The Micromobility Revolution Gathers Momentum

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With the global population of urban areas set to increase by 50% to 6.7 billion by 2050, managing mobility in cities will be crucial. Micromobility has the potential to substantially reduce congestion and pollution in urban areas and increase productivity. However, several challenges are currently facing the micromobility industry, including rider and battery safety. The UK needs to ensure regulation and safety keep pace with burgeoning transportation choices.

Introduction

The electrification of transport is accelerating with the uptake of battery electric vehicles (BEVs) increasing sharply and micromobility vehicles (MMVs) becoming more prevalent in cities across the world. The term micromobility was initially used to describe small lightweight vehicles used over short distances.[1] However, this term has since widened to encompass electric vehicles typically operating at speeds below 25 km/h. This wider definition (Box 1) now includes e-bikes, e-scooters and larger electric three-wheelers such as tuk-tuks, while excluding smaller internal combustion engine (ICE) vehicles such as motorbikes.[2]

Micromobility vehicles, such as e-scooters and e-bikes, provide a convenient and cost-effective transport alternative for many people. Increasing uptake could reduce transport congestion, air pollution and carbon emissions. Maximising the potential of the micromobility revolution will require tailored regulation and further improvements to battery safety.

MMVs are typically used for short distance trips within urban environments, including trip purposes such as commuting, leisure, delivering goods and transporting cargo. MMVs are therefore well-placed to replace cars for certain short journeys. This is a substantial market given that a quarter of trips in Great Britain are under one mile and 71% are under 5 miles.[3] The provision of efficient, affordable and accessible short-distance transportation options is crucial to this market.

The roll out of e-scooter rental trials in the UK and lower prices for e-bikes has increased demand for MMVs. However, the UK's rate of adoption is lower than the European average, with the UK fleet of shared MMVs accounting for around 5% of the combined UK and EU total.[4]

Increasing the uptake of MMVs offers substantial benefits. Not only do MMVs use urban spaces more efficiently, but they also offer convenience, practicality, modal shift opportunities from private cars, environmental benefits, inclusivity for people with disabilities, usefulness for 'last-mile' deliveries and reduced congestion.[5] As an indicator of their potential impact, for example, the time lost because of congestion already costs the UK economy approximately £2 billion per annum.[6] However, issues around battery safety and regulation need to be addressed to maximise their potential given that regulation on battery and road safety has not kept up with the rapid growth of the MMV market and concerns with battery fires in MMVs have recently emerged.

1 Drivetech (May 2022). Micromobility – What is it?
2 Zemo Partnership – Powered Light Vehicles.
3 Department for Transport (September 2021). National Travel Survey 2020.
4 ESRC Consumer Data Research Centre (unpublished).
5 Department for Transport (October 2020). Future of Transport Regulatory Review Summary of Responses.
6 Department for Transport (March 2019). Future of Mobility: Urban Strategy.

Box 1: Defining Micromobility Vehicles

MMVs can be grouped into two vehicle families: two-wheeler or three-wheeler. Although manually-powered bicycles could be considered MMVs, these fall into the category of 'active travel', which encompasses cycling and walking, and are not included in this definition.

Two-Wheelers

E-Bikes: A bicycle containing a motor powered by an internal battery pack. Under the UK's Electrically Assisted Pedal Cycles (EAPC) regulations the motor for e-bikes is capped at 250 W. Propulsion is aided by two means: electric assist, where the motor and battery provide power to assist the rider in pedalling, or by using the throttle, where the power from the battery pack is delivered directly to the motor without pedal input. In the UK, pedal assist vehicles are more popular as these are regulated under EAPC regulations, while e-bikes with throttles, which power the bike beyond a permitted 'walk assist' speed are regulated as L-category vehicles.[7] E-bikes can be purchased for private use in the UK as well as being available for hire in many UK cities.

E-Scooters: A light two-wheeled vehicle where the driver stands on a floorboard. These are mechanically propelled using one or two motors powered by an internal battery pack. E-scooters are available to be purchased privately but are not currently legal on public roads in the UK. Shared e-scooters are available for hire through the trials being held in many cities across the UK.

E-Moped or E-Motorbike: A large two-wheeled vehicle where the driver sits over an enclosed battery pack. These are mechanically propelled using one motor powered by the internal battery pack and are available for purchase in the UK. The power of these vehicles is comparable to ICE versions of motorbikes and mopeds. A motorbike license is required for legal operation.

Three-Wheelers

E-Cargo Bikes: These are propelled in the same way as e-bikes, but can come in the form of two, three or four wheeled models. E-cargo bikes enable the transport of goods using a smaller vehicle than a conventional van. These are available for private purchase in the UK and are also in use by several different companies across the UK.

Tuk-Tuks: Small, motorised vehicles working on the same principle as an e-bike. Used to transport passengers or cargo. Although these are classified as motor vehicles in the UK, they are widely popular globally and particularly in Asia, with a significant proportion currently electrified.

For example, the only legal avenue for public e-scooter use in the UK is currently via the UK Government e-scooter trials, despite use by private users publicly in other regions. This Faraday Insight assesses the market, technology and charging infrastructure used for MMVs. It also discusses the need for enhanced battery safety and the regulatory challenges that need to be overcome when MMVs are rolled out more widely across the UK. The Insight highlights the issues of road safety and driver behaviour but does not analyse these issues in any great detail.

Ownership Models for Micromobility Vehicles

There are three ownership models (or use cases) for MMVs: Personal, shared and fleet ownership.

Personal ownership

MMVs in the private ownership category cover a broad range of vehicles, with the most popular being bicycles, e-bikes and e-scooters. Bicycles are by far the largest MMV within this category, but electrified alternatives have been increasing in popularity. Cumulative sales of private e-scooters in the UK totalled over 1 million units to 2021, with 750,000 believed to remain in use currently.[8] Other personal MMVs include electric skateboards, segways and electric unicycles, although these are not sold on the same scale.

Mobility scooters and powered wheelchairs for people with disabilities are increasingly using lithium-ion instead of lead-acid batteries. These types of vehicles are typically not included in the various statistics on the size and shape of the MMV market provided in this Insight but are already a very valuable form of mobility across the UK.[9] Benefits include wider travel options, cheaper travel, increased independence and inclusion in society.

Shared ownership

Rental and ride-sharing schemes for MMVs are now widespread across Europe and China. Schemes were originally introduced by city councils as far back as the late 1990s,[10] but it wasn't until around 2017 that electric MMVs featured within these schemes. Since then, the market has been flooded with start-ups offering low-cost and easy to access rental e-scooters to consumers, with larger companies such as Voi or Lime offering products such as e-bikes and e-cargo bikes. The global shared micromobility industry is expected to reach a US $300-500 billion market by 2030.[11]

Business / fleet ownership

Fleets of larger MMVs are generally used for cargo transport and delivering goods. Although this currently represents a much smaller part of the micromobility market, there is a sizeable opportunity to take a share of the US $120 billion

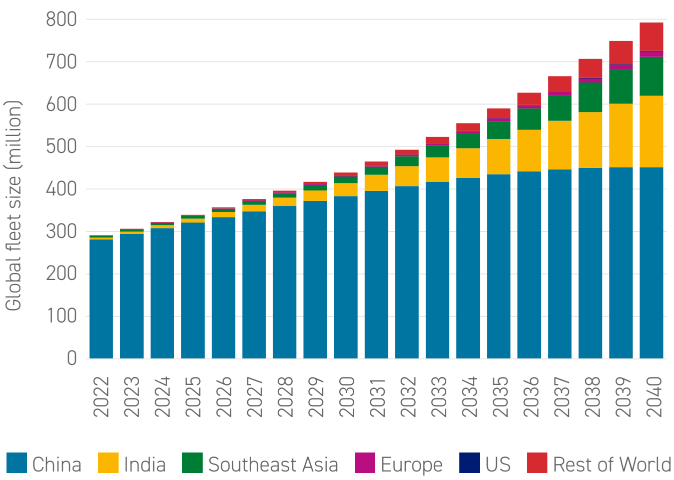
7 DfT (July 2022). L-Category Vehicle Classification.
8 Parliamentary Advisory Council for Transport Safety (March 2022). The Safety of Private E-scooters in the UK.
9 See Motability for a more detailed discussion.
10 Micromobility (April 2019). The Three Eras of Micromobility.
11 McKinsey Centre for Future Mobility (Jan 2019). Micromobility's 15,000-mile checkup.

last-mile delivery market.[12] Sales of e-cargo bikes have also increased in the UK by 37% on the preceding 12 months in May 2022.[13] In the UK, companies such as DPD, DHL, Amazon and ASDA, for example, have all purchased e-cargo bikes from EAV (a supplier of e-cargo bikes).[14,15] There are companies in the automotive sector starting to move into e-cargo bike production such as Renault Trucks, which announced a deal with Kleuster (an e-cargo bike manufacturer) in October 2022 to assemble and distribute e-cargo bikes from its Venissieux site.[16]

Market Size

MMVs represent an important part of the global BEV market, with the fleet size of electric two- and three-wheelers expected to increase from around 290 million in 2022 to almost 800 million vehicles in 2040 (Figure 1). This compares to around 27 million passenger BEVs, electric buses and commercial vehicles in operation in 2022. The MMV market is currently the fastest electrifying transport sector globally, with higher fuel prices and falling battery costs driving the uptake of electric MMVs. Geographically, the MMV market is dominated by China with adoption in India expected to increase substantially in the coming years.[17] So far, this is a missed opportunity for Europe and the US – use of MMVs is only expected to grow to around 12 million and 2 million respectively by 2040.

Figure 1: Fleet size of two- and three-wheeled BEVs (2022-2040)

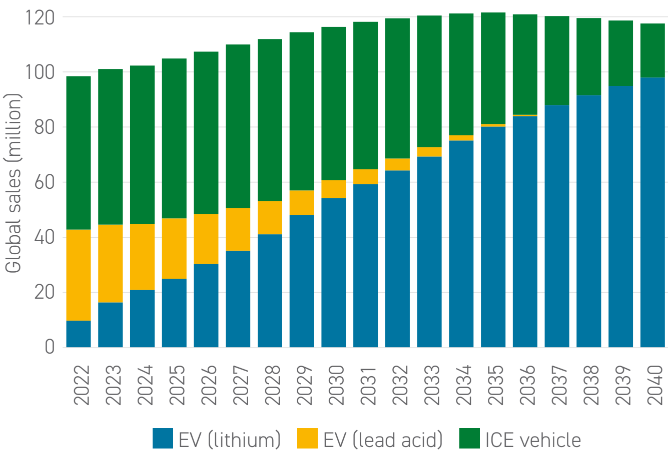


Source: BNEF (June 2022). Electric Vehicle Outlook 2022.[18]

In addition to the imbalance in the location of the MMV market, the popularity of vehicle types also differs by region. Sales of e-mopeds or e-motorbikes are much higher in Asian and African markets,[19] whereas e-scooters and e-bikes are more popular in European and US markets. Historically, lead-acid batteries were the technology of choice for use in small electric two- and three-wheelers. However, lithium-ion batteries are currently ubiquitous in micromobility, and are likely to dominate the sector in the future due to falling manufacturing costs and high energy density.

Going forward, lithium-ion battery powered MMVs will initially replace sales of lead-acid run MMVs in the 2020s followed by the replacement of ICE powered vehicles in the 2030s. By 2030, 46% of two- and three-wheelers sold globally are expected to be electric rising to 83% by 2040 (Figure 2).

Figure 2: Global sales of two- and three-wheeled vehicles by drivetrain (2022-2040)



Source: BNEF (June 2022). Electric Vehicle Outlook 2022.[18]

The UK is behind other European countries in MMV adoption for both passenger and freight applications.[20] There are currently around 33,000 MMVs (e-scooters and e-bikes) available for hire in the UK, which represents only 5% of the combined UK and EU total of 636,000.[4] However, the UK is making good progress carrying out innovative research into MMVs through the Niche Vehicle Network.[21] This collaborative R&D programme supports SME-led projects to focus on developing and demonstrating low carbon vehicle technologies in niche vehicle applications.

Battery Requirements for MMVs

Battery pack requirements for MMVs are vastly different to that of BEVs. E-scooters typically use only 5% of the energy that a BEV requires, so for every 1 kWh (kilowatt hour) of energy used a BEV can only travel 4 miles compared to 82 miles in an e-scooter.[22] These lower energy requirements, alongside advances in battery technology, result in a range for MMVs that is already more than suitable for most journeys.

[12] Straits Research (July 2021). Last Mile Delivery Market.
[13] Bicycle Association - Market data 2022.
[14] EAV eCargo.
[15] Amazon expands electric cargo bike deliveries in Manchester and London.
[16] Renault Trucks.
[17] TIFAC (June 2022). Forecasting Penetration of Electric Two-Wheelers in India.
[18] The BNEF definition of two-wheelers includes mopeds, scooters and motorcycles, but excludes e-bikes.
[19] BBC News (June 2022). Will electric motorbike sales take off across Asia?
[20] ELEVATE – Innovative Light Electric Vehicles for Active and Digital Travel.
[21] Niche Vehicle Network, supported by the Office for Zero Emission Vehicles, Advanced Propulsion Centre, Innovate UK and other partners.
[22] CB Insights (October 2021). The Micromobility Revolution.

However, there is a need and scope for improvements in battery safety, which will require the attention of researchers, business, regulators and Government.

Battery performance

Lower energy requirements mean MMVs have much smaller battery packs than BEVs, although battery size differs by the type of MMV (Table 1). E-scooters typically have a range of up to 30 miles, with the battery the sole source of power to generate movement. As such, the battery and the motor for e-scooters must be able to handle higher power outputs for efficient transportation in comparison to e-bikes. In contrast, e-bikes are capable of longer ranges of up to 70 miles, but a broadly similar battery pack size to e-scooters is used as both the rider and an electric motor will often be used to provide motion, lowering the power output needed from the battery.

Battery chemistries currently used for MMVs are focused on lithium-ion chemistries such as lithium iron phosphate (LFP), lithium nickel manganese cobalt oxide (NMC) and lithium cobalt oxide (LCO), which is similar to the battery market for BEVs.

Table 1: Characteristics of typical battery packs used in MMVs

MMV type	Typical pack size / Wh	Battery chemistries	Range / miles	Top speed / mph	Cell types
E-Scooters	280 – 450	NMC, LFP, LCO	12 – 30	15.5-20	18650
E-Bikes	200 – 700	NMC, LFP	20 – 70	15.5 (for pedal assist)	18650
E-Cargo	250 – 2500	NMC, LFP	40	15.5	18650 & others
Average BEV	40,000	NMC, NCA, LFP	150+	90+	Cylindrical & pouch cells

Source: Faraday Institution research

MMV battery packs will continue to improve in line with advancements in cell manufacturing for BEVs. Going forward, next generation technologies such as sodium-ion could increasingly be used in MMVs. Sodium-ion batteries are more suited to applications with lower energy density requirements such as MMVs and offer the potential to reduce battery costs and improve the safety of MMVs relative to other chemistries.[23] These characteristics could help sodium-ion to become the dominant technology for MMV electrification in the longer-term. Sodium-ion is currently being researched heavily around the world, with a particular relevance for stationary storage and some automotive applications in developing countries (Box 2). This is illustrated by the recent acquisition of the UK company Faradion by the Indian multinational conglomerate Reliance Industries.[24]

Solid-state batteries could also be an important future technology. Prologium, a world leader in solid-state lithium-ion battery manufacturing, recently unveiled the world's first swappable solid-state battery prototype. This was developed alongside Gogoro, a Taiwanese based company providing battery swapping services for e-mopeds.[25]

Box 2: The Importance of Sodium-ion Technology for MMVs

Sodium-ion technology promises to be a low-cost alternative to lithium-ion batteries, including for MMVs. The Faraday Institution is a leader in sodium-ion research through its NEXGENNA research programme led by the University of St Andrews. The project is accelerating the development of sodium-ion battery technology by taking a multi-disciplinary approach incorporating fundamental chemistry right through to scale-up and cell manufacturing. NEXGENNA is partnering with industry leaders such as Faradion to develop low-cost sodium-ion technology with applications in both stationary storage and mobility. The University of St. Andrews and IIT Madras have also recently signed an MOU to help India reach 100% of its energy requirements through renewable energy.[26] These partnerships highlight the potential importance of sodium-ion technology in decarbonising India.

Battery safety

Lithium-ion batteries are safe to use if used correctly. Millions of devices across the UK, from laptops to BEVs, rely on lithium-ion batteries as a power source without any issues. However, fires do happen on rare occasions. The London Fire Brigade was called to 104 fires involving lithium-ion batteries in 2021.[27] As MMVs are often stored at home, the impact of fires originating in MMVs have the potential to be more problematic than in BEVs.

Improving the safety of batteries in MMVs even further will need to address the following factors:

- **Regulation of electric MMV manufacture and trading.** E-bikes in the UK are currently subject to a highly respected standard (BS EN 15194) that specifies requirements and test methods, including electrical compliance of the battery.[28] However, an equivalent standard does not yet exist for e-scooters. Such a standard should be developed and implemented to reduce the risk of battery pack failure in MMVs. Although the shipping of cells is subject to strict international

[23] Faraday Insight 11 (May 2021). Sodium-ion Batteries: Inexpensive and Sustainable Energy Storage.
[24] Faradion (December 2021). Reliance New Energy Solar to Acquire Faradion Limited.
[25] Gogoro (March 2022). World's First Swappable Solid-State Battery.
[26] University of St Andrews and IIT Madras MOU.
[27] Cycling Weekly (March 2022). London Fire Brigade urges customers to buy through 'reputable sellers'.
[28] EU Standard BS EN 15194:2017.

standards,[29] the online trade of lithium-ion cells is not so well regulated. The UK Government should therefore examine whether the various manufacturing and consumer markets for MMVs need to be subject to tighter regulations and product standards.

- **Battery chemistry**. There is no requirement for battery manufacturers to label the battery pack with the cell chemistry used, such as NMC, LCO or LFP. Labelling will help the consumer understand the level of safety of MMV batteries as different chemistries have different levels of safety. LFP cathodes, for example, are inherently safer than NMC and LCO cathodes as they have a smaller risk of a cell failure leading to a thermal runaway event.[30] Mandatory chemistry labelling requirements are also being considered for lithium-ion batteries to make them easier to recycle.[31] The UK could go further than labelling regulations by stipulating that MMVs should only use certain battery chemistries, but this could result in less effort being put towards improving the performance of prohibited chemistries and potentially missing out on possible breakthroughs, such as the creation of safer and more powerful systems.
- **Consumer behaviour and education.** Information campaigns are needed to educate consumers on the hazards of battery failure, including fire and the production of toxic fumes and vapours. Consumers should be made aware of safe battery charging behaviours, such as avoiding or limiting MMVs being charged in the home due to the fire risk, being encouraged not to build a 'home-made' battery pack due to safety issues and to purchase MMVs from reputable dealers. Information could also be disseminated through user manuals when MMVs are purchased covering, for example, that:
    - Batteries must be used in line with manufacturers guidelines to avoid risk of damage or injury;
    - Consumers should ensure that the correct charger is used;
    - Charging should be done outside the home when possible and under supervision if done indoors;
    - Care should be taken to avoid damage to cells by dropping/knocking battery packs;[32]
    - Batteries should be allowed to cool down after charging; and
    - Spare batteries should be purchased from the original supplier of the vehicle and not made from cells bought online.
- **Battery management systems (BMS).** BMS systems are built into the battery pack as safety mechanisms to protect the cells from over charging, which can lead to thermal runaway events, as well as monitoring cell health. These systems are critical to the safety of the user but not all systems are robust enough to ensure the safety of the battery, or may not even be installed at all. Improving the robustness and quality of BMS systems in MMVs is the biggest technological improvement that can be made to ensure the safety of MMV users. Further investigation is needed to determine the cost to consumers of installing BMS systems against the safety benefits they provide. BMS systems for MMVs when installed should be subject to regulation that requires them to be tested for their effectiveness in preventing safety incidents such as catastrophic cell degradation.

While regulation around battery trading, battery transport and battery safety mechanisms may help to addresses these four issues, further battery research is also needed to better understand failure mechanisms within lithium-ion batteries.[33]

Battery charging

Current MMVs do not require any specific charging infrastructure and can be charged using standard 13 amp plug sockets. Charging MMVs in the home is therefore quite common but this does put the home at risk from a battery fire. Safety benefits could arise from installing dedicated MMV charging points in other locations, such as in garages, outside the home or in shared areas of accommodation or flats.

Battery swapping

Battery swapping, where an existing battery pack is removed and replaced by a charged battery pack, is becoming more common and offers substantial benefits to consumers and businesses (Box 3). Infrastructure to enable battery swapping is currently being developed in markets where MMVs are popular such as Africa and Asia. Gogoro and Mobile Power are two leading companies offering battery swapping services in these regions.

European micromobility companies such as Voi, Tier and Dott are also increasingly offering battery swapping services. These companies have also committed to only purchase new MMVs with battery swapping functionality as they consider this helps to optimise operations and improve safety, sustainability and security.[34] Battery swapping is typically undertaken at night when engineers service e-scooters.

Wireless charging

Wireless charging would provide further efficiency savings compared to battery swapping. Wireless charging uses electromagnetic induction to provide wireless power transfer and is already available for portable electronics

[29] Li-ion Tamer. Top 11 Lithium-ion Battery Regulations.
[30] Electrochemical Society (2012). E. Peter Roth, A General Discussion of Li Ion Battery Safety.
[31] EU Battery Regulation – 2020.
[32] National Fire Chiefs Council (January 2022). E-bikes and e-scooters fire safety guidance.
[33] Faraday Insight 10 (March 2021). Why Batteries Fail and How to Improve Them: Understanding Degradation to Advance Lithium-Ion Battery Performance.
[34] TIER (April 2021): Why swappable batteries are the way to go.

such as smart phones. Voi is currently staging the UK's first trial scheme for wireless e-scooter charging at the University of Warwick.[35] Allowing e-scooters to be charged on charging pads while on standby would also improve the user experience of charging and hiring MMVs.

Box 3: Benefits of Battery Swapping

Battery swapping improves safety, optimises network operations and makes recycling easier. Spillover benefits for the BEV industry are also possible.

Safety

Designing MMVs with swappable batteries allows the battery pack to be regularly inspected to monitor battery health and performance, thereby reducing cell failure and improving safety. Swappable batteries do not compromise safety, as they are either enclosed in the base of the scooter or integrated into the front stem of the scooter. These systems can withstand 380 kg of horizontal pull force or 700 kg of vertical pull force before failing.[34]

Optimising operations

Using battery swapping has the potential to reduce the number of logistics trips from the city centre to the storage warehouses, reducing operational costs, transport congestion and carbon emissions.

Recycling

The recyclability of swappable batteries is greater than for an embedded battery pack as it can be easily separated from the vehicle. This extends the service life of the MMV, as it can continue to be used with a new battery pack, while the original battery pack will be recycled.

Technology transfer to BEVs

BEVs typically have packs weighing 500 kg, which makes battery swapping much more challenging than the smaller packs used in MMV. As a result, battery swapping is not currently widely used for BEVs. Nevertheless, the nascent MMV battery swapping industry will provide companies with the knowhow and experience that could then make the leap to BEVs in the coming years.

The Roll-Out of Micromobility in the UK

The UK has taken a different approach to facilitating the roll out of MMVs from the rest of Europe. While many European cities have allowed MMV companies to set up, the UK opted to test the use of e-scooters through the use of rental schemes in a limited number of trial areas (Box 4).

In addition, a ban was put in place on the use of private e-scooters in public unless they comply with road traffic laws. The UK trials, which are taking place from July 2020 to May 2024, are being used to inform government decision-making on future legislation for e-scooters.[36]

Despite the prohibition of MMVs in the UK, there is considerable demand for making MMV solutions more widely available and "widespread support for legalising some or all of the micromobility vehicles".[37] In a recent survey carried out by McKinsey, 45% of respondents in the UK would be willing to use MMVs for their daily commute, while the global figure was almost 70%.[38]

Wider Challenges for Micromobility in the UK

In addition to battery safety, there are wider challenges facing micromobility around regulation, accident prevention, infrastructure and sustainability.

Regulation

MMVs are a relatively new technology so regulatory approaches are emerging as knowledge and experience improves. In the UK, minimum safety requirements have not yet been defined, so regulation is needed to ensure the safety of MMV users and other road users, but care needs to be taken to avoid unnecessary and disproportionate restrictions that may inhibit the growth of this nascent industry. Proposed regulations for three categories of MMVs from the University of Warwick are shown below (Table 2). E-bikes are not included as they are already regulated by EAPC regulation.[39]

Other bodies have been calling for more stringent regulations, particularly on e-scooters. The Parliamentary Advisory Council for Transport Safety (PACTS), for example, made several recommendations for the Department for Transport (DfT) to consider if e-scooters should be legalised in the future. These include a 12.5 mph speed limit, 250 W maximum power rating, anti-tampering mechanisms and a minimum rider age of 16.[8]

Accidents

In 2020, the DfT undertook a safety review of privately owned e-scooters, identifying 460 accidents and 484 casualties. The level of incidents appears to be a similar to that of cycling.[40] Both the London Cycling Campaign and Institute for Transport argue more data is needed to determine the relative safety of MMVs compared to other transport modes.

After a series of high-profile fire incidents on transport services, Transport for London banned the use of privately-owned e-scooters on its transport network from December 2021. E-scooters are also banned on the national rail

[35] Voi launches UK's first wireless e-scooter charging trial.
[36] UK Government (February 2022). E-scooter trials: guidance for local authorities and rental operators.
[37] Department for Transport (October 2020). Future of Transport Regulatory Review.
[38] McKinsey (December 2021). Why micromobility is here to stay.
[39] Association of Cycle Traders – Guide to eBikes.
[40] London Cycling Campaign (June 2020). Micromobility and Active Travel in the UK.

Box 4: UK and London Trails

The UK e-scooter trials began in July 2020 in Middlesbrough. Since then, the trials have been expanded into over 50 towns and cities across the UK. Multiple companies have provided a fleet of e-scooters that can be temporarily leased to individuals for short distance travel. As of April 2022, over 18 million journeys had been completed by 20,000 e-scooters. In the London trials, which began in June 2021, 180,000 riders have collectively travelled 585,000 total trips.

Provider	Sites (UK)
Ginger	Middlesbrough, Hartlepool, Stafford, Milton Keynes, Chester, Scunthorpe, Whitehaven and Great Yarmouth
Spin	Milton Keynes, Basildon, Chelmsford, Colchester, Clacton, Brentwood and Braintree
Lime	Rochdale, Salford and Milton Keynes
Voi	Northampton, Birmingham, Liverpool, Cambridge, Bath, Bristol, West Bromwich, Kettering, University of Warwick, Oxford, Corby, Wellingborough, Rushden & Higham Ferrers, Portsmouth, Southampton & Barnstaple
Zwings	Newcastle-under-Lyme, Cheltenham, Gloucester, Yeovil, Crewkerne and Chard
Beryl	Norwich, Isle of Wight and Bournemouth
Bird	Redditch and Canterbury
Neuron	Slough, Newcastle and Sunderland
Tier	York
Wind	Nottingham and Derby
Zipp	Taunton, Aylesbury and High Wycombe

Source: Zag Daily, Intelligent Transport; Transport for London; Department for Transport; Bikesharp

Table 2: Proposals for regulation of MMVs

Regulation	E-scooter	Light electric cargo vehicle	Light e-mopeds
Max speed	15.5 mph	15.5 mph	20 mph
Max power	500W	2kW	1kW
Weight limit	55 kgs	Gross vehicle weight 600 kg	As declared by manufacturer
Type approval	Required, independent testing of certain features	Required, testing per scooter	Per MMV, dependent on max speeds
Vehicle registration	Required, via Vehicle Identification Number and registration mark	Required, via Vehicle Identification Number and registration mark	Required, either like e-scooters or full number plate
Licensing/training	Not required, bikeability-style training recommended	Per scooter requirement, specific training courses allows employee training	'Compulsory Basic Training' license
Minimum age	14 years+	16 years+	16 years
Vehicle tax	Not required	Not required	Not required
Vehicle insurance	Not required	Per MMV	Per MMV
PPE requirements	Not required, strongly recommended	Per MMV	Motorcycle helmet mandatory
Enforcement	New civil offences created to allow Police Community Support Officers to issue fines	Per MMV	Per MMV

Source: WMG University of Warwick (2022). Micromobility a UK Roadmap.

network. However, e-bikes are allowed by certain operators if they are not being (re)charged while onboard.[41]

Transport infrastructure

The approval of MMVs for use on UK roads would be a challenge in both spatial and safety terms. Although MMVs may help to reduce trips in cars, it may be spatially difficult to accommodate MMVs on road space that is already heavily congested with cars and other motor vehicles. Furthermore, MMVs could even generate additional road trips through a modal shift from walking to MMVs. Parking also faces similar competition for space, although up to 10 e-scooters can be parked in a single car park space and they can be parked in a much wider variety of locations than cars.

How road space is shared between different modes will therefore need careful consideration and planning by local authorities. Learning from the interaction between cycling and cars will be especially important as consumers view transport by MMVs similarly to cycling. For example, around 50% of e-scooter users felt safer on protected cycle paths than on the open road and 93% of riders in Paris used cycle paths when available.[40] Limited road space and the similarity with cycling suggests that dedicated MMV paths or shared MMV/cycleways will be needed to ensure the safety of riders and walkers in urban areas and to encourage adoption of MMVs.[42]

Energy infrastructure

The pressure on energy infrastructure posed by MMVs is an area of uncertainty and depends upon energy efficiency per traveller. It is widely accepted that MMVs are much more energy efficient than current ICE vehicles, given that the range of an e-scooter is around 90-100 km per kWh, compared to 2 km per kWh for a motor vehicle.[43] However, the energy efficiency of MMVs compared to public transport, particularly buses and mass rapid transit systems, is not well understood and requires further research.

Sustainability

Many leaders in the MMV industry, such as Dott, Voi, and Tier have committed to standards of environmental and social sustainability. These include commitments on recycled content for manufacturing, responsible growth to prevent overcrowding of walkways, using renewable energy, and recycling batteries at the end of life. Work to build infrastructure for at-site charging or swappable batteries is also important as this will reduce the emissions created around daily collection of MMVs for charging.[44] Within the UK there is also huge potential to reduce congestion and reduce inefficient use of transport, with around 39% of e-scooter journeys with Voi replacing car trips since January 2020.[45] Globally, around 36% of trips on e-scooters are estimated to have shifted from private vehicles and 13% from public transport.[40]

Evidence on the impact of MMVs on carbon emissions is promising but depends heavily on the lifetime of the MMV. A recent study by the Fraunhofer Institute highlighted the potential carbon savings of MMV by looking at MMV transportation data from six cities around the globe: Seattle, Melbourne, Paris, Dusseldorf, Stockholm and Berlin. Overall, their results show that MMVs (particularly e-scooters and e-bikes) provide emission savings ranging from 14.8 gCO_2/passenger km to 42.4 gCO_2/passenger km within the cities studied, with the largest benefits arising when replacing trips by taxis.[46] In some situations, however, MMVs can increase carbon emissions if they replace already sustainable modes of transport such as walking and cycling.

These findings reinforce the need to further improve MMV lifespans and to reduce the environmental cost of battery and vehicle manufacturing, as well as promoting active travel alongside micromobility. Furthermore, MMVs present an opportunity to expand the reach of public transport by combining MMVs with public transport networks to enhance accessibility. This will need careful planning as a modal shift from walking to MMVs could reduce the health benefits from active travel.

Recent research in the UK has also concluded that e-bikes have the potential to reduce carbon emissions. Around 24 million tonnes of CO_2 per annum in England could be removed by combining e-bikes with reduced demand for car transport.[47] MMVs, particularly e-bikes, are viewed as also offering considerable health benefits and increasingly feature as part of active travel strategies. Active travel helps improve physical fitness while simultaneously contributing to improving the air quality in towns and cities.

[41] London North-East Railway. Travelling With an E-Scooter.
[42] WMG, University of Warwick (2022). Micromobility a UK Roadmap.
[43] Energies (January 2022). Determination of Electricity Demand by Personal Light EVs (Brdulak, Chaberek & Jagodzinski).
[44] DriveTech (2022). Micromobility, Navigating new technologies and the safety and business risks.
[45] Voi (June 2022). Cities made for living, Vision Statement.
[46] Fraunhofer Institute (October 2022). Do shared e-scooters and e-bikes reduce the emissions of urban transportation systems?
[47] Transport Policy (February 2022). E-bikes and their capability to reduce car CO2 emissions, Ian Philips et al.

Conclusion

Micromobility is growing globally and is currently the fastest electrifying sector within transportation. MMVs provide cheap and efficient transportation over short distances, which will help reduce congestion in urban areas. MMVs have changed people's transportation behaviours and enabled alternative transport solutions to be offered by the delivery industry. Widespread adoption in the UK will require:

- Further research into battery failure to improve battery safety and reduce the risk of fires related to charging;
- New regulations to set battery safety standards and encourage safe charging behaviours, as well as labelling of battery chemistry and recycling potential;
- Development of a regulatory regime which ensures adequate testing of battery pack BMS systems for MMVs;
- Consideration of whether the manufacturing and consumer markets for MMVs need stricter regulations and product standards; and
- An information campaign to promote standards and charging behaviours.

Overall, the UK needs to quickly consider how to include MMVs in the UK's transport strategy, taking incorporating the benefits for consumers and any implications for safety, infrastructure and sustainability. The e-scooter trials taking place across the UK are providing valuable insights into how local authorities and MMV companies can work together to enable safe and accessible transportation options in urban areas. This evidence will be invaluable and will help shape regulation on MMVs as the revolution gathers pace.

About the Faraday Institution and Faraday Insights

The Faraday Institution is the UK's independent institute for electrochemical energy storage research, skills development, market analysis, and early-stage commercialisation. We bring together academics and industry partners in a way that is fundamentally changing how basic research is carried out at scale to address industry-defined goals.

Our 'Faraday Insights' provide an evidence-based assessment of the market, economics, technology and capabilities for energy storage technologies and the transition to a fully electric UK. The insights are concise briefings that aim to help bridge knowledge gaps across industry, academia and government. If you would like to discuss any issues raised by this "Faraday Insight" or suggest a subject for a future Insight, please contact Stephen Gifford.

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