constant speed the rider only needs to provide enough torque to overcome the aerodynamic forces acting on them and the bicycle and the small force resulting from the rolling resistance of the bicycle. Transmitting high forces during the acceleration phase leads to the possibility of breaking components or spinning the driven wheel and losing control of the vehicle. These failures are not usually seen when a bicycle is travelling at a steady speed.

The other situation in which high torque is required is when climbing hills. In this situation the bicycle is subject to a force due to gravity. Gearing permits a rider to multiply the force they are applying to the pedals and thus climb steeper hills than they would otherwise be able to. This extra force is traded for a comparable reduction in forward speed. Thus if a rider uses a gear that doubles their output torque, their forward speed will be halved. Power remains a composite of torque and angular velocity. So if the rider wants to double their torque, to climb a steeper hill, while maintaining the same forward speed, they must double their power input. From the perspective of cycles designed to pedal then, the regulation of assistance factor, which effectively applies a cap to the maximum power that the bicycle can transmit, has the effect of regulating forward speed, not force or torque. Forward speed is of course a limited characteristic in its own right in the type approval legislation. Limiting power thus creates a duplicate regulation for forward speed.

The velocity of passenger vehicles is usually controlled by regulating the amount of torque supplied to the driven wheels. The 'accelerator' pedal in a passenger car and the hand throttle on a motorcycle are actually torque controls. Typically, in vehicles fitted with an internal combustion engine, these controls regulate the flow of fuel into the engine. The driver uses this torque control to regulate how quickly the vehicle accelerates. When driving at a constant velocity the driver holds the accelerator or throttle in a position that supplies sufficient torque to balance the aerodynamic or gravitational forces acting against the vehicle's forward motion. If those forces change, for example when coming to a hill, the driver must request more torque from the engine by opening the throttle further as they climb the hill and then closing it as they descend. With practice drivers and motorcycle riders are able to modulate the throttle position to maintain a steady forward speed without giving the process any thought. Automated systems that maintain a set forward speed regardless of external influences, like cruise control systems fitted to passenger cars, require sensors to measure the vehicle speed in order to provide feedback to the torque control to maintain a constant speed.

3.2 Electric motors

Electrically assisted bicycles typically use direct current (DC) electric motors. The speed of a DC motor is regulated by the voltage supplied to it. The torque generated by a DC motor is regulated by the current supplied to it. In electrical terms power is a composite of voltage and current.

i.e. power = voltage x current

It should be born in mind that mechanical power and electrical power are equivalent measures of energy flow, i.e. 1 Watt of mechanical power is the same as 1 Watt of electrical power.

DC electric motors can be controlled by regulating either current or voltage. Controllers that regulate current, and thus torque, can be considered equivalent to the throttle control on a motorcycle. Thus in a current controlled system the motor is supplied with sufficient current to generate sufficient torque to produce the acceleration demanded, or balance the aerodynamic and gravitational forces acting against the forward motion of the vehicle.

On an electrically assisted bicycle the maximum voltage available to the motor will be limited by the voltage available from the battery pack fitted. Given that motor speed is controlled by voltage, the maximum speed of the motor is thus effectively controlled by the voltage available from the battery. With a simple control system it is possible to change the top speed of the vehicle by exchanging the battery for one of a higher voltage. This is certainly the case with some electrically assisted bicycles that are assembled from components by the end user. A voltage regulating controller effectively sets the speed required from the motor by setting the voltage supplied to it. Often the current supplied is allowed to self-regulate and thus the torque available to accelerate the vehicle is only limited by the electrical resistance of the battery or the fuse protecting the system.

A bicycle rider controls the speed of the vehicle by regulating the speed at which they turn the pedals. Electrically assisted bicycles use a sensor to measure the speed at which the pedals are turned and use this as the speed demand control for the electric motor. Clearly it is important to measure the direction in which the pedals are turned, otherwise it would be possible to request more electrical assistance, and therefore make an electrically assisted bicycle go faster, by rotating the pedals backwards.

The forward speed of the bicycle is measured using a sensor fitted to one of the wheels. The electrically assisted bicycle’s control system must measure the forward speed of the bicycle to ensure that electrical assistance is switched off at the maximum speeds stipulated by the Regulations.

In order to regulate assistance factor of an electrically assisted bicycle it is necessary to measure the power that is being generated by the rider. This requires that the control system measures both the angular velocity with which the pedals are turning and the torque that is applied through them. Therefore, in order to be compliant with the Regulations the control system must be capable of regulating both the voltage and current supplied to the motor.

4 MARKET ANALYSIS

Data obtained from CONEBI (2018) indicates that in 2017 20.6 million bicycles of all types were sold in the EU. Of these around 2 million were electrically assisted. CONEBI does not disaggregate sales of electrically assisted bicycles, but they estimate that only around 20-25,000 (*circa* 1%) of those sales were of cycles designed to pedal in either L1e-A or L1e-B.

Four type approval authorities were contacted and asked to provide information on the numbers of different types of cycle designed to pedal in L1e-B. The Vehicle Certification Agency (VCA) in the UK noted that across the EU in total there were 238 types listed under L1e, but they were unable to provide a breakdown between L1e-A and L1e-B, or say how many of those types are cycles designed to pedal.

The Spanish Ministerio de Economía, Industria y Competitividad indicated that they had not type approved any cycles designed to pedal in L1e-B.

The German Kraftfahrt-Bundesamt (KBA) type approval authority responded that they had approved 42 types in L1e-B since Regulation (EU) No 168/2013 came into force and of those 28 were classified as cycles designed to pedal. They provided data (Appendix 12.1) that showed that the average level of assistance factor in the cycles designed to pedal in L1e-B, type approved in Germany, was 2.83, with a range between 2.39 and 3.3.

Rijksdienst voor het Wegverkeer (RDW), the type approval authority for the Netherlands interrogated the European Type Approval Exchange System (ETAES) database to find all cycles designed to pedal in L1e-B type approved in Europe (Appendix 12.2). They found 57 separate type approvals. The average level of assistance factor across these 57 types was 2.86, with a range between 0.9 and 4. Of the 57 types identified by RDW, 16 were also listed in the data provided by KBA. However 12 of the type approvals issued by KBA did not appear in the list provided by RDW. RDW suggested that this may be due to a lag between type approvals being completed by national agencies and them then being logged on the ETAES database. The total number of unique type approvals found for cycles designed to pedal in L1e-B was 69.

TRL conducted its own review of cycles designed to pedal in L1e-B on sale in the EU (Appendix 12.3). This review used internet searches and direct contact with bicycle retailers in several EU states to ascertain the models that they had for sale. While not exhaustive, this investigation found 30 types of cycle designed to pedal with maximum assistance speeds of more than 25km/h. TRL were unable to establish whether all of the types found were actually 'type approved', but according to their maximum assistance speeds they should have been. Intriguingly there was some disagreement between the list supplied by KBA and the vehicles found for sale. For example the KBA listed 11 types from the manufacturer Riese and Müller, but only three types from that manufacturer were found on sale, none of which matched the names given in the KBA list. This is perhaps an indication that some types are no longer in production despite still retaining their type approval. The difference in names found may be due to manufacturers updating their branding without actually changing design of their vehicles, or indeed using different names for the same product in different European markets.

This investigation also sought to collect some technical details on the types for sale. The maximum claimed assistance factor found for a cycle designed to pedal in L1e-B was 4, with many manufacturers offering systems that allow different levels to be selected according to the rider's requirement for a specific journey. The most powerful bicycle found for sale had a motor with an output of 850W, but half of those found had motors with an output of less than 400W. Of the 30 types identified, 19 used a drive system with the motor mounted in the centre of the frame; the remainder used motors mounted in the rear wheel hub. No cycles designed to pedal in L1e-B were found to be using motors driving the front, despite this being a common configuration for non-type approved electrically assisted bicycles.

5 EXCEPTIONS FROM THE REGULATIONS

Regulation (EU) No 168/2013 is far from universal in its coverage of vehicles that would be considered as cycles designed to pedal, and the enforcement of that Regulation is also prone to omissions, either deliberate or accidental. A range of loopholes were identified during this study that are acting as routes for cycles designed to pedal, that fall within the spirit of the Regulation, to enter the market for use on the road.

A difficulty exists for law enforcement authorities in identifying vehicles that fall within Regulation (EU) No 168/2013. While it might be relatively easy to identify that a bicycle is electrically assisted, it is very difficult for a law enforcement officer to determine the output of an electric motor or the maximum assistance speed of a controller. It is thus very easy for a rider to illegally use a bicycle with electrical assistance, which should fall within EU type approval legislation, with very little risk of detection. Three key routes for vehicles with the potential for illegal use were identified:

- Retrofit systems
- Modified systems
- Off-road bikes

5.1 Retrofit systems

An extensive market exists for components and kits that permit individual riders to convert their conventional bicycles to electrically assisted bicycles. Components available via this route often offer much higher power motors than are common in the complete vehicle market; 1kw motors being commonly offered by far eastern suppliers via ecommerce platforms. However, more mainstream suppliers are emerging, offering retrofit kits from bases within the EU. The challenge of incorporating such components and systems into an existing bicycle frame are well within the capabilities of riders with even modest levels of technical competency. Given that these components are being sold individually or as part of a kit that does not include a frame it is easy for them to avoid type approval enforcement and are thus effectively deregulated. Through its collision investigation activities, TRL is aware of at least one serious collision involving a bicycle that had been modified in this way.

5.2 Modified systems

There is a significant body of anecdotal evidence to suggest that many electrically assisted bicycles, that fall outside of type approval legislation because they have motors of 250W or less and top speeds of 25km/h or less, are being modified to permit them to be ridden with electrical assistance greater than 250W or with assistance at speeds above 25km/h – thus bringing them within the realms of L1e-B type approval. Online forums and websites offer a range of advice on how this may be done, including altering the position of speed sensors to give them false lower readings, cutting speed limiting links in motor controllers, modifying controlled software or uprating batteries to run motors at higher voltages.

5.3 Off-road bikes

Paragraph (g) of article 2(2) of Regulation (EU) No 168/2013 excludes "vehicles primarily intended for off-road use and designed to travel on unpaved surfaces". This effectively excludes electrically assisted mountain bikes from the scope of the Regulation. A wide range of electrically assisted mountain bikes has proliferated, particularly in the USA, where bicycles with top speeds of 80km/h and above are available. Similar products have been found for sale online in the EU.

6 LITERATURE REVIEW

This review of literature was prepared with the aim of determining whether any evidence exists in literature indicating a relationship between assistance factor and the safety of cycles designed to pedal in L1e-B.

Searches were conducted using a range of search engines and catalogues including Google, Google Scholar and Science Direct. Additionally, some authors were contacted directly and asked to provide papers that were not readily available via conventional online routes. Searches were limited to publications written in English. Searches were also predominantly focused towards publications dealing with European bicycles and their riders. This approach excluded a substantial number of papers that deal with cycling in South East Asia. It was felt that this approach was justified as the regulatory framework and pattern of usage differ significantly from those seen across Europe.

Given the relative recency with which the L1e-B sub category has been created and the relatively low numbers of cycles designed to pedal in L1e-B in the European fleet there are very few publications that deal specifically with this type of vehicle. Two studies that specifically address assistance factor in cycles designed to pedal in L1e-B were found and are included in this review. Some work was found and included in the study from outside the EU that concerned vehicles that might be considered equivalent to cycles designed to pedal in L1e-B due to the power output or maximum assistance speeds of the cycles concerned. Multiple studies were found from inside and outside the EU that concern electrically assisted bicycles generally. These have been included in this study where they contribute to the narrative or provide some insight into the safety of cycles designed to pedal in L1e-B, but it should be noted that the findings of studies into the overall safety of electrically assisted bicycles may not be generalizable to cycles designed to pedal in L1e-B.

6.1 Studies specifically concerned with assistance factor

Two studies were identified that specifically address the assistance factor of cycles designed to pedal in L1e-B. The first by Groß (2013) assessed the effect of the limitation of assistance factor and the conformity with prescriptions regarding strength and construction of front forks and frames. The second, by Rotthier et al. (2017), attempted to present a case for the deregulation of assistance factor in L1e-B. Neither study specifically set out to measure the effect of assistance on the causes or severities of collisions involving cycles designed to pedal.

Groß's primary aim was to determine whether the structural integrity of the bicycles tested was appropriate and compliant with the relevant standards. He used four different models of cycle designed to pedal that are type approved in L1e-B. He used six test riders, four male and two female aged between 22 and 52 years old with body masses between 55 and 98kg. He instrumented his test vehicles to measure strains in the handle bars, seat posts, front forks, and frames. He also measured the torsional forces in the frame close to the bottom bracket in order to estimate the forces being applied to the pedals and thus the torque being transmitted by the rider, and the angular velocity of the pedals. From these data he was able to estimate the power being transmitted by the rider. He measured the voltage and current supplied to the electric motor and from these data was able to calculate electrical input power. He could thus determine assistance factor by comparing the human power at the pedals to the electrical power supplied by the motor. Groß attempted to measure motor torque by measuring strains in the rear chain stays, although he did not include any of those data in his paper. The bicycles were ridden on a variety of surfaces to provide a range of road loads. It is unclear whether a specific duty cycle was selected for this purpose, although, as Groß notes that the distribution of tracks used by each rider was different, it seems that this was not the case and that route selection was essentially random.

Groß attempted to investigate whether assistance factor affected the safety of two of the bicycles he tested. He did this by having the manufacturer manipulate the control algorithm of the motor controller. Groß explains that in one of these tests the controller was programmed to work in "…bang-bang mode meaning full electric power is provided independent of the pedal power as soon as a certain low threshold value is reached". Presumably, since power is a function of both torque and angular velocity, Groß actually meant that the system was programmed to provide maximum current and thus torque when the threshold value is reached. This is the equivalent of having a throttle control that has only two possible positions - either fully open or fully closed. Unsurprisingly perhaps Groß found that the bicycle programmed in this way was difficult to control and took this as an indication that it is necessary to limit assistance factor. It must be noted however that Groß did not quote any power or assistance factor data for this experiment so it is not possible to ascertain what the actual assistance factor used in this experiment was. Rather than being a test of the effect of assistance factor, this experiment was actually a test of the effect of torque control. Groß does quote some motor current, pedal force and vehicle speed data from this experiment which shows that the motor current switches between zero and the maximum set value of 25amps. Unfortunately, despite Groß's claim, this experiment doesn't seem to provide any useful data on the effect of assistance factor. It does demonstrate that the design of the control algorithm used in the motor controller can have an important effect on the controllability of the bicycle. However, it is the control of motor current and thus motor torque that is important here. In the same way that it would not be acceptable to build a motorcycle with a throttle that had only two possible settings, it is not acceptable to build an electrically assisted bicycle with a motor controller that allows for only 'on' or 'off'.

In the second of his experiments on assistance factor, Groß had the manufacturer modify the motor control software so that it could be switched between four different assistance factors, 2:1, 4:1, 5:1 and 6:1.

It is unclear what tests were actually performed with this vehicle, but it could be surmised that it followed a test route similar to the other vehicles tested. Groß noted that the available electric motor power was 350W. He also included a table that purports to show pedal power at various speeds and assistance factors (Table 3.1).

Table 3.1: Pedal power measured at various speeds and assistance factors on a bicycle with a modified motor controller (Groß, 2013)

Ratio of electrical power: pedal power	"Eco" 2:1	"Tour" 4:1	"Turbo" 6/1
Pedal power at 10km/h	47 W	36 W	27 W
Pedal power at 20km/h	93 W	70 W	56 W
Pedal power at 30km/h	186 W	162 W	154 W

Studying this table shows that at 30km/h the motor does not have sufficient power to be able to provide the level of assistance factor quoted at any of the levels tested. Groß did not quote any dynamic power or assistance factor data for this experiment, but notes that this mismatch between assistance factor and available motor power "…results in an uncomfortable riding experience" that is more pronounced at higher levels of assistance factor. He does not provide any further explanation of what he meant by 'uncomfortable' or whether increasing the motor power to permit it to supply the power necessary to match the pedal power would improve the comfort of the vehicle. He did note that one of the other test vehicles with a more powerful (650W) motor and a control algorithm that adapted the assistance factor based on the pedal force was more comfortable to ride, although it isn't clear whether that was because of the control algorithm or the extra power available. He also did not provide any indication of what objective measure was being employed to measure comfort.

Unfortunately it would appear that the experiments conducted by Groß to attempt to measure the effect of assistance factor on the safety of cycles designed to pedal in L1e-B failed to collect a data set of sufficient scope or quality to be able to support any conclusions in this area. His assertion that "A limitation of the ratio of the added auxiliary propulsion power dependent on the actual pedal power is necessary to provide safe handling for starting, during cornering or for low speed cruising" is not supported by the evidence he presented. This paper cannot be used to justify the limitation of assistance factor on safety grounds and its conclusions in this area should be disregarded.

Rotthier et al. (2017) presented a counter argument to that made by Groß. They argue that the regulation of assistance factor leads to cycles designed to pedal being slower and more 'fickle' in their ability to maintain speed in response to environmental factors and claim that the regulation discriminates against weaker riders.

Rotthier et al. used a simple simulation to demonstrate that untrained cyclists, riding cycles designed to pedal with an assistance factor of four, would not be able to transmit enough power to reach the 45km/h limit. The results of Rotthier et al's simulation agree with the results that Groß (2013) obtained through measurement using a bicycle on a smooth flat track. Groß noted this result, but suggested that cycles designed to pedal should not be intended to drive at a constant 45km/h.

Rotthier et al. used their simulation to investigate the effect of environmental factors on the speeds of cycles designed to pedal. They found that with a headwind of 10km/h the maximum speed of a cycle designed to pedal, ridden by a rider who could produce 100W of pedal power, was limited to 32km/h. They also provided data to demonstrate that on a 4% slope the maximum sustainable speed was reduced to 27km/h. They argue that, given the legal requirement for vehicles in L1e-B to drive on roads rather than cycle paths, this reduction in maximum cruise speed places cycles designed to pedal at a disadvantage when compared to more conventional mopeds.

It should be born in mind that Rotthier et al. made a philosophical argument for why limiting assistance factor to a value of four is inappropriate and supported it with a simulation that demonstrated the potential practical consequences of that regulation. While Groß undertook an experimental study to attempt to demonstrate how assistance factor affects the safety of cycles designed to pedal. But neither Rotthier et al. nor Groß provided a compelling body of evidence to show that assistance factor actually has an effect on the safety of cycles designed to pedal, either positive or negative. Given that these studies were the only ones found in literature or through engagement with stakeholders that specifically attempted to address the effect of assistance factor, there would seem to be a crucial gap in knowledge that prevents the adoption of a scientifically robust position on the regulation of assistance factor.

6.2 Studies into the safety of electrically assisted bicycles

Having exhausted sources that directly address the issue of assistance factor, a further search was conducted in order to find information that could provide a broader context to the issue of safety of electrically assisted bicycles. No studies were found that specifically examine cycles designed to pedal in L1e-B, but several studies were found from Switzerland, where there is an equivalent set of national regulations that allow electrically assisted bicycles with assistance up to 45km/h. Other studies were found from within the EU that focus more broadly on the safety of electrically assisted bicycles in general.

Schleinitz et al. (2015) conducted a study of cycling behaviour in Germany. They recruited 85 cyclists who rode either conventional bicycles (n = 28), electrically assisted bicycles with a maximum assistance speed of 25km/h (n = 48) or electrically assisted bicycles with a maximum assistance speed of 45km/h (n = 9). Their data was collected between July and November 2012, before Regulation (EU) No 168/2013 came into force and created the current sub-categories. The participants used their own bicycles for the study. They were fitted with a video camera facing forwards and another facing the rider and a speed sensor measuring wheel speed. The study was conducted in and around Chemnitz, Germany. In total they collected data on 4,327 trips, covering a total distance of 16,873km.

Schleinitz et al. (2015) found that the riders of the electrically assisted bicycles with assistance up to 45km/h rode at an average of 24.5km/h, compared to 17.4km/h for the electrically assisted bicycles with assistance up to 25km/h and 15.3km/h for the conventional bicycles. However, they also noted that while the mean speeds for electrically assisted bicycles with assistance up to 25km/h or 45km/h were different, that difference was not statistically significant. This may be due to the small number of 45km/h riders included in the study. When considering the speeds at which the most distance was covered, the riders of the electrically assisted bicycles with assistance up to 45km/h were found to be riding at more than 20km/h for more than 80% of the distance covered and at more than 30km/h for 34% of the distance. The riders of the electrically assisted bicycles with assistance up to 45km/h covered 18% of total distance on cycle paths, despite this being illegal. The riders of electrically assisted bicycles with assistance up to 45km/h travelled faster on all types of infrastructure (roads, cycle paths, pavements, pedestrian precincts and unpaved roads) than the riders of conventional bicycles and electrically assisted bicycles with assistance up to 25km/h. Their mean speed when riding on cycle paths was 23.6km/h, compared to 18.4km/h for electrically assisted bicycles with assistance up to 25km/h and 16.7km/h for riders of conventional bicycles.

Stelling-Konczak et al. (2017) conducted a study on behalf of Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV, the Dutch Institute for Road Safety Research) in which they attempted to study the behaviour of the riders of cycles designed to pedal in the Netherlands. Their study was conducted between May and July 2017; Dutch law having been changed in January 2017 from its previous position in which cycles designed to pedal in L1e-B had a 25km/h speed limit, were allowed to be ridden without a helmet and were allowed to be ridden on cycle paths to one in which helmets were mandatory, the speed limit was 45km/h on the road and riding on dedicated cycle paths was prohibited, although they are permitted to use combined cycle and moped paths. The study employed cycles designed to pedal in L1e-B fitted, in a similar manner to Schleinitz et al. (2015), with front and rear facing video cameras. The cameras also incorporated GPS receivers and accelerometers. These vehicles were provided to participants for a period of two to three weeks each. Participants were also supplied with helmets appropriate to this category of vehicle.

Stelling-Konczak et al. (2017) found that the average riding speed on roads with a 50km/h speed limit was 32km/h, although they did not collect any comparative data for other traffic on those roads. On all roadways the riding speed was between 30 and 40km/h for 56% of the distance travelled and above 40km/h for 25% of the distance travelled. This is obviously somewhat in excess of what Schleinitz et al. (2015) found a few years earlier in Germany. Stelling-Konczak et al. found that 23% of the journeys made using cycles designed to pedal in L1e-B were conducted (illegally) on cycle paths. It should be born in mind that the study was conducted only a few months after Dutch law had been changed, reversing the requirement that insisted that electrically assisted bicycles with assistance up to 45km/h be ridden on cycle paths when they were available. It is unclear whether Stelling-Konczak et al. issued any instructions or guidance to participants regarding the legality of where they should ride. When travelling on cycle paths the average riding speed was 29km/h, but over 75% of the distance ridden on urban cycles paths was covered at speeds in excess of 25km/h. More than 50% of the distance covered on urban cycle paths was ridden at speeds in excess of 30km/h and 11% was ridden at speeds in excess of 40km/h.

Stelling-Konczak et al. (2017) noted a number of issues concerning the integration of cycles designed to pedal in L1e-B with other traffic. On urban roads with a speed limit of 50km/h they noted that the presence of the cycle designed to pedal caused the flow of traffic to slow on average once every 2km. They noted that they had no comparable data with which to determine whether that represented a major or a minor disruption to traffic. Expressions of irritation toward the cycles designed to pedal in L1e-B, such as the sounding of car horns or the flashing of headlights, was observed on average once every 27.5km/h. It is unclear what elicited these reactions and it is possible that they were a response to these cycles being ridden on the roadway rather than the cycle path as they had been previously. The participants were questioned about their experiences of riding the cycles designed to pedal in L1e-B. They noted that riding on the roadway felt unsafe and was stressful and not particularly pleasant.

Schepers et al. (2014) attempted to understand the safety of electrically assisted bicycles compared to that of conventional bicycles without electrical assistance. The study attempted to compare the likelihood of collisions and their injury consequences between electrically assisted bicycles and conventional bicycles in the Netherlands. They found that, when controlled for age, gender and amount of bicycle use, use of electrically assisted bicycles increased the likelihood of being involved in a collision which would result in injuries needing treatment at an emergency department. Schepers et al's (2014), regression analysis produced an odds ratio of 1.92 for collisions involving electrically assisted bicycle compared to conventional bicycles for this outcome. However, they also observed that the odds ratio of being required to stay in hospital having visited the emergency department following a collision involving an electrically assisted bicycles was not statistically significant (OR = 1.15). Their data also showed that cyclists of both conventional and electrically assisted bicycles were more likely to require admission to hospital if they were travelling at more than 25km/h at the time of the collision.

Schepers et al. (2018) sought to develop the evidence base used in their earlier project. They used two questionnaires commissioned by the Dutch Ministry of Infrastructure and the Environment for their study. The first questionnaire "Survey of bicycle crash victims treated at Emergency Departments" was carried out by The Dutch Consumer and Safety Institute. The study targeted victims of bicycle crashes seeking information about the crash characteristics and bicycle use before the accident. 2,383 victims over the age of 16 responded and they were categorised and weighted according to their age and gender. It is not clear if this information was broken down into types of bicycles used by the victims. This was self-reported data, and, as such, injury severity may be perceived by the victim incorrectly. The second study was conducted by KANTAR and was a questionnaire sent to 200,000 people. Participants were asked to participate in one survey per month in return for a reward. These responses were weighted for age, gender, and other demographic characteristics. The survey was conducted from week 27 to week 43 (late summer to mid-autumn) of 2016.

Schepers et al. (2018) showed that having controlled for the distance cycled, there was no difference in the likelihood of being involved in an injury causing collision between electrically assisted and conventional bicycles. They were also able to conclude that there was no significant difference in the odds of being admitted to the emergency department between users of electrically assisted and conventional bicycles. They also showed that electrically assisted bicycles users are not, as had previously been suggested in Schepers et al. (2014), more often involved in dismounting collisions than conventional bicycle users; 39% of mounting/dismounting collisions affecting electrically assisted bicycle compared to 61% for conventional bicycles.

In collisions with multiple vehicles, including cyclists and other vehicles such as cars or vans, electrically assisted bicycles accounted for fewer cyclists' collisions than classical bicycles. 33% (n = 588) of conventional bicycle collisions involved multiple vehicles, while only 23% (n = 132) of electrically assisted bicycles collisions involved multiple vehicles. There was no clear evidence to indicate that electrically assisted bicycles were involved in collisions more often, either in single bicycle events or in multiple vehicle collisions.

Schepers et al. (2018) also found that road layout did not affect the relative likelihood of suffering a collision when using either an electrically assisted or conventional bicycle. They were able to conclude that higher age and more frequent riding correlates with an increased likelihood of being involved in a bicycle crash. They acknowledged that the distance travelled (exposure) was not part of the survey but the level of exposure will have an impact on collision frequency. Schepers et al. (2014) were initially able to identify, from their research (including information from Van Boggelen et al. (2013), that electrically assisted bicycle users tended to be older than the average conventional bicycle user and came to the same conclusion after re-conducting the study for the 2018 paper. The increase in ease of mobility for elderly users increases their exposure to the risk of collisions. Electrically assisted bicycles enable more elderly people to ride for longer and further but this increases their exposure to collisions with other road users. It will also increase their exposure to single bicycle accidents, i.e. (dis)mounting and collisions with the environment.

In their 2018 paper, Hertach et al. reported a study conducted in 2016, in which they attempted to understand the "Characteristics of single-vehicle crashes with e-bikes in Switzerland". Hertach et al*'s* study made use of a survey involving 3,658 participants, who claimed to use electrically assisted bicycles as a mode of transport in 2016. Of the 3,658 respondents 638 were involved in single vehicle collisions (an impact with no other road users) while riding their electrically assisted bicycles. This segment of the survey population was analysed further and their collisions were broken down into causation, riding exposure, injury severity and journey purpose. The data collected from the study was analysed using a logistical regression method and similar to that utilised by Schepers et al. (2014) and (2018).

Hertach et al. (2018) initially undertook research to find the current state of the art and the then current use/uptake of electrically assisted bicycles in Switzerland. Hertach et al. cited Velosuisse (2018) showing that in 2006, 3,000 electrically assisted bicycles were sold, however, in 2016 that had increased to 75,000 units. A previous report, cited in this paper and co-authored by Hertach, Uhr & Hertach (2017) was able to discover, from Swiss police reports only, that the total number of injured electrically assisted bicycle riders, per year in all types of collisions, had tripled in the years of 2011-2016 to almost 700 collisions. It must be stated there will have been a significant under-reporting of collisions to police forces as many members of the public will not feel the need to do so, especially in single-vehicle collisions. This point was conceded by Hertach et al. upon commencing their data analysis.

Hertach et al's survey was conducted during the months of September-November of 2016. The survey focused on riders who used electrically assisted bicycles with pedal support up to 45 km/h (e-bike45), which are analogous to cycles designed to pedal in L1e-B and electrically assisted bicycles with support up to 25 km/h (e-bike25), which may be analogous to L1e-A or deregulated electrically assisted bicycles in the EU. Hertach et al. attempted to contact 484 registered participants of electrically assisted bicycle training courses and 2,400 owners of an e-bike45. Of those who responded to the questionnaires, 1,156 reported that they use an e-bike45 and 2,502 reported that they use an e-bike25. 4,044 members of the public responded to the questionnaire. 386 of those participants were excluded due to either having stopped riding their electrically assisted bicycle or because they rode their electrically assisted bicycle infrequently. Participants were 14 years and older, with 60% of e-bike45 users being male and 40% female. The gender distribution was not specified for e-bike25 users but the overall mean age for both types of electrically assisted bicycles was 54.4 years.

Hertach et al. interrogated the data for the 638 e-cyclists who suffered a single-vehicle collision. They were able to establish the distribution of users at the time of the collision, with 55% riding an e-bike25 and 45% riding an e-bike45. Around 70% of users who had a single-vehicle collision were aged between 35 and 64 years. The most common cause of injuries or collisions was skidding. This was believed to be due largely to icy or wet roads. After conducting a regression analysis on the data they had collected, Hertach et al. were able to conclude that increased riding speed increased the likelihood of having a single-vehicle collision. They could identify no effect of the electrically assisted bicycle type (e-bike25 vs. e-bike45) and age on the risk of a single-vehicle collision; all age groups were equally affected by this collision type. They were not looking for any effects of assistance factor and didn't mention it as being significant in their findings.

From the data Hertach et al. presented, extracted from the surveys of the 638 e-cyclists who had experienced a single-vehicle collision, it was possible to see the leading two causes of the collision. The most common causation factor was a slippery road surface with 51% of participants describing it as the leading cause. The second most common cause was riding too fast for the situation, as 37% of the 638 participants described it as a leading cause of their collision. Hertach et al. also attempted to quantify the effect of speed on injury severity. They calculated the odds ratio for suffering moderate to severe injuries compared to no-injury or minor injuries in relation to collision speed. As a reference stationary collisions were given an OR of 1. The odds ratio for suffering a moderate to severe injury when a collision occurred at up to 25km/h was found to be 1.44, while the odds ratio for suffering a moderate to severe injury when a collision occurred at more than 25km/h was 5.86.

Conversely Schepers et al. (2018) did not observe a strong association between speed and the likelihood of suffering a collision that resulted in hospital admission having visited an emergency department (indifferent of injury severity). Of those who were admitted to hospital having visited an emergency department (460 of the study's participants), 33% (largest percentage) were involved in a collision at less than 5 km/h.

Both reports were based on studies in which accident speeds were self-reported, leaving an opportunity for participants to over/under-estimate their travel speeds, especially after the event. Schepers et al. required their participants to recall details of their collision events after a significant period of time (sometimes 3 years). Hertach et al. required the participants to attribute causation factors to their collision. The leading factors reported were skidding and travelling too fast for the conditions. Therefore, participants of Hertach et al's study may have an altered opinion of their own travel speed and may assume they were travelling faster than their true speed in order to slip.

6.3 Conclusions to the literature review

Very little research has been published on the effect of assistance factor on the safety of cycles designed to pedal in L1e-B. The studies that were found that specifically address this issue are contradictory and fail to provide an adequate evidence base for their conclusions.

Schleinitz et al. (2015) observed that there was no statistically significant difference in the average speeds at which electrically assisted bicycles with a 25km/h and a 45km/h maximum assistance speed were ridden. On average electrically assisted bicycles with assistance up to 25km/h were ridden at 17.4km/h, while those with assistance up to 45km/h were ridden at an average speed 24.5km/h. By comparison, conventional bicycles were ridden at an average speed of 15.3km/h. Stelling-Konczak et al. (2017) observed higher average speeds than Schleinitz et al. for cycles designed to pedal in L1e-B.

Schepers et al. (2018) concluded that for the most part there was very little difference in the likelihood or severity of collisions affecting conventional and electrically assisted bicycles. However, they did observe that the availability of electrically assisted bicycles increased cycling by more elderly riders and thus increased their exposure to collisions. The study was primarily concerned with electrically assisted bicycles outside the scope of type approval legislation and it is not clear whether it is possible to generalise its conclusions to include cycles designed to pedal in L1e-B. It also isn't clear whether this study is relevant to countries with cycle infrastructure less well developed than that seen in the Netherlands.

Hertach et al. (2018) observed that in Switzerland, which has categories of electrically assisted bicycles analogous to L1e-A and cycles designed to pedal in L1e-B, the most common cause of collisions was skidding. They also concluded that higher riding speeds were strongly associated with a higher risk of moderate to severe injury.

7 COLLISION DATA

Given the small numbers of cycles designed to pedal in L1e-B in the European fleet, most national agencies that collect collision data combine them with either other bicycles, or mopeds. Currently only the German and Belgian authorities routinely record collisions involving cycles designed to pedal in L1e-B in a category of their own in their annual collision statistics reports.

7.1 German collision data

The German national statistics agency Destatis include a specific category for cycles designed to pedal with maximum assistance speeds between 25 and 45km/h in their annual report on collisions involving two-wheeled vehicles. These data (Table 7.1) show a steady rise in the number of collisions involving cycles designed to pedal between 2014 and 2017 (Figure 7.1), perhaps reflecting a steadily increasing population of cycles designed to pedal in the German fleet. However the total number of collisions involving cycles designed to pedal in L1e-B is extremely small compared to other light two-wheelers (Figure 7.2).

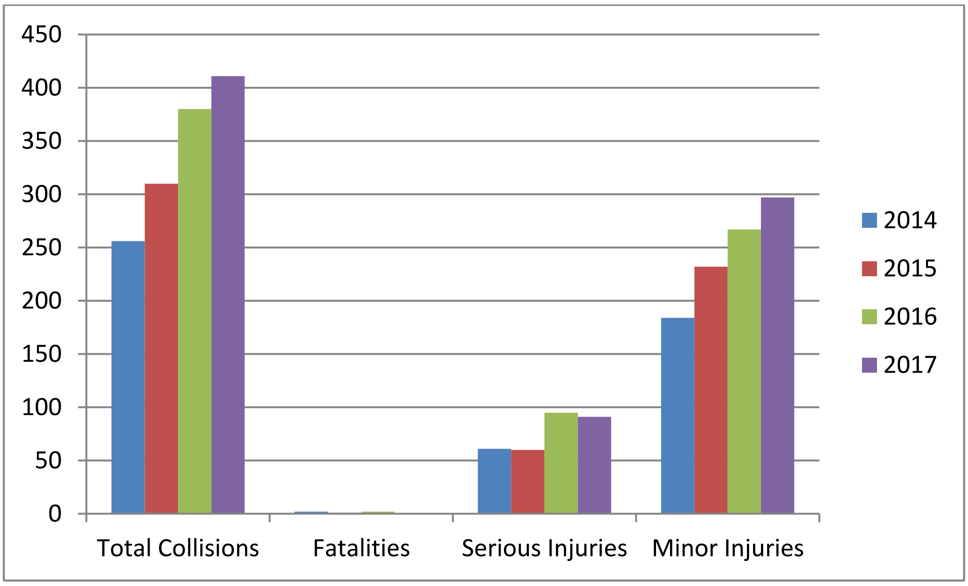

Figure 7.1: Collisions involving cycles designed to pedal in L1e-B and resulting casualties reported to police in Germany in 2014-17. (Data from Destatis 2015, 2016, 2017, 2018)

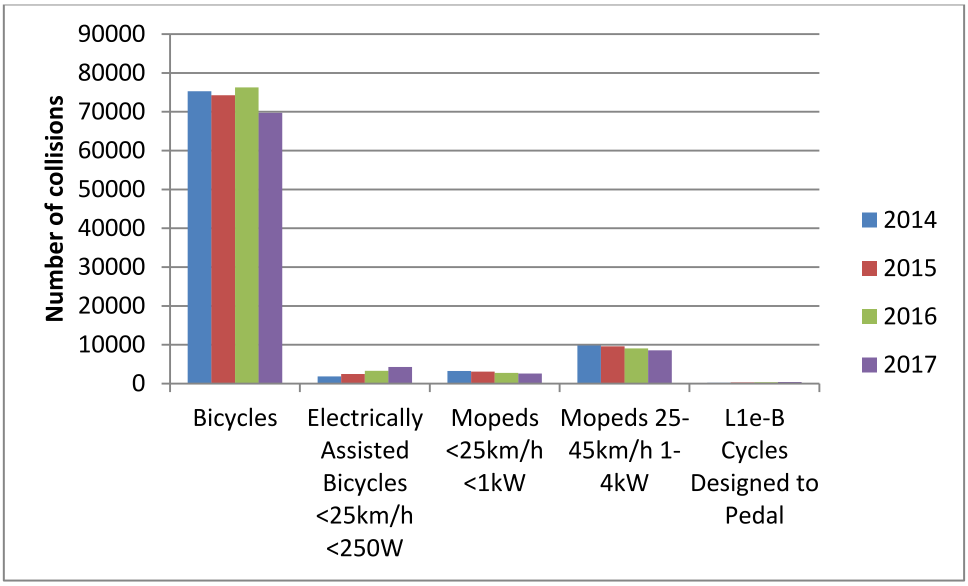

Figure 7.2: Total collisions reported to police in Germany in 2014-17. (Data from Destatis 2015, 2016, 2017, 2018)

Fortunately the number of fatal collisions involving cycles designed to pedal in L1e-B has remained consistently low and even dropped to zero in 2017 (Figure 7.1). However, the numbers of serious injuries (admitted to hospital overnight) and minor injuries rose significantly between 2014 and 2017. There is no obvious trend in the proportion of serious injuries resulting from these collisions, which remains around 20%. Compared to other light two wheelers, the number of fatalities (Figure 7.3), serious injuries (Figure 7.4) and minor injuries (Figure 7.5) sustained by riders of cycles designed to pedal in L1e-B were all numerically much lower.

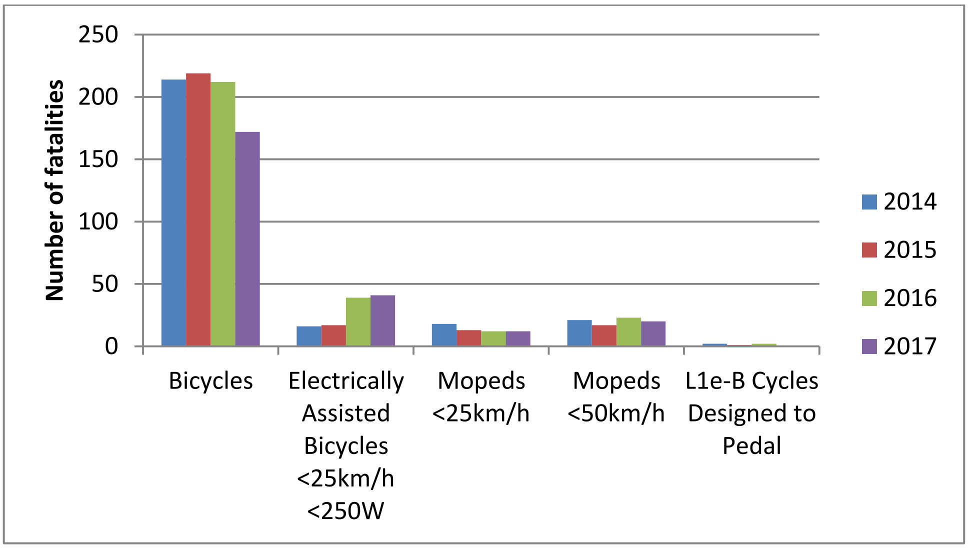

Figure 7.3: Numbers of fatalities resulting from collisions reported to police in Germany in 2014-17. (Data from Destatis 2015, 2016, 2017, 2018)

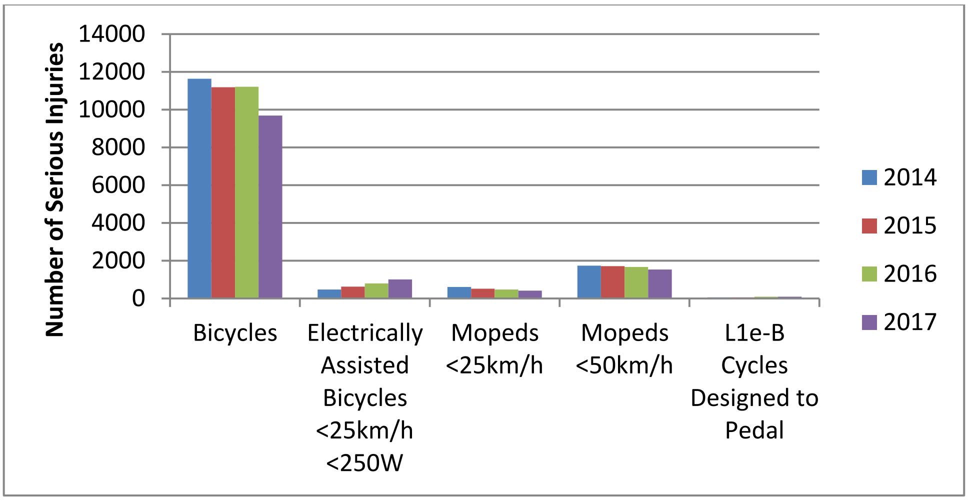

Figure 7.4: Numbers of serious injuries resulting from collisions reported to police in Germany in 2014-17. (Data from Destatis 2015, 2016, 2017, 2018)

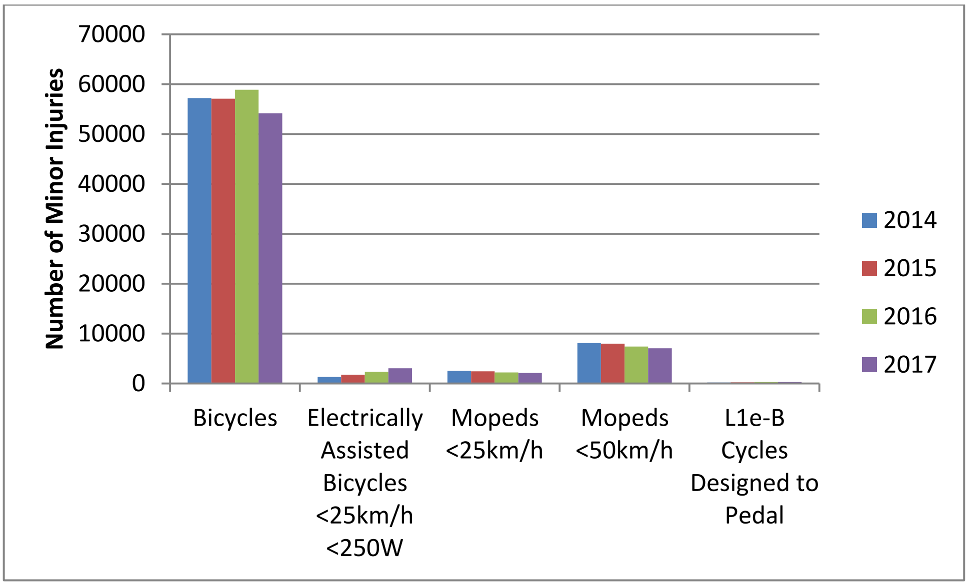

Figure 7.5: Numbers of minor injuries resulting from collisions reported to police in Germany in 2014-17. (Data from Destatis 2015, 2016, 2017, 2018)

CONEBI estimate that in total 3.85million bicycles were sold in Germany in 2017. Of those 720,000 were electrically assisted bicycles. It is estimated that between 0.5 and 1% were cycles designed to pedal in L1e-B (≈3,600 – 7,200). ACEM estimate that around 30,000 mopeds are registered each year in Germany.

Cycles designed to pedal in L1e-B are involved in a very small proportion (0.2 - 0.4%) of the total number of collisions involving two wheeled vehicles in Germany, which annually suffers over three hundred thousand such incidents, over a hundred thousand of which result in injury. They also represent a very small proportion of the collisions involving two wheeled vehicles that carry the German 'insurance plates', which suffered between 13,750 and 15,853 collisions per year during the period 2014-2017. However, the number of collisions involving cycles designed to pedal in L1e-B is rising while the overall number of collisions involving two-wheelers with insurance plates is falling. Collisions involving cycles designed to pedal in L1e-B are thus a growing proportion of the total number of collisions affecting this group, however that proportion was still only 3.5% of the total in 2017. This may of course simply be the effect of the growing proportion of the relatively new cycles designed to pedal in this group, rather than an indication that cycles designed to pedal are becoming inherently more dangerous.

While these data are interesting, they do not provide any insight into the causes of collisions involving cycles designed to pedal and thus do not help to resolve the question of whether the limitation of assistance factor affects the safety of these vehicles.

Table 7.1: Collisions involving German light two-wheeled vehicles. No data is available for vehicles in L1e-A. (Adapted from Destatis 2015, 2016, 2017, 2018)

	Year	2014	2015	2016	2017
Total Collisions	Bicycles	75,272	74,276	76,297	69,738
	Electrically Assisted Bicycles <25km/h <250W	1,860	2,478	3,307	4,277
	Mopeds <25km/h	3,244	3,065	2,767	2,601
	Mopeds <50km/h (<45km/h from 2017)	9,782	9,609	9,072	8,546
	Cycles Designed to Pedal in L1e-B	256	310	380	411
Fatalities	Bicycles	214	219	212	172
	Electrically Assisted Bicycles <25km/h <250W	16	17	39	41
	Mopeds <25km/h	18	13	12	12
	Mopeds <50km/h (<45km/h from 2017)	21	17	23	20
	Cycles Designed to Pedal in L1e-B	2	1	2	0
Serious Injuries	Bicycles	11,632	11,191	11,215	9,689
	Electrically Assisted Bicycles <25km/h <250W	474	632	801	1,008
	Mopeds <25km/h	615	516	478	415
	Mopeds <50km/h (<45km/h from 2017)	1,739	1,716	1,674	1,531
	Cycles Designed to Pedal in L1e-B	61	60	95	91
Minor Injuries	Bicycles	57,210	57,074	58,880	54,158
	Electrically Assisted Bicycles <25km/h <250W	1,317	1,750	2,327	3,054
	Mopeds <25km/h	2,535	2,442	2,192	2,102
	Mopeds <50km/h (<45km/h from 2017)	8,094	7,971	7,410	7,040
	Cycles Designed to Pedal in L1e-B	184	232	267	297

7.2 Belgian collision data

CONEBI estimate that Belgium had a total fleet of 4,700 cycles designed to pedal in L1e-B by the end of 2017. This compares to sales figures for 2017 of approximately 500,000 conventional bicycles and 218,000 electrically assisted bicycles with motors of less than 250W and assistance up to 25km/h. Data from ACEM indicates that annually around 10,000 mopeds are registered in Belgium.

The Belgian authorities started specifically categorising ‘speed pedelecs’, i.e. cycles designed to pedal in L1e-B, in their collision data in 2017. So far only one year of data has been published. The Belgian data (Table 7.2) shows a total of fifteen collisions involving cycles designed to pedal in L1e-B were reported to police in 2017. These collisions caused one death, two serious injuries and twelve minor injuries. This compares to over eight thousand collisions and fifty five deaths involving conventional bicycles, and over three thousand collisions and twenty two deaths involving mopeds. It would be unwise to draw too many conclusions from a single year’s data, particularly with such small numbers of collisions involving cycles designed to pedal in L1e-B. It is however notable that the numbers of collisions, injuries and fatalities are very similar for cycles designed to pedal in L1e-B and electrically assisted bicycles, despite the latter having a fleet size around a hundred times larger than the former. It is unclear whether that discrepancy is the result of the technical characteristics of the vehicles themselves, or the effect of national laws requiring cycles designed to pedal in L1e-B to be ridden on the road, rather than cycles paths, thus bringing them more often into conflict with road vehicles.

Table 7.2: Collisions involving light two wheelers reported to police in Belgium in 2017. No data is available for vehicles in L1e-A.

Data for 2017	Conventional Bicycles	Electrically Assisted Bicycles <250W, <25km/h	Mopeds Class A <25km/h	Mopeds Class B <45km/h	Cycles Designed to Pedal in L1e-B
Total Collisions	8,320	13	1,542	1,488	15
Fatalities	55	1	7	15	1
Serious Injuries	725	4	110	149	2
Minor Injuries	7,540	8	1,425	1,324	12

8 STAKEHOLDER ENGAGEMENT

TRL conducted a stakeholder mapping exercise to develop an understanding of the key interested parties in this area. Stakeholders from manufacturers, industry bodies, user groups and regulators were engaged and asked to provide technical assistance or opinion to help develop and advance this study.

8.1 List of stakeholders engaged for this study

- ACEM
- Bosch
- CERTH
- CONEBI
- ECF
- ETSC
- FEMA
- FIM
- KU Leuven
- LEVA
- Southampton University
- Stromer
- TUHH

Type approval authorities

- Great Britain
- Spain
- Germany
- Netherlands

8.2 EC Motorcycle Working Group

Dr Ianto Guy of TRL gave presentations to the EC Motorcycle Working Group on the 27th of November 2018 and the 19th of March 2019. In the first of these presentations he outlined the purpose of the study and requested input from stakeholders (Appendix 12.4). In the second presentation Dr Guy described the progress to date in the preparation of the study and made a further request for engagement from stakeholder (Appendix 12.5).

Dr Guy dealt with a range of questions and observations in the session in March. Several attendees at the meeting cautioned against broadening the scope of the current study beyond the specific question of the regulation of assistance factor in L1e-B.

The German representative observed that the assistance factor limit had been set to four to prevent riders of cycles designed to pedal from riding too quickly.

Ceri Woolsgrove of the European Cycling Federation observed that care should be exercised when seeking to use research conducted on deregulated (under 250W/under 25km/h) electrically assisted bicycles to draw conclusions about the safety of cycles designed to pedal in L1e-B.

8.3 Bosch/CONEBI

A teleconference was conducted with two representatives from Bosch and one representative from CONEBI on the 7th of March 2019.

Bosch explained that they felt that the regulation of assistance factor was important as a device for differentiating cycles designed to pedal from mopeds. They were not able to offer an opinion on the reasons why power rather than torque was regulated.

Bosch stated that they did not have any collision data for cycles designed to pedal.

Bosch explained that mounting the motor in the centre of the frame gave the best weight distribution for good handling and that centre mounting was easiest from a packaging point of view. They said that they were not aware of any cycles designed to pedal that drove the front wheel.

Bosch suggested that the 4kW maximum power limit was too high for cycles designed to pedal.

8.4 ACEM

A teleconference was conducted with three representatives from ACEM on the 15th of April 2019.

ACEM stated that they believed assistance factor had value as a method for differentiating cycles designed to pedal from other vehicles in L1e-B. They stated that they had no strong opinion of what the appropriate value for assistance factor should be.

ACEM suggested that bicycle manufacturers found type approval onerous because it was a system with which they were unfamiliar, but that should not be a reason to abandon it for cycles designed to pedal in L1e-B.

ACEM claimed that anecdotal evidence exists that people were buying deregulated (under 250W/under 25km/h) electrically assisted bicycles and hacking them to allow them to be ridden with assistance at powers and speeds that placed them within the realms of type approval.

ACEM believe that manufacturers of cycles designed to pedal in L1e-B are not using the full range of the 4kW maximum power allowance because of restrictions on cost, weight and battery life.

ACEM stated that law enforcement authorities were struggling to enforce current regulations due to the difficulty of distinguishing which bicycles were covered by type approval regulations as it is very difficult to distinguish one bicycle from another.

ACEM were asked why they thought assistance factor was defined in terms of power rather than torque. They explained that regulations commonly define performance using a power measurement and occasionally a power to weight ratio, but never using torque.

ACEM were asked whether they were aware of any research into the relationship between safety and assistance factor. They stated that they were not aware of any specific studies on that subject, but were aware of some studies on the general safety of electrically assisted bicycles and mopeds. They made the speculative remark that electrically assisted bicycles may be involved in collisions with cars because they look like bicycles but travel much faster.

ACEM stated that they hoped that the current study would be restricted specifically to issues around assistance factor and would not stray into other areas of regulation.

8.5 LEVA

LEVA provided a range of input in both written and verbal form over the course of this investigation.

LEVA is strongly opposed to the regulation of assistance factor for cycles designed to pedal in L1e-B. Their primary objections are that this regulation is unnecessarily restricting the scope for the development of electrically assisted bicycles and in the process unfairly disadvantaging riders who are either less fit or live in more mountainous areas.

They pointed out that there are very few organisations capable of conducting the tests required to measure assistance factor in cycles designed to pedal. To their knowledge these are:

- RDW
- TÜV SÜD
- TÜV Rheinland
- TÜV Taiwan
- Idiada, ES,
- TÜV Hungary

They suggested that test houses often struggle to interpret the Regulations correctly and may misunderstand the implications of failing to meet the requirement to limit assistance factor to a value of four.

9 Conclusions

No data were found that provide firm evidence that the regulation of assistance factor has any effect, either positive or negative, on the safety of cycles designed to pedal in L1e-B. The studies conducted so far, by Groß (2013) and Rotthier (2017), which specifically aimed to address the effect of assistance factor failed to provide definitive evidence to support or refute the idea that assistance factor has a direct effect on safety.

Groß (2013) and Rotthier (2017) demonstrated that the current assistance factor limit of four limits the cruising speed of cycles designed to pedal to significantly less than 45km/h for all but the fittest of riders. Stelling-Konczak et al. (2017) demonstrated that the average riding speed of cycles designed to pedal in L1e-B on roads with 50km/h speed limits was 32km/h.

The work conducted by Groß (2013) indicates that the design of the motor control algorithm may make a more important contribution to the safety of cycles designed to pedal in L1e-B than the regulation of assistance factor.

Assistance factor is viewed by many stakeholders as a convenient method for differentiating cycles designed to pedal from other vehicles in the L1e-B category, rather than a specific requirement for safety.

The process of measuring assistance factor as part of the type approval process is difficult for manufacturers to comply with because there are very few test houses with the equipment required to undertake the relevant tests or a full understanding of how the Regulations should be applied.

The highest level of assistance factor found in a cycle designed to pedal in L1e-B was 4. Manufacturers are not using the full range of motor power open to them in L1e-B. The most powerful motor found on a cycle designed to pedal in L1e-B was rated at 850W. The limitation of assistance factor by the legislation effectively imposes a limit on the maximum power of any motor fitted. The observed effect of this is that half of the cycles designed to pedal in L1e-B found for sale in the EU have motors with an output of less than 400W.

The numbers of cycles designed to pedal in L1e-B sold annually in the EU is only around 20-25,000 units or 1% of the two million strong electrically assisted bicycle market. Very few vehicles are being type approved in L1e-A. This seems to be because of the overlap between electrically assisted bicycles outside the scope of the EU type approval legislation and L1e-A. Manufacturers see no advantage in being able to use motors with more than 250W of output power when the maximum speed of the vehicle is restricted to 25km/h.

Data from Germany indicates that electrically assisted bicycles outside the scope of type approval are involved in ten times as many collisions as cycles designed to pedal type approved in L1e-B. The number of fatalities and injuries resulting from collisions involving electrically assisted bicycles outside the scope of the type approval legislation rose sharply between 2014 and 2017.

Data from Germany shows a growing number of collisions involving cycles designed to pedal in L1e-B. However this is to be expected as the size of the fleet of this type of vehicle grows. Data from Germany and Belgium suggests that cycles designed to pedal in L1e-B might be suffering a disproportionate number of collisions when compared to other electrically assisted bicycles and mopeds. However, extreme caution should be employed in interpreting these data as this apparent effect may simply be a statistical anomaly due to the small numbers of collisions involving these vehicles.

The scope of Regulation (EU) No 168/2013 does not cater for the many variants of electrically assisted bicycles and the possibilities that exist to modify those vehicles. This has had the effect of permitting vehicles that do not comply with either the spirit or letter of the Regulations to be sold legally but then operated illegally on the roads in the EU. These include retrofit systems, which allow conventional bicycles to be converted to electrical assistance effectively without any regulation of motor powers or assistance speeds, the modification of electrically assisted bicycles outside the scope of the Regulations to have electrical assistance at higher speeds or with higher motor powers, and off-road bicycles which are effectively unregulated.

10 RECOMMENDATIONS

Given the small numbers of cycles designed to pedal in L1e-B currently in the European fleet, it will inevitably take some time to build up a body of evidence from collision reports that would help to provide a scientific basis for this regulation. This also assumes that investigating authorities have the awareness of this issue and take note of it in their individual investigations. As a minimum national authorities should be encouraged to disaggregate collisions involving cycles designed to pedal in L1e-B in their annual collision statistics.

Given that cycles designed to pedal are intended to have a very different character to other vehicles in the L1e-B sub-category it would seem appropriate to separate them into a sub-category of their own. This could perhaps be achieved by extending the scope of the existing L1e-A sub-category, which currently contains very small numbers of vehicles. There is a substantial overlap between L1e-A and electrically assisted bicycles outside the scope of the type approval regulations. Both type approved and non-type approved electrically assisted bicycles are restricted to a maximum speed of 25km/h. The only practical implication of type approval in L1e-A is that the vehicles are permitted to have a 1kW, rather than 250W motor, thus permitting motors with much more torque to be fitted. This additional torque allowance only seems relevant to bicycles that carry cargo or other heavy loads. Analysis of the existing fleet of cycles designed to pedal in L1e-B indicates that all vehicles currently in production would be within the 1kW motor power limit applied in L1e-A. The L1e-A sub-category could perhaps be modified to include 'cargo-carrying' bicycles and 'high-speed electrically assisted bicycles', however the details of how those should be defined is outside the scope of this investigation.

Single vehicle accidents in which the rider loses control of the cycle and hits an obstacle, or loses stability and falls to the ground, form a large proportion of reported bicycle accidents. It is possible that the level of assistance factor could affect the stability and controllability of cycles designed to pedal, and thus affect the safety of the ride. Physical trials should be conducted to establish whether a causal link exists between assistance factor and stability and controllability.

The scope of the EU type-approval legislation could be adapted to take into consideration a number of issues such as the type approval of bicycles primarily intended for off-road use, the ready availability of retrofittable components that permit the creation of high power and high speed electrically assisted bicycles and the ease with which electrically assisted bicycles outside the scope of type approval regulations can be modified to increase their speeds and powers. An increase in market surveillance and auditing of law enforcement authorities should be conducted to quantify the number of non-type approved vehicles that are being operated in a manner that brings them within the scope of type approval legislation.

Given the limited maximum speed of cycles designed to pedal in L1e-B, consideration should be given to the appropriateness of national regulations that require cycles designed to pedal in L1e-B to use roads rather than purpose built cycle infrastructure. This perhaps requires a separate investigation to understand the potential conflicts that might arise from cycles designed to pedal being permitted to us cycle paths and cycles designed to pedal using roads.

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12 APPENDICES

12.1 List of types approved as cycles designed to pedal in L1e-B by KBA in Germany

Approval number	Manufacturer	Type	Type of drive	Pedal support	Maximum assistance factor
e1*168/2013*00069*00	Biketec AG	Upstreet5 Tiefeinstieg	Pure electric and hybrid electric propulsion and control	yes	2.39
e1*168/2013*00110*00	Biketec AG	Upstreet5 Trapez/Herren	Pure electric and hybrid electric propulsion and control	yes	2.39
e1*168/2013*00122*00	Derby Cycle Werke	S49	manpower-electric	yes	2.75
e1*168/2013*00126*00	Derby Cycle Werke	S63	manpower-electric	yes	3.2
e1*168/2013*00138*00	Diamant Fahrradwerke	SC	manpower-electric	yes	2.75
e1*168/2013*00139*00	Diamant Fahrradwerke	825+	manpower-electric	yes	2.75
e1*168/2013*00156*00	HNF GmbH	XD2	manpower-electric	yes	2.75
e1*168/2013*00137*00	Kreidler Europe	SP	manpower-electric	yes	3.2
e1*168/2013*00072*00	M1-Sporttechnik GmbH & Co. KG	Zell	manpower-electric	yes	3.2

e1*168/2013*00073*00	Riese und Müller	ChargerB2	manpower-electric	yes	2.8
e1*168/2013*00074*00	Riese und Müller	CruiserB1	manpower-electric	yes	2.8
e1*168/2013*00075*00	Riese und Müller	DeliteB2	manpower-electric	yes	2.8
e1*168/2013*00076*00	Riese und Müller	HomageB2	manpower-electric	yes	2.8
e1*168/2013*00077*00	Riese und Müller	LoadB1	manpower-electric	yes	2.8
e1*168/2013*00078*00	Riese und Müller	NevoB1	manpower-electric	yes	2.8
e1*168/2013*00079*00	Riese und Müller	L1e, L1e-B	manpower-electric	yes	2.8
e1*168/2013*00080*00	Riese und Müller	PonyB1	manpower-electric	yes	2.8
e1*168/2013*00143*00	Riese und Müller	RoadsterB2	manpower-electric	yes	2.8
e1*168/2013*00144*00	Riese und Müller	NevoB2	manpower-electric	yes	2.8
e1*168/2013*00116*00	Riese und Müller	HomageB3	manpower-electric	yes	2.8
e1*168/2013*00085*00	Rijwielh. Gebr. Van den Berghe	S-Pedelec	manpower-electric	yes	2.75
e1*168/2013*00054*00	STEVENS Vertriebs GmbH	E-Triton 45	manpower-electric	yes	2.75
e1*168/2013*00089*00	Winora-Staiger GmbH	SDURO Trekking Y	manpower-electric	yes	2.8
e1*168/2013*00090*00	Winora-Staiger GmbH	SDURO Trekking B	manpower-electric	yes	2.8
e1*168/2013*00095*00	ZEG Zweirad-	G18	manpower-electric	yes	3.3

	Einkaufs-Gen. eG				
e1*168/2013*00096*00	ZEG Zweirad-Einkaufs-Gen. eG	G19	Pure electric and hybrid electric propulsion and control	yes	3.3
e1*168/2013*00097*00	ZEG Zweirad-Einkaufs-Gen. eG	G20	manpower-electric	yes	2.75
e1*168/2013*00098*00	ZEG Zweirad-Einkaufs-Gen. eG	H08	manpower-electric	yes	2.75

12.2 List of types approved as cycles designed to pedal in L1e-B in the ETAES database, provided by RDW

Type Approval Number	Maximum Assistance Factor		Type Approval Number	Maximum Assistance Factor
e1*168/2013*00072*00	2.8		e1*168/2013*00109*01	3.2
e1*168/2013*00072*01	2.8		e1*168/2013*00111*00	2.39
e1*168/2013*00072*02	3.2		e1*168/2013*00116*00	2.75
e1*168/2013*00073*00	2.8		e1*168/2013*00140*00	2.75
e1*168/2013*00073*01	2.8		e1*168/2013*00143*00	2.8
e1*168/2013*00073*02	3.2		e1*168/2013*00144*00	2.8
e1*168/2013*00074*00	2.8		e1*168/2013*00157*00	3.2
e1*168/2013*00074*01	2.8		e1*168/2013*00161*00	3.2
e1*168/2013*00076*01	2.8		e13*168/2013*00029*00	3.27
e1*168/2013*00076*02	3.2		e13*168/2013*00085*00	2.4
e1*168/2013*00077*00	2.8		e13*168/2013*00085*01	2.4
e1*168/2013*00077*01	3.2		e13*168/2013*00085*02	2.4
e1*168/2013*00078*00	2.8		e13*168/2013*00181*00	3.2
e1*168/2013*00078*01	3.2		e13*168/2013*00282*00	2.8
e1*168/2013*00079*00	2.8		e13*168/2013*00282*01	2.8
e1*168/2013*00079*01	3.2		e13*168/2013*00283*00	2.9

e1*168/2013*00080*00	2.8		e13*168/2013*00387*00	0.9
e1*168/2013*00080*01	3.2		e13*168/2013*00387*01	0.9
e1*168/2013*00082*00	2.75		e13*168/2013*00425*00	3.2
e1*168/2013*00082*01	3.2		e13*168/2013*00425*01	3.2
e1*168/2013*00085*00	2.75		e13*168/2013*00480*00	4
e1*168/2013*00090*00	4		e13*168/2013*00480*01	4
e1*168/2013*00095*00	3.3		e13*168/2013*00480*02	4
e1*168/2013*00096*00	3.3		e13*168/2013*00545*00	2.5
e1*168/2013*00097*00	2.75		e13*168/2013*00585*00	1
e1*168/2013*00098*00	2.75		e4*168/2013*00026*00	3.28
e1*168/2013*00105*00	2.75		e4*168/2013*00072*00	2.75
e1*168/2013*00108*00	2.39		e9*168/2013*11371*00	2.8
e1*168/2013*00109*00	2			

12.3 List of types with assistance speeds above 25km/h found for sale in the EU

Make	Model	Motor power	Assistance factor (if available)	Configuration (front wheel/rear wheel/central drive etc.)	Mass (kg)	Control method (throttle/activated by pedalling etc.)
BATAVUS	*Razer Turbo E-go®*	250W(500W?) 70Nm	HIGH: 280% STD: 190% ECO: 100% +ECO: 50% 4 assistance levels	Yamaha PW-System central-crank (mid-engine)	22.5kg without battery +2.8kg battery	activated by pedalling (Sensors: pedalling force, speed & rotation)
BATAVUS	*Wayz E-go Deluxe*	7-speed battery and motor not specified, 60 Nm engine capacity		E-Motion Performance motor, central-crank (mid-engine)	22.4+3.5	activated by pedalling (Sensors: pedalling force, speed & rotation)
Riese&Muller	*Supercharger GT touring HS*	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine		activated by pedalling (Sensors: pedalling force, speed & rotation)
Riese&Muller	*Nevo touring HS*	350W		Bosch Drive Unit Performance Speed, mid-engine		activated by pedalling (Sensors: pedalling force, speed & rotation)
Riese&Muller	*Delite GT touring HS - 2x500WH battery*	350W		Bosch Drive Unit Performance Speed, mid-		activated by pedalling (Sensors: pedalling force, speed &

				engine		rotation)
Giant	*Quick-E+45km/h*	250W, 80Nm		Giant SyncDrive Sport powered by Yamaha, mid-engine	21.8	Throttle/pedalling
Hercules	*Futura 45*	370W		Bosch Drive Unit Performance Speed, mid-engine	27.2	activated by pedalling
Specialized	*Turbo Vado 5.0*	250W nominal	320%	MOTOR Specialized 1.3, custom Rx Street-tuned motor, rear wheel driven	25.2	activated by pedalling
Stromer	*ST3*	820W	Bicycle mode (the motos is off), support mode 1, 2 and 3	Syno Drive II, rear-wheel driven		activated by -/+ buttons on the screen / activated by pedalling
Stromer	*ST2/ST2S*	500W		rear wheel driven	27	
Stromer	*ST5/ST1X*	850W /800W		rear wheel driven	30.2	
Gazelle	*SpeedZen 380*	350W		central-crank (mid-engine)	22.5kg	activated by pedalling
QWIC	*RD11*		Off, tour, eco, sport	rear-wheel driven	26.0kg	activated by pedalling
QWIC	*MA11*		Off, tour, eco, sport	mid-engine, Shimano		
QWIC	*MD11*		Off, tour, eco, sport	rear-wheel driven		

QWIC	*RD10S PERFORMANCE*	500W	Off, tour, eco, sport	rear wheel driven	26.4	
Klever	*B-Speed*	600W		Rear wheel drive Klever BIACTRON V2	28.5	Max throttle speed 18 km / h
Klever	*X Speed*	500W		rear wheel Klever BIACTRON V2	27kg	max throttle speed 4km/h, pedalling
Bulls	*Green Mover E45*	500W		rear wheel SR Suntour	29.6	activated by pedalling
Kalkhoff	*Endeavour Impulse S10 XT*	350W		Middle engine with Shift-Sensor technology		activated by pedalling
TREK	*XM700+ Lowstep*	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine	21.9	activated by pedalling (Sensors: pedalling force, speed & rotation)
Victoria	eSpezial 10.7	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine	23	activated by pedalling (Sensors: pedalling force, speed & rotation)
BH	*BH E-motion Cross*	500W		rear wheel		
i:SY	*i:SY electric folding bike*	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine		

Releight		350W	eco - sport - power - ultra	mid-engine, Impulse Evo Speed		Walk function: <6 km / h,
WINROA	Winora 500Wh 45 km / h	500W		Drive unitYamaha PW-System		
Oxford	Oxford S-Pedelecs	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine		
eFlow	ER5	500W		rear-wheel driven	24.5	
FLYER	U-Series	250W		Panasonic, (2-powers) mid-engine	22.0 excluding battery	
Trek	Pull Super/ Pull Super Commuter 8S +	350W	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosch Drive Unit Performance Speed, mid-engine		
Koga	Koga E Xlr8 2016	500W, 60Nm	TURBO: 275% SPORT: 190% TOUR: 120% ECO: 55%	Bosh Drive Unit Performance Cruise	22.7	

12.4 Presentation to the EC Motorcycle Working Group 27/11/18

Introduction

- TRL have been asked by the European Commission to investigate whether the assistance factor[1] affects the safety of cycles designed to pedal in the L1e-B sub category.
- Currently, under Commission Delegate Regulation (EU) No3/2014, the ratio is limited to four, i.e. the electric motor can provide no more than four times the power generated by the rider.

1. The ratio of power provided by the electric motor to power provided by the rider

Objectives

1. Determine the nature, cause and severity of typical collisions involving speed pedelecs
2. Determine whether evidence exists to suggest that the level of assistance factor could play a role in these typical collisions
3. Determine whether evidence exists to suggest that other powertrain features, e.g. the choice of driven wheel, could interact with assistance factor, to affect these typical collisions
4. Make recommendations to the Commission regarding priorities for future legislation in this area
5. Make recommendations to the Commission regarding future work required in this area to enhance the evidence base for legislation

Methodology

1. Study of collisions involving speed pedelecs
2. Review of literature relating to assistance factor
3. Stakeholder engagement

1. Study of collisions involving speed pedelecs

- Determination of the nature, cause and severity of **typical** collisions involving speed pedelecs
  - Gather a body of anecdotal evidence to illustrate the phenomenon of speed pedelec collisions.
  - Present a series of collision examples to illustrate the nature, cause and severity of collisions involving speed pedelecs.

1. Study of collisions involving speed pedelecs

- Determination of the frequency of collisions involving speed pedelecs
  - TRL will also use national and international collision databases and previous academic studies to attempt to quantify the number and severity of collisions involving speed pedelecs.
  - It is unlikely that a sufficient body of accident data will be available to permit statistically significant conclusions to be drawn regarding that specific group of cycles
  - Data will be presented to illustrate the frequency with which collisions occur, but not to attempt to draw conclusions regarding their underlying causes.

2. Review of literature relating to assistance factor

- The effect of the use of electrically assisted bicycles on road safety has been a topic of scholarly research for some years.
- The bulk of that research has concentrated on the differences between conventional bicycles and those with electrical assistance.
- Very few studies have examined the effects of differences in particular design features between different makes or models of electrically assisted bicycles.
- We are aware of studies by Eric Groß at TUHH and Bram Rotthier at KU Leuven that specifically address the effect of assistance factor on safety of this sub-category of e-bike.
- We would be very interested to hear from anybody else who has conducted work in this field.

3. Stakeholder engagement

- Stakeholders will be engaged to provide:
  - an overview of current design philosophy of speed pedelecs
    - e.g. the choice of assistance factor, powertrain configuration and control methodology
  - current usage profiles
    - e.g. types of journeys undertaken, rider's age and gender, whether journeys are conducted on cycle paths or highways
  - any issues encountered while riding
    - e.g. collisions or incidents, interactions with other road users;
  - perceptions of the effects of assistance factor on safety
    - e.g. issues with controllability or stability encountered while riding.

3. Stakeholder engagement

- We will conduct a stakeholder mapping exercise to identify key stakeholders
- We would also like interested stakeholders to contact us to express their interest in supporting the project
- We will engage with stakeholders via e-mails and online meetings and workshops in the first half of 2019

Summary

- TRL will conduct an investigation into the effect of assistance factor on the safety of speed pedelecs in sub-category L1e-B
- This project will last 6 months
- We require your input to our stakeholder engagement exercise
- We would also like to hear from anybody who has any research in the area of assistance factor and safety


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12.5 Presentation to the EC Motorcycle Working Group 19/03/19

Introduction

- TRL have been asked by the European Commission to investigate whether the assistance factor[1] affects the safety of cycles designed to pedal in the L1e-B sub category.
- Currently, under Commission Delegate Regulation (EU) No3/2014, the ratio is limited to four, i.e. the electric motor can provide no more than four times the power generated by the rider.

1. The ratio of power provided by the electric motor to power provided by the rider

Objectives

1. Determine the nature, cause and severity of typical collisions involving speed pedelecs
2. Determine whether evidence exists to suggest that the level of assistance factor could play a role in these typical collisions
3. Determine whether evidence exists to suggest that other powertrain features, e.g. the choice of driven wheel, could interact with assistance factor, to affect these typical collisions
4. Make recommendations to the Commission regarding priorities for future legislation in this area
5. Make recommendations to the Commission regarding future work required in this area to enhance the evidence base for legislation

Methodology

1. Study of collisions involving speed pedelecs
2. Review of literature relating to assistance factor
3. Stakeholder engagement

Initial findings

- Cycles designed to pedal in category L1e-B represent a tiny proportion of the overall pedal cycle fleet in the EU.
  - CONEBI note that overall sales of pedal cycles in the EU in 2017 = 20.6million units.
  - Of these around 2million were electrically assisted pedal cycles
  - CONEBI estimate that only around 20-25,000 of those would be classed as speed pedelecs i.e. type approved in L1e (A or B)
  - Market analysis by TRL indicates that only around 30 types approved in category L1e-B are on sale in the EU
- The types available for sale do not make use of the 4kW power allowance available in L1e-B
  - The highest powered speed pedelec found has an 850W motor
  - Half the types on sale have motors of less than 400W power output
- Manufacturers do not seem to be using assistance factor as a marketing tool – of those that quantify it in their marketing material the highest found claimed a maximum assistance factor of 3.2
- All of the speed pedelecs on sale use either centre drive or rear wheel drive – none drive the front wheel

Initial findings

- So far no definitive evidence has been found to support the notion that the level of assistance factor provided by a pedelec affects the safety of the vehicle in either a positive or negative way.
- Evidence from literature suggests that differences in accident rates and severities between e-bikes (of all types) and conventional bicycles are due to differences in the demographics of the users (e-bike riders tending to be older and suffering from more co-morbidities) and the level of exposure due to the distances travelled.
- The requirements applicable to L1e-A and L1e-B categories do not make them attractive to manufacturers and users.
- The regulation of assistance factor is regarded as being important in differentiating pedelecs from mopeds but not in influencing the safety of the machine.
- From a safety perspective the most important implications of differentiating 'cycles designed to pedal' from the rest of the vehicles in L1e-B is their maximum mass is limited to 35kg
- The current assistance factor test method fails to address the most common accident type, which occur at low speed

On-going stakeholder engagement

- We are still seeking engagement from stakeholders, in particular we would like to hear from:
  - User groups with experience of speed pedelecs
  - Victims of collisions involving speed pedelecs
  - Engineers involved in the design and testing of speed pedelecs
  - Those with experience of the type approval and registration process for L1e-Bs
- We would like your views on
  - The effectiveness of regulating assistance factor with respect to safety
  - Alternative methods by which 'cycles designed to pedal' could be differentiated from mopeds
  - The level of regulation that is appropriate for this category of vehicle

Questions?

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ET-01-19-664-EN-N

Publications Office

doi:10.2873/085443