Powered Light Vehicles:
Challenges and Opportunities for Low Carbon L-Category Vehicles in the UK

Module Three: Regulation of L-Category Powered Light Vehicles

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Micro Vehicles Module Three

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Project Brief:

The L-Category vehicle sector has been identified as offering economic, environmental and societal benefits. However, the UK currently lags behind other countries in exploiting the advantages of this transport sector. Following a LowCVP seminar and workshop on the subject, it was agreed that further work would be worthwhile, to explore L-Category vehicles' potential in greater detail. The primary focus was to be around the larger three and four-wheeled L-Category vehicles, dubbed **Powered Light Vehicles (PLVs)**, as Powered Two-Wheelers (PTWs), such as motorbikes and mopeds, are already established markets in the UK.

A consortium of specialists from seven UK universities have come together to produce a series of reports, pro bono, in conjunction with the LowCVP's Innovation Working Group and including input from stakeholders to ensure relevance.

These reports are not intended as an end in themselves, but instead to act as a spur to action: to build the UK's capability in ultra-light automotive engineering and to provide conditions which support the market for micro vehicle uptake.

For more information about the LowCVP and the Partnership's work on Powered Light Vehicles visit:

LowCVP.org.uk/PLV

Regulation of the L-category Powered Light Vehicle sector and opportunities for UK

Regulation of the automobile has developed from a concern for the safety of road users as well as a concern for the protection of the (human) environment. In the development and application of regulation, different responses have evolved dependent on the region. This is due to historical differences in producer and consumer preferences as well as the role of government and industry practices. From an economic perspective an appropriate regulatory process is one in which regulations themselves are clear, who must meet them is clear, and industry accepts the regulations and begins innovating to address them, rather than spending years attempting to delay or relax them (*Porter and Linder, 1996*). Taking the lead in imposing new regulatory frameworks may give rise to competitive advantages if later on the respective frameworks diffuse to other markets. In this case, companies operating in the early regulating country may gain early mover advantages in the respective technology. This chapter discusses the development of regulation as applied to the automobile (and motorcycle) with the purpose of highlighting the key problems associated with, and the economic opportunities resulting from, regulation of the lightweight vehicle sector.

3.1 Background

The majority of the regulation applied to the automobile has been in direct response to problematic conditions. For example, the fatalities, injuries, and property damage associated with automobile accidents are the problems that animate regulation. The accidents that give rise to these problems in turn arise from a myriad of causes such as driver error, road conditions, and mechanical failure. Regulation takes aim at these various causes of accidents by imposing requirements for driver training, vehicle operation, and engineering design. The policy development that drives regulation is therefore primarily evidence based. Furthermore, the most wide-reaching evolution in regulation has been experienced in the vehicles themselves. The world forum for harmonization of vehicle regulations is tasked with creating a uniform system of regulations for vehicle design to facilitate international trade. When approving the vehicle for operation on the road, each vehicle must meet all the technical requirements established by the appropriate regulatory acts. The infrastructure and the drivers' behaviour have been more difficult to regulate on an international stage since the member state (EU) and state (US) is seen as the body to legislate on these issues.

For vehicle safety, the outcome is that in the U.S., manufacturers must self-certify that they are meeting federal motor vehicle safety standards (FMVSS). Government agencies then select samples for testing to ensure compliance. Whilst in Europe, on the other hand, vehicles must obtain “type approval” from a government or government-approved agency before an automaker can bring out a new model. As a result, statistics show that cars have become increasingly (crash) safe during the last few decades, driven by a 30-year effort of sustained research, industry innovation, applied legislation, and consumer awareness initiatives. The latest passenger cars on the market in the US, Europe, and Japan are safer than ever before through the development of technologies promoting crash protection (air bags, crumple zones, intelligent seat belts systems etc.) and new crash avoidance systems (ABS, electronic stability control etc.). It must also be noted that the vehicle manufacturers had a determining impact in the launching, the extension and the success of the type-approval method, which allowed them to achieve economies of scale and made the European automotive industry more competitive.

For environmental protection, the concern about the impact of motorized vehicles has centred around five general issues: emissions, energy consumption, noise, congestion and land use. All of these have been subject to regulatory and legislative control somewhere in the second half of the 20th century, however most of the debate and regulation has focused on toxic emissions of carbon monoxide (CO), oxides of nitrogen (NOx), various hydrocarbons (HC) and particulates (PM). Whilst US and EU rules address a similar range of pollutants, including carbon monoxide, nitrogen oxides, and non-methane organic oxides, allowable emissions levels in the EU are different from those in the United States. However, they are stricter in more than a dozen U.S. states that follow California Air Resources Board (CARB) standards than in the other states that follow Federal standards. The United States and the EU have similar “type approval” systems for new engine models. Additionally, in the US, the government has also legislated for fuel efficiency; its Corporate Average Fuel Economy (CAFE) standard was introduced in 1978 in response to the 1973/4 energy crisis and it set a maximum average fuel economy figure for all cars and later also light trucks, sold by a manufacturer during a given year. There were penalties for non-compliance, although credits were tradable among manufacturers and importers. The EU does not directly set fuel economy standards, but it effectively does so by regulating carbon dioxide emissions of new vehicles in combination with high fuel excise duty. Within Europe, the result is that despite a significant increase in fuel use over the period 1990–2006, road transport emissions of carbon monoxide (CO), nitrogen oxides (NOx) and fine particulate matter have reduced by between 40 and 60 % compared to a no-policy scenario (*EEA, 2011*).

3.2 Defining Lightweight Vehicles for Regulatory Purposes

The policy development that drives regulation is primarily evidence based. This presents a number of problems when discussing lightweight vehicles. The first is that there is a paucity of evidence upon which to base policy. The second is the variation in vehicles types that exist in different regions due to regulatory frameworks. Globally, the lack of a clear definition for a lightweight vehicle makes it difficult to disaggregate data, identify problem areas and apply solutions. In various regions there are some limitations on the size, weight or power of the vehicles to categorize them as ‘lightweight’. However, the approaches are different.

A suitable lightweight car-classification is considered to be the European L- category, which has limitations in terms of weight, power and speed. These categories classify vehicles for regulatory purposes. Another relevant classification is the Japanese minicar (commonly referred to as ‘Kei’ car) and latterly micro-mobility. The Japanese market has long featured this ‘Kei’ car segment although the precise definition has been subject to fine-tuning over the years. Vehicles in this segment currently have a maximum length of 3.4m, a maximum width of 1.48m and a maximum height of 2m. Maximum engine capacity is 660cc and there is no limitation in terms of vehicle weight asides from a maximum payload of 360kg. In return they enjoy a favourable regulatory regime. Kei cars tend to be exempt from the expensive urban parking permit requirement, for example, although many Japanese do not regard them as ‘proper’ cars and tend to avoid them. In 2011, according to survey figures provided by The Japan Mini Vehicles Association the proportion of Japanese households owning Kei cars passed 60 percent for the first time since the survey began in 1986 (*Green Car Reports, 2011*).

The South Korean government also adopted a minicar policy during the 1990s. Here the principal driver was social equity and access to cars in the then newly-motorising nation. Korean regulation differentiated their minicars from the Japanese Kei model to avoid imports from Japan and promote indigenous designs; this has also helped make them more appealing in Europe. Korean minicars have a maximum engine capacity of 800cc and are slightly larger than Kei cars. Korean manufacturers fearing small profits resisted the introduction of minicars, but several have been successful with these products worldwide. Daewoo’s (subsequently Chevrolet) Matiz is an example.

In the United States, the equivalent vehicle category is Low Speed Vehicles (LSV, see below). For this classification the maximum speed is limited as well as maximum permissible weight.

3.2.1 Case Study: US NEV and LSV

A potentially useful precedent for developing new vehicle categories for environmental optimisation is the story of the "Neighborhood Electric Vehicle" (NEV) in the USA. EV advocates such as Riley (1994) and Sperling (1996) had long been promoting the idea of introducing new regulatory regimes for environmentally optimised vehicles of various kinds, particularly small, lightweight, often electric vehicles. Similarly, grass-roots initiatives in various communities in the US put pressure on regulators to accommodate such vehicles even though they fell outside the scope of existing legislation. Among the latter, we should mention the pioneering work done in the city of Palm Desert, California, where special provision was made to allow golf buggies to use certain roads. At the time, existing legislation only permitted golf carts on roads with a speed limit of no more than 26mph within 1.6 miles from a golf course. At the behest of Palm Desert, the Attorney General for California produced an opinion in 1992 allowing golf carts on any road with a speed limit of no more than 26mph (*Sperling, 1996*). Based on this, Palm Desert introduced a pilot programme to test the feasibility of golf buggies as a local transport mode. As part of this initiative, golf carts were allowed in mixed traffic on 26 mph roads, in dedicated lanes on faster roads and on newly created paths separate from other traffic. Based on such experiments, the NEV concept gained traction and when car manufacturers argued, successfully, some years later that such vehicles should be allowed to count as ZEVs under the California ZEV Mandate, they gained more mainstream support. Of course, the car manufacturers saw a cheap way of gaining ZEV credits, but the industry that made NEVs also benefitted, as did user groups.

In response to such developments, NEVs came to be classified as Low-speed Vehicles (LSVs) in the US from 1998 under Federal Motor Vehicle Standard (FMVSS) 600. Under this, they are defined as a 4-wheeled vehicle with a GVW of no more than 1400kg, with a top speed of between 20 and 26mph (32-40kph). In addition, individual states can add their own provisions and usually restrict them to roads with a speed limit of either 36 or 46mph. Such vehicles are subject to specific safety standards which are limited to: three-point seat belts or lap belt, daytime running lights, headlights, brake lights, reflectors, rear view mirrors and indicators. These are items that are not needed on a golf cart and these provisions therefore created a new and separate category of vehicle. They are exempt from crash and emissions standards that apply to cars or trucks. Although IC engines are possible, it is generally assumed such vehicles use a BEV powertrain and the exemption from emissions standards should not be an issue.

FIGURE 3.2.1: GEM E2 (licensed under CC BY-SA)

Most states allow such vehicles (currently 46 out of 50), although some add further restrictions to the federal standards outlined above. Thus New York requires some additional equipment reflecting their climate, such as windscreen wipers, some form of windscreen defrosting system, a speedometer, odometer and reversing light. In most states, conforming vehicles can be registered, and the driver must have a valid driver's license. Following the example set by Palm Desert, other towns and some communities and neighbourhoods have made special provision to promote the use of NEVs/LSVs; these include Celebration and The Villages in Florida; Peachtree City, Georgia; Alameda, Lincoln, Coronado and Playa Vista in California; Put-in-Bay, Ohio, as well as Leaf Rapids in Manitoba, Canada.

This is therefore a good example of how a combination of grass-roots initiatives, local authority pressure and input from industry can bring about a new vehicle category that is optimized from an environmental perspective, perhaps in line with the concept of Socio-technical transitions (*Geels et al. 2012*). Currently, moves are underway to capture 3-wheeled vehicles under similar regulation. This is driven by Louisiana Governor David Vitter who is keen to support local 3-wheeler commuter vehicle manufacturer Elio Motors, which has taken over GM's old facility at Shreveport and – if a market materializes – could potentially provide employment for many of the staff made redundant by the closure of the GM factory. A Three-Wheeler Vehicle Working Group (3WVWG) has been set up under the aegis of the American Association of Motor Vehicle Administrators (AAMVA). It is likely any regulation will follow a different approach from the European L6 category.

3.2.2 Case Study: France VSP

Within the EU, for many years developments in the lightweight vehicle segment were led by France, which in recent years has operated a system of 'light' and 'heavy' quadricycles. The 'light' quadricycles are known locally as 'voiturettes' or 'VSP' (*voitures sans permis*), as these can often be driven without a driver's license. In the past this has allowed certain user categories to be specifically drawn into the use of the VSP, such as the elderly, particularly in rural areas, who either never passed a driving test, or lost their license in old age. These people are then able to retain their independent mobility through the use of a VSP, which is equivalent to an L6e vehicle. In the past, 16-year olds could also drive a VSP without license, allowing them automobility before the legal car driving age. The final category was car drivers who had lost their license, because of, say, drunk driving, but who could still drive a VSP; in fact, some insurance companies offered insurance to drivers to cover such a risk.

FIGURE 3.2.2 AIXAM COUPE GTI
(source: www.aixam.com/en/licence-free-car-coupe/gti)

This situation is gradually changing, as France is aligning its regulation with broader developments in the EU. A major change came on 19 January 2013 with the introduction of the 'Permis AM', a new class of driver's license for drivers of L6-category vehicles in France (for L7 a full car driver's license is needed). This is now compulsory for all people born after 1 January 1988 and on a rolling basis will therefore eventually cover the entire population. This license has official status and is issued by the local prefecture after 7 hours of driver training to people from the age of 14. While there is no exam, the training – combining theoretical and practical elements – is compulsory and has to be signed off by an approved driving school. Where the training is carried out using a powered 2-wheeler, this gives eligibility to drive a 'light' quadricycle (L6) as well as a 3-wheeled vehicle, although where the training is carried out in a VSP, the license extends only to a 3-wheeler, not a 2-wheeler (*GSP, 2016*). The new license in then valid for 16 years, but as it has official status, where a car driver loses his or her license, the eligibility to drive a VSP is now also lost, thereby reducing that segment of the market, albeit on a gradual, rolling basis as the population entitled to this gets older. The impact of the AM License on the market in France is not yet clear and, in any case, would be gradual. The extension of the age group back down to 14 could make a difference, as some parents in France prefer to see their 14 and 16-year olds in a quadricycle rather than on a scooter or moped and are encouraging them to take the training, despite the high cost of quadricycles. Others, as is the case in the UK, increasingly drive their teenagers themselves to where they need to go (*GSP, 2016*).

3.3 Regulatory Convergence in the Lightweight Vehicle Sector

Environmental pressures are forcing us to reconsider our transport options. Global emission targets and high fuel costs are two motives for car manufacturers to reduce vehicle weight. Therefore, there is an emerging requirement – driven by environmental targets, increasing urbanization and resource scarcity – to downsize personal transport. This dictates that new modes of transportation need to arise and that the functional expectations of cars should adapt accordingly. It is also an argument for electro-mobility, as these ultra-light vehicles can cover longer distances with the same battery capacity. Commensurately, expansion of the vehicle fleet within the lightweight vehicle sector can be expected.

At present, and as a consequence of the divergence in the classification of lightweight vehicles across nations, technical standards for these vehicles are non-homogeneous. This has not been an issue whilst the lightweight category vehicle industry tends to be national and the further economies of scale from uniformity in regulatory frameworks would not necessarily be realised. However, with the expectation of the vehicle fleet to grow, the existing system of national approvals has the potential to negatively influence the industry, because approving at a national level (potentially to different country specific requirements) may inhibit the market and would ultimately increase the costs to manufactures and consumers. Furthermore, the increasing popularity of these vehicles gives cause for concern, as it is acknowledged that the regulation in the areas of crash safety and environmental protection is not at the same level for these lightweight vehicles as for passenger cars.

Within the EU there has already been the beginning of a movement towards pan-European regulation of the L-category sector. Building on earlier EU attempts to standardize rules across member states – most notably 2002/24/EC – the recent Regulation 168/2013 establishes the detailed technical requirements and test procedures regarding environmental and propulsion unit performance for the approval of L-category vehicles and the systems, components and separate technical units intended for such vehicles. This regulation repeals 2002/24/EC and 14 other Directives on 1 January 2016. As of this date, it is only possible to grant a new whole vehicle type approval according to (EU) 168/2013 for the vehicle categories L3e, L4e, L6e and L7e. Whole vehicle type approvals granted under Regulation (EU) 2002/24 are to remain valid until 1st January 2017.

Although regulation 168/2013 is a move in the right direction, there remain fundamental differences between the regulation of lightweight vehicles and the regulation of passenger cars. One of the main concerns arising from the promotion of vehicles with a reduced size and weight is the potential dangers to occupants in the event of a collision. Also, vulnerable road users would increasingly come into conflict with these vehicles – especially as these types of vehicles would be primarily used in heavily congested urban centres with high levels of pedestrian traffic and cyclists. At present, a significant proportion of the on-road injuries and casualties are borne by pedestrians and cyclists. As presently structured, Regulation 168/2013 does not demand crash tests or homologations as applied to passenger cars in the M1 class and defined by the relevant UN-ECE regulations. Further to this, with an increase in the share of L-category vehicles another objective has to be to keep constant or reduce the share of total road-transport emissions from L-category vehicles as compared to other road vehicle categories. Regulation 168/2013, although specifying emissions standards for L-category vehicles together with implementation dates, is not as strict as the regulations currently applied to passenger cars.

3.4 Safety Regulations of L-Category Vehicles in the EU

The safety regulations applicable to vehicles can be divided into device and component (the functional safety) standards and collision (the crash safety) standards. Device and component standards dictate the minimal safety devices, which must be installed into a vehicle for it to be considered road-worthy. Collision standards specify the protection that a vehicle must give to its occupants or vulnerable road users in the event of a crash.

As presented, Regulation 168/2013 primarily consolidates current type-approval requirements regarding the functional safety of L-category vehicles.

Whilst there are concerns regarding the crash safety provision of L-category vehicles, there is no problematic condition as such. Although not all countries collect figures for quadricycles (e.g. Germany), available data suggest that there are around 320,000 quadricycles on European roads, with only about 20,000 new quadricycles sold each year, primarily in France where 10,704 were sold in 2016 (*EQuaL, 2016*). When this is compared to the 13 million new M1 vehicles (*ACEA, 2016*) and 800,000 million new motorbikes and 400,000 new mopeds, (*ACEM, 2016*) the quadricycle population is therefore relatively small. Due to the relative low volumes of quadricycles in European countries the accident statistics information for quadricycles is limited. Based on the available accident data, figures compiled by the UK Transport Research Laboratory for Austria, France and UK show that whilst there was a higher indicated fatality risk (between 10 and 14 times that of passenger car occupants), the data was ambiguous in identifying problems as the data was not disaggregated by quadricycle type, making the safety risk of different types of quadricycle difficult to determine (*TRL CPR383*). Based on accident data alone, the question is whether these vehicles require legislating at a European level, or whether national or local solutions are more appropriate (see US NEV case study above).

If the numbers of powered lightweight vehicles in the fleet were to increase in response to environmental pressures, then the higher fatality risk combined with greater intensity of use would undoubtedly refocus concerns on their crashworthiness. As an example, a study based on French accident data calculated the mortality rate for different vehicle mass categories in vehicle-to-vehicle accidents. The study clearly showed an increased mortality rate for the occupants of lighter vehicles, with a mortality rate for lighter vehicles almost double that of heavier vehicles (*Adalian, 1998*). In response, a proposal maybe for the L-category vehicle class to adopt the current testing regime developed for M1 passenger cars. However, the application of the M1 passenger car testing regime to the L-category vehicles may prove less than satisfactory.

When considering self-protection requirements, the test severity of current safety regulations as applied to M1 passenger cars depends on the vehicle mass. In general, the frontal force levels (the force at which the vehicle deforms) are related to vehicle mass. This is demonstrated in Edwards (2003), which shows the increase in the peak force measurements for increasing vehicle mass in the EuroNCAP offset deformable barrier test. Whilst for single vehicle impacts this variation in frontal force level is less of an issue, it presents a challenge for vehicle-to-vehicle collisions.

FIGURE 3.4.1 HEAD-ON SAFETY TEST BETWEEN **TWO M1** PASSENGER CARS WITH MASS RATIO OF 2.5:1

The present situation is that although there is significant variation in the vehicle mass for the European vehicle fleet it mainly relates to the extremes. Indeed, studies have shown that 80% of vehicle-to-vehicle accidents have a mass ratio (between the collision partners) of 1.6 or less (Zobel, 2001). Replacing a significant part of the vehicle fleet with light weight vehicles with a mass of 760kg or less would see a mass ratio in vehicle-to-vehicle accidents significantly higher than this. As an example, the mass ratio for a 760kg vehicle in a collision with the average European vehicle mass of 1600kg would be 2. For a collision of an L-category vehicle with an average European vehicle the mass ratio would be higher still. Such high mass ratios, and the corresponding differences in the frontal force levels, would be potentially detrimental to the occupant of the lighter vehicle, as not only would the lighter vehicle be unable to deform the heavier vehicle at the higher force levels required, it would absorb more than its share of impact energy and the higher compartment loading would also likely result in structural failure of the compartment as a consequence. Hence, a simple extension of the M1 test approach (in which the frontal force level is linked to vehicle mass) to the L-category vehicle would not provide the holistic evaluation of a lightweight vehicle's compartment strength as required for both single and vehicle-to-vehicle crash protection.

It is possible to make lightweight vehicles crash compatible with the heavier opponent vehicle by compensating for the lower mass of the car through higher rigidity and the use of improved restraint systems – even if the structure was of a sufficiently high structural strength to resist structural failure, the lighter vehicle would undergo a more severe deceleration without such improvement would result in worse injury outcomes. Low mass vehicles, designed taking crash compatibility criteria in consideration, can reduce occupant injury severity significantly. This was the approach taken for the MCC Smart, for example, which was tested against larger Mercedes vehicles, essentially using their crumple zones as part of the Smart's safety system (*Zöllter and Diez, 2007; Heinz, 2004*).

A significant proportion of the on-road injuries and casualties are borne by vulnerable road users, such as pedestrians. These road users would increasingly come into conflict with these vehicles – especially as these types of vehicles would be primarily used in heavily congested urban centres with high levels of pedestrian traffic and cyclists. If the goal is to improve the overall safety record of the system, then the interaction between lightweight vehicles and vulnerable road users should be explored and regulated as this can reduce the number of severe injuries and fatalities, especially in low speed urban settings. For example, regulation 168/2013 currently requires that "on front and rear protective structures" the interpretation is that the vehicle structure shall be designed to avoid pointed and sharp parts that may cause injury. This is substantially different to the current pedestrian protection regulation as applied to M1 passenger vehicles where the injury causing mechanisms (accelerations and deformations) are evaluated through testing of the vehicle structure. Neither does the L-category vehicle class undergo consumer tests, for example the EuroNCAP pedestrian protection ratings as adopted for M1 vehicles.

There is also a cost element to consider in extending the existing M1 test to the L-category. A report by the UK Transport Research Laboratory, quoted the cost of aligning the quadricycle (L7 and possibly L6) requirements with M1 vehicles was to be in the region of €700,000. Nevertheless, to date several of the French quadricycle manufacturers, including the market leaders Aixam-Mega and Ligier-Microcar have voluntarily built their vehicles to comply with existing M1 crash standards in order to avoid losing sales through adverse publicity around this issue. In addition, some have started offering airbags. Although airbags are not compulsory even on M1 vehicles in the EU, they have become an industry standard and having thus become commodified, have become affordable for such smaller manufacturers. Such initiatives by the market leaders may, however, not be feasible for some of their smaller competitors.

3.5 Environmental Impact Regulation in the EU

In Europe, the USA, Japan and several other countries, toxic emission, vehicle fuel economy and/or greenhouse gas emission targets and standards have been notified and mandated. The European Union is considered to be setting the most restrictive targets worldwide, although it can be said to be competing with California for this position; for historic reasons, California is the only state allowed to set its own separate vehicle emissions standard separate from US Federal standards, although other states are free to adopt them.

For passenger cars in the M1 class, there are EU emission limits for each category of pollutant emissions and for the different types of fuel. For the emissions of toxic pollutants, the EURO 6 standard came into force on 1st September 2009 and the EURO 6 standard on 1st September 2014, as set out in Table 1.

TABLE 1 – EU TOXIC EMISSIONS STANDARDS (M1)

Europe - Diesel Engines

	CO	*HC+NOx*	*NOx*	*PM*
Euro 5 (2009)	0.60g/km	0.23g/km	0.18g/km	0.006g/km
Euro 6 (2014)	0.60g/km	0.17g/km	0.08g/km	0.006g/km

Europe - Petrol Engines

	CO	*HC*	*NOx*	*PM*
Euro 5 (2009) & Euro 6 (2014)	1.00g/km	0.10g/km	0.06g/km	0.006g/km

Recent European Union legislation also sets mandatory CO_2 emission reduction targets for new passenger cars in the M1 class. The fleet average to be achieved by all new cars is 130 grams of CO_2 per kilometre (g/km) by 2016 – with the target phased in from 2012. A subsequent limit of 96g/km has been set for 2021, to be phased in from 2020. The 2016 and 2021 targets represent reductions of 18% and 40% respectively compared with the 2007 fleet average of 168.7g/km. The CO_2 emission standards as applied for Europe are provided in Table 2.

TABLE 2 – EU CARBON DIOXIDE STANDARDS (M1)

Europe – CO_2

Regulation [EC] No 433/2009	130 g CO_2/km by 2016 (phased in from 2012) 96 g CO_2/km by 2021 (phased in from 2020)

In contrast, for the L-category vehicle class, from an air quality perspective, the primary objective has to be to keep constant or reduce the share of total road-transport emissions from L-category vehicles as compared to other road vehicle categories (so any observed shift from M1 class to L-category is neutral or has a net benefit). Regulation (EU) No 168/2013 established implementation dates for Euro 4 (2016 new and 2017 existing; see table 3) and 6 (2020 new and 2021 existing; see table 4). This Euro 6 obligation, however, will be subject to a "comprehensive environmental study" by the European Commission, the conclusions of which are to be published 2016. Reporting of carbon dioxide (CO_2) emissions as part of the type approval process is now required.

TABLE 3 – EU TOXIC EMISSIONS STANDARD EURO 4 (L-CATEGORY)

Vehicle category	Vehicle category name	Propulsion class	CO (g/km)	THC (g/km)	NOx (g/km)	PM (g/km)	Test Cycle
L5Be	Commercial tricycle	PI/PI Hybrid	2.00	0.66	0.26	-	UNECE R40
		CI/CI Hybrid	1.00	0.10	0.66	0.08	
L6Ae L6Be	Light on-road quad Light quadricycle	PI/PI Hybrid	1.90	0.73	0.17	-	UNECE R47
		CI/CI Hybrid	1.00	0.10	0.66	0.08	
L7Be L7Ce	Heavy all terrain quad Heavy quadricycle	PI/PI Hybrid	2.00	0.66	0.26	-	UNECE R40
		CI/CI Hybrid	1.00	0.10	0.66	0.08	

TABLE 4 – EU TOXIC EMISSIONS STANDARD EURO 6 (L-CATEGORY)

Vehicle Category	Vehicle category name	Propulsion class	CO (g/km)	THC (g/km)	NOx (g/km)	PM (g/km)	Test Cycle
L1Ae	Powered cycle	PI/CI/Hybrid	0.60	THC 0.10 NHMC 0.068	0.060	0.0046	Revised WMTC
L1Be-L7e	All other L-category vehicles	PI/PI Hybrid	1.00		0.060	0.0046	Revised WMTC

An alternative to the EU approach maybe is the Japanese fuel economy regulation, which since 1998 has been using the ‘top runner’ principle, whereby current best practice informs future targets. The targets introduced in 2007 were designed to lead to an average new car fuel economy by 2016 of 16.8 km/L, equivalent to a CO_2 figure of 126 g/km, giving Japan the lowest CO_2 emitting new car fleet by 2016 (*ICCT, 2011*). Despite the promotion of a minicar segment (see above), South Koreans have increasingly favoured larger engine cars and SUVs, so in 2010 the government proposed a combined fuel economy and CO_2 emissions target of 17km/L and 140 g/km of CO_2 on the Korean drive cycle for the 2016 model year. This equates to 160 g/km on the European NEDC drive cycle (*ICCT, 2011*).

3.6 Opportunities for the UK in Regulating L-Category Powered Light Vehicles

Imposing strict regulatory frameworks may give rise to competitive advantages if at a later date the respective frameworks diffuse to other markets. In this case, companies operating in the early regulating country may gain early mover advantages in the respective technology. The asset is the knowledge that is created in response to the emerging regulatory frameworks and this has a value that can be exploited and marketed for commercial advantage.

Traffic congestion in urban areas, environmental awareness and operating costs of a conventional passenger car have all contributed to a growing interest in small lightweight vehicles. At present other countries, notably France and, to a lesser extent, Italy, have an advantage over the UK in terms of the maturity both of their L-category markets and of the industries that supply them. However, this is not to say there are no opportunities for the UK. At present, technical standards for lightweight vehicles are generally insufficient and non-homogenous, which restrict the development of this sector outside of their core markets. Current and evolving policy frameworks will speed up adoption and expansion of the global light vehicle market. To support this requires regulatory convergence, which will have the outcome of reducing complexity and the burden on vehicle manufacturers, approval authorities and technical services. This presents opportunity for the UK industry and the technical service providers, especially if the regulatory change is aligned to their core competencies.

As an example, a common safety issue for many of these vehicle types is crashworthiness and in particular their compatibility in crashes with heavier opponents. Within the area of vehicle safety, the UK has led on the development of crash safety standards that have encouraged the deployment and development of appropriate safety solutions and technologies for passenger cars (both for self-protection and for protection of vulnerable road users). It is possible to make low-mass vehicles that meet safety standards in frontal collisions with heavier vehicles by compensating for the lower mass of the car through higher rigidity and the use of improved restraint systems. The safety technologies, which allow occupants to survive very high-energy crashes, have been available in motor racing for years, and some sub-A segment cars have utilized it. Extending the safety improvements observed in the passenger car sector into the lightweight vehicle sectors offers opportunities for these UK specialist sectors. The development of appropriate testing and certification would be the remit of the specialist technical services sector, whilst the development of product to meet these requirements would provide opportunity for diversification (supply of product and/or knowledge) for the motorsport sector.

In addition, in line with the European strategy on air quality, the European Union has constantly tightened the emission standards for motor vehicles, in particular for hydrocarbons, carbon monoxide, nitrogen oxides and particulate matter. This will now also be the case for PLVs with this delegated act regarding their environmental performance. This should help achieve the EU's goals in terms of environmental objectives and setting harmonised, uniform rules for vehicle manufacturers and other stakeholders to determine the propulsion unit performance of L-category vehicles. To comply with the limited standard imposed thus far, the approach, as exemplified by a large proportion of the French L-category vehicle sector, has been to share a limited set of common powertrain options. Most vehicles produced by this industry now use small diesel engines produced by Lombardini. This component sharing allows for economies of scale, while Lombardini uses what is essentially an industrial engine adapted to quadricycle use and is therefore able to spread development costs over larger volumes. Other engines used include Kubota and Yanmar, who also use industrial-derived engines thus sharing economies of scale in development and production, while transmissions are mostly CVT systems sourced from Canada (*Nieuwenhuis, 2014*). In addition, most have long offered electric powertrain options, again using proprietary components. This approach significantly reduces costs for each manufacturer. The benefit to the UK from shared standards is twofold; one is that a larger market for drivetrain technology and/or product, the other is that the cost barrier for new entrants is reduced. Something that could be considered when assessing the cost of imposing tighter emissions or safety limits on such vehicles is the availability and accessibility of solutions within regions, such as the UK.

Further to the above, the expertise in the UK in the areas of lightweight vehicle technology and alternative powertrain is unequalled, stemming both from a long history of low volume vehicle manufacturing in all segments, and from the world-leading motor sport and aerospace sectors in the UK. These strengths would certainly suggest the UK is well placed to benefit from any future development of the L-category segment. Experience in the US, as outlined in the case study, also shows how a combination of private and public initiatives can lead to changes in regulation to create new segments, accommodating new vehicle classes into existing regulatory frameworks. Such opportunities may also arise in the UK context, whereby the EU legal framework can form an initial space within which to shape such a sub-segment.

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