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Innovative active travel solutions and their evaluation

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Contents

1 Executive Summary

This project has reviewed the state-of-the art in developments in innovative active travel modes and investigated techniques for monitoring and evaluating their health impacts. The review has covered cycling, skateboards, scooters and electrically assisted vehicles such as Electrically Assisted Pedal Cycles (EAPC; also known as e-bikes), powered scooters, skateboards, hoverboards and Segway scooters, also known as Personal Light Electric Vehicles (PLEVs). It brings together a diverse range of evidence related to active travel and health benefits in one place, to provide a starting point for identifying fruitful areas for further work aimed at further encouraging active travel and in particular innovative forms of active travel.

The project carried out a review of the technologies involved in e-bikes, personal light electric vehicles and electrically powered mobility aids and has created a single source of reference on these technologies and the standards which are in operation or under development.

The legal and regulatory issues associated with using innovative active travel modes in England and Wales were identified. Bicycles and non-road legal vehicles (apart from vehicles for disabled people) are not permitted to be ridden on pavements (unless there are special measures to allow it), but guidance to police states that discretion is to be used in enforcing the law, taking safety into account. However the legal position about riding kick-scooters on pavements is unclear, while electric scooters are classed in the same way as a moped and are not legally allowed to be used on pavements. There are regulations governing the power and maximum speed of EAPC; in simple terms those within the EAPC regulations may be used in the same way as a standard pedal cycle while more powerful electric bikes (over 250W) are subject to the laws governing mopeds. Some simplification and clarification of the legal and regulatory aspects of using newer modes of active travel may be helpful in encouraging their safe use in future. Another issue which may affect use of such modes is the EU's intended review of the Motor Insurance Directive, which could lead to a requirement for third party liability insurance for "some non-road-traffic motoring activities".

Several sources of evidence were found which indicate the extent to which active travel has been shown to reduce the incidence and mortality associated with diseases such as cardio-vascular disease and cancer. For example over a five year period, cycle commuting in a sample of over 250,000 people in the UK was associated with a 41% decrease in incidence of all causes of mortality compared with people using non-active commuting modes. Although less physically demanding than conventional bicycles, several studies have shown that riding an e-bike also provide health benefits. In response to the growing rates of obesity and health issues associated with sedentary lifestyles, Chief Medical Officers have issued guidance on recommended levels of physical activity.

Economic appraisal techniques used for transport interventions have recently been extended to recognise the benefits to society of increased physical activity. The World Health Association's Health Assessment Tool (HEAT) can be used to estimate the economic impact of health improvements among people who cycle or walk regularly. The Department for Transport's Active Mode Appraisal Tool (AMAT) enables a range of benefits to be calculated for interventions involving active travel modes. Such developments may be expected to raise the profile of active travel when considering alternative options for transport schemes, enabling practitioners to assess the potential impacts of active travel on physical activity, absenteeism, journey quality, environmental impacts, accidents, travel time and infrastructure.

It is important to bear in mind that a shift to electrically assisted active travel modes will not make the same contribution to improving the health of the population as shifting to fully active modes. In the absence of robust data on the health benefits of e-bikes, the project developed a method for re-scaling the health benefits of cycling to apply to e-bikes using the difference in average speed. The results were similar to those achieved by a different calculation method based on oxygen uptake. This technique could be applied to adapt the current health impact assessment tools so that they can be used to assess the health benefits of e-bikes. In an example calculation for a medium-sized town in the UK this project has shown that if 10% of people commuting by motorised modes switched to e-bike, this could reduce the number of premature deaths each year by 3, with economic benefits exceeding the cost of buying the e-bikes within the first year.

To assist transport practitioners tasked with increasing use of active modes, the Propensity to Cycle Tool is designed for estimating the potential for cycling in local areas of England and Wales. The project investigated the parameters used in the tool. From this it was concluded that it would be feasible to adapt the tool to assess the propensity to use other active travel modes.

A small scale trial was carried out to investigate the potential of microscooters for active travel. The microscooters used in the trial were judged to be safe and enjoyable for short leisure trips but their small solid wheels and lack of suspension meant that they were not judged to be suitable for use on surfaces which are hard and uneven. The take up of microscooters as a form of active travel might be encouraged if they had larger wheels and some form of suspension, such as pneumatic tyres.

Technologies for monitoring and evaluating human activity levels were investigated. Some research groups have developed instrumented bicycles for investigating cycling safety and optimising cycle design. These have the advantage that they can be fitted with a range of different types of sensor with minimal impact on weight, but the disadvantages include the costs, the need for custom design and the difficulty of comparing energy expenditure between vehicles. Personal activity monitoring devices were investigated through a short survey and limited trial. The survey showed that such devices are used in a range of ways, with some being designed to monitor a range of activities, and some also monitoring heart rate. A small scale trial was carried out using devices which could monitor heart rate to assess the different levels of exercise involved in using active travel modes. The methodology developed by the project (measuring average heart beats per minute and maximum heart rate) was found to be suitable for identifying the level of effort exerted while using different active travel modes including microscooters and e-bikes; the level of effort can be considered as a proxy for the health impact of these modes. The results were used to develop recommendations for enhancing the methodology to improve the sophistication of the indicators so that it would be suitable for deriving values for the health benefits of active travel which could then be used in the evaluation of interventions to encourage active travel.

Data on mode use were analysed to assess the current and potential future levels of use of active travel modes in Great Britain. Pedal cycle traffic has shown a steady increase over the past decade. Looking simply at distance travelled and ignoring any other constraints on choice of mode, around a quarter of car trips are less than two miles and two-fifths are less than five miles, distances which are generally considered to be manageable by bicycle. The increasing availability of active travel modes which are assisted by an electric motor could encourage a shift from car for such distances, while in the logistics sector trials have demonstrated the potential for e-bikes to replace motor vehicles for last mile deliveries. As well as encouraging non-cyclists, e-bikes enable riders to travel longer distances and on hillier routes, thus extending the range of current active mode users. A number of small scale trials and local schemes have shown the potential for e-bikes to encourage a shift from car travel (in one scheme 46% of regular journeys to work on shared e-bikes were previously made by car), while a series of shared e-bike schemes attracted new riders as well as being used on longer trips (average 3 miles cycle, 5 miles e-bike). Even small increases in the distance travelled will extend the 'active mode catchment area' of facilities such as the rail network. However it is not yet possible to quantify these statements due to the limited data available on patterns of use of scooters, microscooters and e-bikes. The collection of such data would be one of the first steps before designing interventions to encourage greater use of these modes. Trends in sales of e-bikes could be used as an indication of the relative growth in the market, but the available data were not considered to be sufficiently reliable. One retailer has identified the potential for a significant increase in use of e-bikes among older people.

The growth in use of cycles, e-bikes and personal mobility devices raises issues for safety, the environment and the design of current infrastructure and the legislative framework governing their use. Issues associated with regulations, street design, provision of charging points and secure and appropriate storage/ parking when personal mobility devices, cycles and e-bikes are 'parked' which affect the take-up and use of these modes were identified. Safety risks are not yet well understood and there are environmental concerns over the extent to which batteries used to power these new types of device are being disposed of correctly.

The project concluded by identifying proposals for further work in three areas:

- Legal and regulatory aspects – to investigate the potential for clarifying and possibly simplifying the legal position of use of new active modes
- User experiences – to understand the user view and thus help practitioners to make active travel more attractive and safer
- Support for practitioners – to identify the potential for active modes and make the case for interventions to encourage their take-up and wider use.

2 Innovative active travel solutions and their evaluation

The development of vehicle battery and motor technology, and the desire for active travel options, has seen a plethora of new vehicle types emerge but there are few studies on them. It is relevant to investigate the types of technologies and their prevalence; their technical, legal and safety issues; the reasons that people use them; and the potential that they offer for encouraging modal shift away from more energy dependent and polluting technologies.

This project aims to provide insights on innovative active travel solutions and available techniques for monitoring and evaluating their health impacts. It will also facilitate TRL engaging with policy and scientific experts and help build partnerships for future research and consultancy.

The report is structured as follows:

Section 3 provides a literature review about the technologies for active travel.

Section 4 summarises the current road legislation about active transport means, pointing out the legal issues around use of technology on roads and footpaths.

Section 5 discusses the link between physical inactivity and physical health.

Section 6 and Section 7 present two tools (HEAT and AMAT) for the assessment of the health and economic impacts of introducing an active transport scheme for cycling and/or walking.

Section 8 focuses on the suitability of the online 'propensity to cycle tool' for the evaluation of the propensity to use other active modes in selected areas.

Section 9 reports on the experience with one of the fastest growing active travel technologies – microscooters, including a small scale trial.

Section 10 concerns personal tracking devices and a small scale trial of the potential for using them to evaluate the health impacts of active travel.

Section 11 presents the result of a literature review about the observed impact of the new active transport means on travel behaviour in Great Britain.

Section 12 highlights some of the challenges and issues in the use and potential spread of these technologies.

Section 13 outlines proposals for further work.

3 Active travel technologies

This section presents the results of a literature review on currently available active travel solutions. Vehicles and equipment for active travel and leisure are constantly evolving; it includes entirely human powered, assisted and powered equipment.

Entirely human powered vehicles include bicycles, trikes (possibly adapted and extended for carriage of people, animals or goods) and newer devices such as skateboards and scooters. There is also an increasing range of options mostly for children (roller blades, heelies, split scooters, etc.) which may all be used for active travel.

Assisted and powered devices are increasingly available based on recent developments in battery and motor technology. Personal Light Electric Vehicles (PLEVs) include e-bikes, powered scooters and skateboards, hover-boards and Segways. Also, mobility scooters and powered wheelchairs are a growing part of the transport mix, given the ageing population.

Electric quadricycles are attracting a certain level of interest among road users (see Appendix B); however, since they are non-human powered, they do not constitute active travel and are not part of the main body of the report.

As the focus is on roads and pavements, modes involving water (e.g. pedalo, canoe), rail tracks (hand cranked carts) and air (human powered flight) are excluded from consideration here.

3.1 E-bikes

The UK market for electrically assisted cycles is relatively immature, with about 2% of new cycles of this type. This can be compared with more mature European markets where this represents more than 20% of new cycles.

Electric bicycles (e-bikes) are equipped with an electric motor and a rechargeable battery; there are two categories of e-bikes on the market, those designed to assist the rider pedalling (vehicles also known as 'pedelecs') and models capable of entirely providing the propulsion power (power-on-demand; also known as 'twist and go'). Lighter e-bikes can travel up to 25-35 km/h, while more powerful engines enable continuous speeds of around 45 km/h; however, the maximum speed allowed is country specific.

Pedelecs can rely on a cadence or a torque sensor. With the former system the motor is turned on when the pedal effort reaches a pre-set value and gives more power the higher the pedalling frequency. This technology is based on a magnet attached to pedals and a sensor which picks up its movements. The main disadvantage of this type of pedelec is providing less power when it is needed more; for example, when cycling uphill or against a headwind, since pedalling slows down. A torque sensor overcomes this issue, because it measures the force applied to the pedals and provides more power the higher the pressure.

The motor of a power-on-demand e-bike is operated manually; the rider chooses to use the motor (or not) by switching the power on or off through a throttle. This technology can be used to assist pedalling or to fully power the bike ('twist and go' bikes).

E-bikes using a combination of these technologies are also on the market.

According to the standards set by the EU's EN15194 e-bikes are classified as bicycles if:

- The maximum motor power is 250 W
- The maximum assisted speed is 25 km/h (15.5 mph)[1]
- If fitted with a speed throttle, this cannot work independently; but assist throttles up to 6 km/h are allowed

In this case the vehicle can be used legally without registration, road tax, driving licence, insurance or the use of a crash helmet; they can be used on cycle paths.

The EAPC (Electrically Assisted Pedal Cycle) regulations, that is, the piece of legislation governing e-bikes in the UK, was updated in 2015 in order to be compatible with the European standards. The requirements listed above are now included, but there are still some differences; for example in the age restrictions, which remained 14 years as a minimum in the UK while the European standard does not give a minimum age for the rider.

Further details on e-bikes in the legislation are discussed in Section 4.2.

3.2 Trikes

Riding a trike can be the solution for those who have balance or mobility issues but still want to cycle. A number of models specific to those with disability are available. These started as simple addition to a wheel chair, to supplement models where the rider had a hand crank to power an additional front wheel. Nowadays, specific powered wheel chairs with a driven front wheel are available in this market.

Trikes also find application as heavy loads carriers for business, for example in warehouse duties or stock movement. They are all exempt from motor vehicle legislation provided that they meet the requirements listed in Section 3.1.

Various electric models are available as well as conversion kits for tricycles; vehicles can be operated through:

- A front wheel hub motor – simple to install. It is ungeared and not designed for slippery surfaces, especially if riding up-hill due to limited traction
- Crank motors – use gears and the rear wheel drive provide good traction. Not suited for heavy loads
- Mid drive motor – usually placed under the cargo box and drives the differential directly via uprated chains. Some trikes have a regenerative braking option. Ideal for commercial cargo applications
- Brushed DC Motors – cheap, robust and simple; often internally geared, offers good torque performance. Rather noisy though

[1] Note that some e-bikes are fitted with off road buttons, which allow higher speeds. The UK has deemed these are not legal, but there has been no action to prevent their use in public places.

- DC brushless Motors – they are as reliable as the brushed version, but less noisy and more efficient. They are widely used in industry
- Cadence sensor operated. In addition to pedal assisted trikes there are power-on-demand models fitted with throttles so that power can be applied without the need for pedalling (see Section 3.1 for a definition)

3.3 Personal light electric vehicles (PLEV)

Personal light electric vehicles (PLEVs) are compact portable electrically-powered vehicles, such as electric skateboards, electric kick (also push or step) scooters, self-balancing unicycles and hoverboards. The European Commission established in 2016 a Workgroup (CEN/TC 354/WG 4) devoted to the definition of standards concerning:

> "*safety, testing and performance requirements in the field of light motorized vehicles (with combustion engine or electric motor) intended for the transportation of persons and goods: go-karts, recreational and utility quads, mini quads, powered two wheelers, mini-motorcycles, dirt bikes, side-by-side vehicles, light electric vehicles and self-balancing vehicles when not subject to type-approval (i.e. covered by Machinery Directive 2006/42/EC) […] safety requirements for infrastructures when these vehicles are used […]"* (CEN, 2017).

PLEVs are divided into 4 classes:

1. Speed limit up to 6 km/h, non self-balancing, no seating position
2. Speed limit up to 25 km/h, non self-balancing, no seating position
3. Speed limit up to 6 km/h, self-balancing, optional seating position
4. Speed limit up to 25 km/h, self-balancing, optional seating position

A 25 km/h PLEV has a pedestrian mode (i.e. 6 km/h), and higher safety requirements (such as redundant power management and control system) which need to be met. All the vehicles must be fitted with a bell or with a measure (such as, a wire or radio connection) that prevents the device functioning unless the rider carries a bell.

Electric skateboard

Typical electric skateboards (or e-boards) use Lithium ion batteries with continuous power between 250 W and 2,000 W. Charging times span from one hour up to 6 hours.

Different kinds of motors are produced; they can be direct motor-to-wheel power (Direct Drive, with a motor to wheel revolution ratio of 1:1); geared; belt driven (motor placed next to the axle with a transmission belt connected to the wheel); and hub-in, that is a motor incorporated into the hub of a wheel and which directly drives it. Some skateboard models are equipped with dual in-hub motors. The higher the power the better the hill climbing ability; 25% percent of an uphill climb can be provided by two 2,000 W motors.

The speed (which can be as high as 40 km/h) is regulated through a throttle or by shifting weight, while steering is obtained by tilting the board to one or the other side. Remote controls communicate to the vehicle through radio waves or Bluetooth.

E-boards can be designed for pavement and flat ground only, or also for off-roading. The range is determined not only by the battery characteristics but also by several other parameters (such as, the rider's weight and driving style, the pressure on the board, the terrain, etc.); therefore the potential range of the same skateboard model can vary widely. The highest ranges currently declared by the manufacturers are over 60 km. Regenerative braking systems help to extend the range as well as improving braking capability. A single wheel version can also be found on the market.

Skateboard riders can find the different components on sale and assemble themselves an e-board, supported by numerous website which provide instructions and suggestions; there are also applications which use smartphones as Bluetooth controllers.

Self-balancing scooter

Self-balancing scooters, also known as 'hoverboards' or 'self-balancing boards', consist of two motorised wheels (between 17 cm and 20 cm in diameter) connected to a pad equipped with a gyroscope and balance sensors. The rider stands on the pad and by leaning forwards or backwards controls the speed (which can vary between 9 km/h and 21 km/h). Steering is possible by twisting the pads or a bar depending on the model.

Electric hoverboards, on the market since 2013, aroused concern in several occasions over devices catching fire. Some manufactures in various part of the world had to recall their products and they have also been banned by many airlines in the US (USA Today, 2015). Self-balancing scooters with only one wheel are known as unicycles.

Further details on the legal aspects of self-balancing scooters can be found in Section 4.3.

Electric stand-up and kick scooters

Electric stand-up scooters have two or three (some models have four) wheels, a deck on which the user stands, an electric motor and control handlebars. They are commonly made of aluminium and are foldable. Electric kick-scooters are a sub-group whose peculiarity is that they can also be user propelled like traditional kick-scooters. The design of some models of electric scooter (e-scooters) enables the user to install a saddle on the standing board.

Further details on e-scooters and legal issues can be found in Section 4.4.

3.4 Electrically powered mobility aids

Electrically powered mobility aids are designed to improve the mobility of people with defined impairment issues. Powered wheelchairs and mobility scooters belong to this category of vehicles.

They are divided into two categories:

- Class 2 -- can only be used on pavements and footpaths. Maximum speed allowed is 6.4 km/h (4 mph)

- Class 3 -- can go on roads (except dual carriageways and freeways), therefore they need to be equipped with hazard lights, horn, brakes, rear-view mirror and rear lights. They reach speeds over 12 km/h. The minimum age to use them is 14 years

According to Rule No. 46 of the Highway Code (DfT, 2015)

> “these vehicles MUST NOT be used on motorways. They should not be used on unrestricted dual carriageways where the speed limit exceeds 50 mph (80 km/h) but if they are used on these dual carriageways, they MUST have a flashing amber beacon. A flashing amber beacon should be used on all other dual carriageways.”

In pedestrian areas there is an issue with the unregulated use of powered wheelchairs and mobility scooters in Class 3; they should have a speed limiter for use on pavements and in pedestrian areas, to prevent them exceeding 6.4km/h (4mph). It must be noticed that these mobility aids do not have a pedometer, thus it is difficult for a user to determine whether they are travelling below that speed.

Powered wheelchair

Powered wheelchairs (also known as ‘powerchairs’ or electric-powered wheelchairs (EPWs)) are typically equipped with rechargeable deep-cycle batteries[2] whose capacity ranges from 12 Ah to 80 Ah. Batteries with smaller capacity are usually used in pairs, so that the EPW has at least one day of autonomy. Both wet and dry options can be used; the latter is often the favourite choice since they can be carried on aeroplanes without the need to load them separately in the aircraft hold for safety reasons. Depending on the model the charger can be an on-board or a separate unit; both use standard electrical sockets.

Dimensions and specific features (e.g. wheels shape and materials) vary with the environment the EPW is intended for, indoor, outdoor or indoor/outdoor. EPWs capable of travelling up to 12 km/h (8 mph), that is Class 3 powered wheelchairs, are allowed on the road as well as on the pavement.

Most of the EPWs are controlled through an arm-rest mounted joystick; alternatives are available to meet the users’ needs (for example, touchpads, iPhone applications, and sip-and-puff controllers, worked by blowing into a sensor). Some EPW models are designed to be controlled by a person walking behind the chair.

Control systems based on the detection of brain waves or nerve signals (travelling through the scalp or muscles) are currently under research. Not only the wheelchair industry and research institutes and universities are interested in brain activated devices, but also car manufacturers. For example Toyota (KD Smart Chair, 2016) and Nissan, which in partnership with the research lab EPFL (Ecole Polytechnique Federal de Lausanne) are developing a BMI (Brain-Machine Interface) (ThinkTech, 2011).

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[2] Deep-cycle batteries are lead-acid batteries designed to be regularly deeply discharged (between 45% and 75% of its capacity)

As for electric cars, EPWs are heading toward autonomous driving by streaming and analysing sensory data in real-time through cloud computing applications; in the near future EPWs will be integrated into the IoT and smart homes ('Smart wheelchairs'), enabling users to remotely control all household appliances (Leaman & La, 2017).

Mobility scooter

Mobility scooters have three, four or five wheels, a platform on which the driver can place their feet, and an adjustable steering column in the front. Mobility scooters can be found in both the DfT categories above mentioned:

- Class 2 -- small scooters, easy to transport since they are light and some can be disassembled or folded. They are small enough to be used indoors; those designed solely (or mainly) for indoor usually have front or mid-wheel drive for better manoeuvrability. The battery is limited since they are designed to cover short distances.
- Class 3 -- larger and heavier scooter; equipped with hazard lights, horn, brakes, rear-view mirror and rear lights. Ranges are typically over 40 km

Mobility scooters can have front-wheel drive or rear-wheel drive. The former is usually small and adapt to be used indoors; the rider weight capacity is 77-110 kg. The latter is used both indoors and outdoors; the weight capacity can be as high as 160 kg.

The DfT advice on the use of mobility scooters states that the user should have some form of disability (however, they are also used by some people as a lifestyle choice, but this use does not appear to be monitored):

"*The law states that a Class 2 and Class 3 vehicle may only be used by a disabled person, or by a non-disabled person who is demonstrating a vehicle before sale, training a disabled user or taking the vehicle to or from a place for maintenance or repair. In addition, a Class 3 vehicle can only be used by a disabled person aged 14 or over. A disabled person in this context is someone with an injury, physical disability or medical condition which means that they are unable to walk or have difficulty in walking*." (DfT, 2015)

3.5 Other

Roller shoes

Roller shoes allow either walking/running or sliding. They have one or more wheels embedded in the sole; through shifting the weight on the wheels the wearer can glide. Even though models for adults are produced, these are mainly sold for children.

Various new ideas and variants have appeared on the market in recent years. These are wheeled overshoes which are worn on normal trainers. The wheels are retractable and are pulled down via a switch, so that it is possible to walk/run normally or roll on them.

3.6 Summary

The review of active travel technologies in this section has identified e-bikes and e-trikes, a range of personal light electric vehicles and roller shoes as well as electrically powered mobility aids. It has summarised the circumstances in which they are designed to be used, relevant legislation concerning their use and the standards which are in operation or under development.

4 Legal and regulatory issues

This review concentrates on the situation in the UK (and even more specifically in England and Wales, as the Scottish situation may be different in detail). It has been compiled from and checked with Government sources where possible but there are several "grey" areas and it is acknowledged that some of the sources may have a particular point of view in interpreting the context. The authors are not lawyers and all information, although correct to the best of our ability, may not represent the actual legal situation.

4.1 Use of rights of way by people and vehicles

A right of way (Riddall & Trevelyan, 2016 (last supplement)) is a path that anyone has the legal right to use on foot, and sometimes using other modes of transport.

- **Public footpaths** are normally open only to walkers
- **Public bridleways** are open to walkers, horse-riders and pedal cyclists
- **Restricted byways** are open to walkers, horse-riders, and drivers/riders of non-mechanically propelled vehicles (such as horse-drawn carriages and pedal cycles)
- **Byways Open to All Traffic (BOATs)** are open to all classes of traffic including motor vehicles, though they may not be maintained to the same standard as ordinary roads
- **RUPPs (Roads Used as a Public Path)** are in the process of being re-classified as BOATs or other highways, but this process will go on for many years yet. Meanwhile their status remains ambiguous

Common law ensures the right to pass along any highway, and in the case of pavements (paths alongside vehicular roads, usually in urban or suburban areas) the pavement is usually included in the highway. This means that it is an offence to obstruct a pavement by limiting the available width available for prams, push chairs, wheel chairs or mobility scooters to pass successfully. However, it does not mean that users can cycle or drive on the pavement, unless there are special measures to allow this (e.g. a designated cycle route).

Under section 72 of the Highway Act 1835 (Crown, 1835) it is classed as an offence to ride a vehicle on the pavement. This says: "If any person shall wilfully ride upon any footpath or causeway by the side of any road made or set apart for the use or accommodation of foot passengers; or shall wilfully lead or drive any horse, ass, sheep, mule, swine, or cattle or carriage of any description, or any truck or sledge, upon any such footpath or causeway; or shall tether any horse, ass, mule, swine, or cattle, on any highway, so as to suffer or permit the tethered animal to be thereon."

Bicycles were classified as 'carriages' in 1888 and cars were classed as 'carriages' in 1903; the current Highway Code refers to section 72 by:

> **Rule 64**: "You MUST NOT cycle on a pavement."
>
> **Rule 145**: "You MUST NOT drive on or over a pavement, footpath or bridleway except to gain lawful access to property, or in the case of an emergency." (The offence of driving on a bridleway is covered by a later act)

Rule 157: "[A non-road legal] vehicle MUST NOT be used on roads, pavements, footpaths or bridleways." (The Department for Transport cited this section in 2006 when it ruled that Segways could not be legally used on pavements in the United Kingdom.)

The fact that the use of some of these devices is critically dependant on the road or pavement surface can constitute an issue. Mobility scooters, for example, may not be comfortable or useable on some uneven surfaces, and some are only for use on well-maintained surfaces. Small wheeled vehicle, and particularly those without suspension, may not be able to climb some kerbs, so that paths with dropped kerb edges are pivotal to their use. In the absence of this, a user may be forced to use the road. Another problem can rise from pavement parking, where the available pavement width is restricted by the thoughtless parking of cars. This may again force a used to travel on the road.

4.2 Specific issues with bicycles and electric bikes

4.2.1 Construction of pedal cycles

Pedal cycles, including electrically-assisted pedal cycles, can only be used on a public road in Great Britain, if they meet certain requirements (SI:1176, 1983). In the case of a pure pedal cycle (no electrical assistance) these regulations are such that the only parts that matter are the brakes. The Pedal Cycles (Construction and Use) (Amendment) Regulations (SI: 474, 2015) updated the braking requirements to the ISO 4210 Standard (BSI, 2015).

4.2.2 Pavement cycling

Cycling UK, a campaign group promoting cycling, has set out the status of pavement cycling as follows[3]

- The legislation does not refer to pavements, and neither does it refer to cyclists. That is important because there are tracks and shared use paths where cycling is not illegal
- It is an offence to drive a carriage on "any footpath or causeway by the side of any road made or set apart for the use or accommodation of foot passengers", essentially a footway next to the highway
- The law also applies to children, but as those under ten are below the age of criminal responsibility they cannot be prosecuted
- When Fixed Penalty Notices (FPNs) were introduced for pavement cycling in 1999, **Home Office** Minister Paul Boateng issued **guidance** saying that: "*The introduction of the fixed penalty is not aimed at responsible cyclists who sometimes feel obliged to use the pavement out of fear of traffic and who show consideration to other*

[3] From: http://www.cyclinguk.org

pavement users when doing so. Chief Police Officers who are responsible for enforcement, acknowledge that many cyclists, particularly children and young people, are afraid to cycle on the road, sensitivity and careful use of police discretion is required"

- The Home Office guidance was re-affirmed in 2014 by the then Cycling Minister Robert Goodwill, who agreed that the police should use discretion in enforcing the law and recommended that the matter be taken up with the Association of Chief Police Officers (ACPO). ACPO welcomed the renewed guidance, circulated it to all forces, and issued a statement referring to "*discretion in taking a reasonable and proportionate approach, with safety being a guiding principle*"

To summarise, cycling on the pavement is still an offence, but there is clear guidance that the police are supposed to exercise discretion.

4.2.3 Pedelecs

A Pedelec ("Pedal Electric Cycle") only assists the rider when they are pedalling. The **Electrically Assisted Pedal Cycles (EAPC)** Regulations state that electric bikes that have powered assistance to a maximum of 25 km/h (15.5 mph) using a motor of no more than 250 Watts (maximum continuous rated power output) are considered to be bicycles and are known as EAPCs, or electrically assisted pedal cycles (SI, 2015).

Pedelecs:

- Do not require type approval, registration, road tax, a driving licence, insurance or the use of a crash helmet.
- They can be used on a cycle path and the rider must obey the laws appertaining to a standard pedal driven bicycle.

The DfT website (DfT, 2017) says that an EAPC can have more than two wheels (for example, a tricycle or quadricycle) and must display:

[1] The power output or manufacturer of the motor
[2] The battery's voltage or maximum speed of the bike

4.2.4 'Twist and gos'

From January 1 2016, the only throttles legal within the UK's EAPC legislation are those that assist the rider without pedalling up to a maximum speed of 6 km/h (3.7 mph) – i.e. walking throttle/starting assistance only. If the rider is rolling – but not pedalling – faster than 6km/h, the throttle cuts off; using the throttle only without pedalling, to achieve the maximum allowed speed of 25km/h, is illegal (the legislation is not retrospective so 'Grandfather rights' apply to previously bought bikes). However in practice, because these are not registered and are often imported, identifying those bought in the UK before 2016 is not straightforward and imports may not adhere to the legislation.

Such electric bikes that can be powered by a throttle alone

- Have to be 'type approved' and have a plate showing its type approval number

- Where the power of 'twist and gos' cuts out at 15.5mph, they are not be considered motor vehicles and do not require registration, tax, insurance and rider licensing (like Pedelecs). However, for both types riders must be over the age of 14.

If a bike meets the EAPC requirements it is classed as a normal pedal bike. This means that it can be ridden on cycle paths and anywhere else pedal bikes are allowed.

4.2.5 Electric bicycle with motor over 250W

In Europe, there are two categories of electric bicycle in type-approval:

1. L1e-A is for powered cycles with a maximum speed of 25 km/h and maximum 1 kW of power.
2. L1e-B includes speed pedelecs (S-Pedelecs) with maximum 45 km/h and 4 kW.

Conditions for use of these vehicles are a matter for individual Member States.

In the UK, electric bikes with motors more powerful than 250W:

- Need to be registered, insured, display a number plate and are required to have MOT inspections.
- Any rider of such a vehicle must hold a current driving licence and keep to the laws relating to mopeds[4].

Anyone found riding an electric bike with a motor more powerful than 250W rated power without the correct documentation is liable to be prosecuted by the police. The rider will be open for prosecution for driving without a licence, driving without insurance, driving an unlicensed vehicle etc. If the person riding such a vehicle has a current driving licence and is prosecuted, they will receive penalty points and may even be banned from driving any motor vehicle.

It worth notice though that to determine whether a vehicle has a motor greater than 250 watts, or whether a cycle can travel at a higher continuous speed unrestricted, is a real world difficulty. This appears to be a nettle that has yet to be grasped by the regulatory authorities. TRL is actively analysing methods for determining both average and peak speed as measured by GPS, cadence monitors and low power radar devices to determine how electrically powered/assisted modes are used in the real world.

'Off-road' switches

The Department of Transport say that electric bikes fitted with 'off-road' switches or modes that enable a bike's motor to continue assisting to speeds beyond 15.5mph, do not comply with UK EAPC law. The term 'off-road' suggests that these bikes can be ridden on parkland, forests or other places away from main roads, which is not accurate. E-bikes with increased motor power (continuous rated power above 250W) or increased speed (with motor

[4] A moped is legally defined as any low-powered motorcycle with an engine capacity no greater than 50cc, and a max speed of 28mph

assistance not cutting out at 15.5mph) cannot be used legally as bicycles anywhere on land accessible by the public; when riding on private land permission would need to be obtained from the landowner.

4.3 Segways, self-balancing scooters and other active travel vehicles

The DfT considers the Segway Personal Transporter to be a motor vehicle for the purposes of the Road Vehicles (Construction & Use) Regulations 1986. Guidance from the Crown Prosecution Service (CPS, 2017) is that Segways and "self-balancing scooters" are motor vehicles and thus cannot be ridden on pavements, but are not licensed either, so are not allowed on public roads. Their use is therefore limited to those private areas which allow it; for example, some country parks, forests and caravan and holiday parks, where adults and children may use these devices, sometimes even on hire from the same park operator.

Most two-wheeled vehicles being registered are made to comply with basic safety standards in accordance with the European rules which came into operation on 17 June 1999. This is known as the European Community Whole Vehicle Type Approval (ECWVTA) and applies to vehicles capable of more than 4mph. A vehicle with a certificate of conformity to ECWVTA is eligible for licensing and registration in the UK.

However, the European Commission have indicated to the DfT that no EC whole vehicle type-approval has been sought as the Segway is not primarily intended to travel on the road (note though that the use of Segways on pavements is common in Europe). They have also stated that “If this manufacturer (or manufacturer of a similarly propelled vehicle), should eventually decide to seek EC type approval for such a vehicle intended for road travel, [the Commission] consider that it would need to be on the basis of Directive 2002/24/EC on the type approval of two or three wheel vehicles."

Once a vehicle is approved, the manufacturer should have processes in place to produce a Certificate of Conformity (CofC) for each vehicle manufactured.

The Commission has also advised the DfT that: "*Member States have the right to lay down the requirements which they consider are necessary to ensure the protection of road users (i.e. may fix the conditions for allowing non EC type-approved vehicles on its roads)*." However, in the UK we have not introduced separate legislation on this subject and there is no separate legislation for non-EC type-approved vehicles.

Certain vehicles used by disabled drivers are exempted from the “no use on pavements” requirements and these electric scooters and wheelchairs have specific regulations covering their use. They’re officially ‘Invalid carriages’ (the law is old):

- ‘Class 2’ invalid carriages are restricted to pavement use and a maximum speed of 4mph
- ‘Class 3’ are legal on the road, given appropriate lights, horn etc., with a maximum on-road speed of 8mph (4mph on pavements). The class 3s have to be registered with DVLA

It worth notice that many Class 2 mobility scooters have a maximum speed above 4 mph, but a user may not be aware of this as there is no speedometer.

Apart from those involved in the demonstration, training or repair of these vehicles, the user must have a defined physical disability.

4.4 Specific issues with microscooters and electric microscooters

4.4.1 Kick scooters

Information from ROSPA July 2003 summarises the legal aspects of kick scooters[5]:

Scooters are subject to the Toys (Safety) Regulations 1995 and must satisfy the "Essential Safety Requirements" and be CE Marked. Ideally, they should comply with the Regulations by meeting the requirements of the Toys Safety Standard EN 71.

Under Product Liability (Part l Consumer Protection Act 1987) any person injured by a defect in the scooter can sue the producer/importer for damages.

Scooters should NOT be used on the road (no certificate of conformity to ECWVTA and so no possibility to register and licence).

Most scooter users seem to ride on the pavement. However, the legal position about riding scooters on pavements seems to be unclear. It has been suggested that they are covered by the same legislation which makes it an offence to ride a bicycle on the footpath. But it seems more likely that police will decide whether or not to take action according to local circumstances.

In general, then, it is not advisable to use scooters on narrow or crowded pavements, or where they will cause inconvenience, fear or danger to pedestrians, especially those who are elderly or disabled.

4.4.2 Electric scooters

Because electric scooters are powered by a motor (an electrical one), they are classed by the Department of Transport as mechanically propelled vehicles, and therefore as motor vehicles. Note that the legislation which applies to pedelecs is very specific to bicycles so does not apply to electrically assisted scooters.

Motor vehicles with less than four wheels, and less than 410kg are classed as motorcycles according to the Road Traffic Act 1988 (Section 185). Due to their low speed they meet the subcategory of moped[4].

So officially in the UK an electric scooter is classed as a moped. “Obviously” then, using an electric scooter on the pavement is technically illegal. This would appear to be the case for scooters providing a “kick boost” as well as those with “twist and go” functionality.

According to one website (Electric scooters for adults, 2017) an electric scooter can be made legal for road use in the UK if they comply with construction regulations and are officially registered. It is claimed to be possible to personally register electric scooters for road use IF

[5] https://www.rospa.com/leisure-safety/advice/scooters/

the manufacturer can provide a certificate of conformity and at least one manufacturer (EVO, 2017) provides such certificates. The process involves a DVLA V55/5 form and a £55 fee. Currently no road tax is payable for an electric scooter but moped insurance is required and there is also a requirement to complete a short road safety test.

4.5 Summary

The legal and regulatory issues associated with using innovative active travel modes in England and Wales have been summarised in this section. Bicycles and non-road legal vehicles (apart from vehicles for disabled people) are not permitted to be ridden on pavements (unless there are special measures to allow it), but guidance to police states that discretion is to be used in enforcing the law, taking safety into account. However the legal position about riding kick-scooters on pavements is unclear, while electric scooters are classed in the same way as a moped and are not technically allowed to be used on pavements. There are regulations governing the power and maximum speed of Electrically Assisted Pedal Cycles; in simple terms those within the EAPC regulations may be used in the same way as a standard pedal cycle while more powerful electric bikes (over 250W) are subject to the laws governing mopeds.

Some simplification and clarification of the legal and regulatory aspects of using newer modes of active travel may be helpful in encouraging their safe use in future.

5 Active travel and health

It is increasingly acknowledged by governmental institutions that active travel has a huge potential in counteracting, and potentially overcoming, several issues affecting public health (see for example the report published by Sustrans (Sustrans, 2016)). The impact on health is due to both direct and indirect factors. Indirect benefits derive for example from the fact that decreasing the number of car trips in favour of active travel might reduce the incidence of serious and fatal accidents. Moreover, active travel can contribute to reducing air and noise pollution.

However, the more intuitive cause-effect link between active travel and health is in contrasting the inactivity epidemic and increasing the physical activity level in the population. It is in fact well known that insufficient physical activity is associated with both mental and physical health (see for example the report by the World Health Organisation (WHO, 2010)). Further details on this topic are reported in Section 5.1, while Section 5.2 presents research findings on active commuting and health and Section 5.3 summarises the level of physical activity in the UK. The evidence on the economic impact of active travel is presented in Section 5.4.

5.1 Health implications of physical inactivity

The World Health Organization ranks physical inactivity among the 10 leading causes of death worldwide (fourth risk factor for mortality in middle and high-income countries) (WHO, 2009); while the Global Observatory for Physical Activity (GoPA) estimates that over 5 million deaths per year are due to inactivity (GoPA, 2016).

Insufficient physical activity leads to a deterioration in overall health, contributing to a rise in, or increase in severity of, a range of diseases and other medical conditions. Strong evidence has been observed in relation to chronic diseases (DfT, 2014), such as:

- Cardiovascular disease
- Stroke
- Obesity
- Cancer (colon, and breast)
- Type 2 diabetes
- Osteoporosis
- Depression

Evidence that increasing active travel has health benefits is reported by several studies. An example is given by the meta-analysis, based on 174 articles, performed for the Global Burden of Disease (GBD) Study 2013 (Kyu & et al., 2016). According to this, individuals with a total activity level corresponding to the minimum recommended (600 MET[6] minutes/week;

[6] MET (Metabolic Equivalent): The ratio of the work metabolic rate to the resting metabolic rate. One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly.

(WHO, 2010)) had a 2% lower risk of diabetes compared to individuals declaring no physical activity. Table 1 summarises other outcomes of the study, concerning the risk of contracting five diseases (specifically, breast and colon cancer, diabetes, ischemic heart disease and stroke) among very active people compared with inactive individuals.

Table 1 Comparison of the risk of contracting specific diseases between inactive and highly active individuals (Kyu & et al., 2016)

Disease	Total activity level several times higher than the minimum recommended (≥ 8,000 MET)
Breast cancer	-14%
Colon cancer	-21%
Diabetes	-28%
Ischemic heart disease	-25%
Ischemic stroke events	-26%

Another proof of the existing relationship between physical activity and health is represented in the chart in Figure 1; this shows that the majority of people in England, Wales and Northern Ireland who are referred to a cardiac rehabilitation service do not lead an active life.

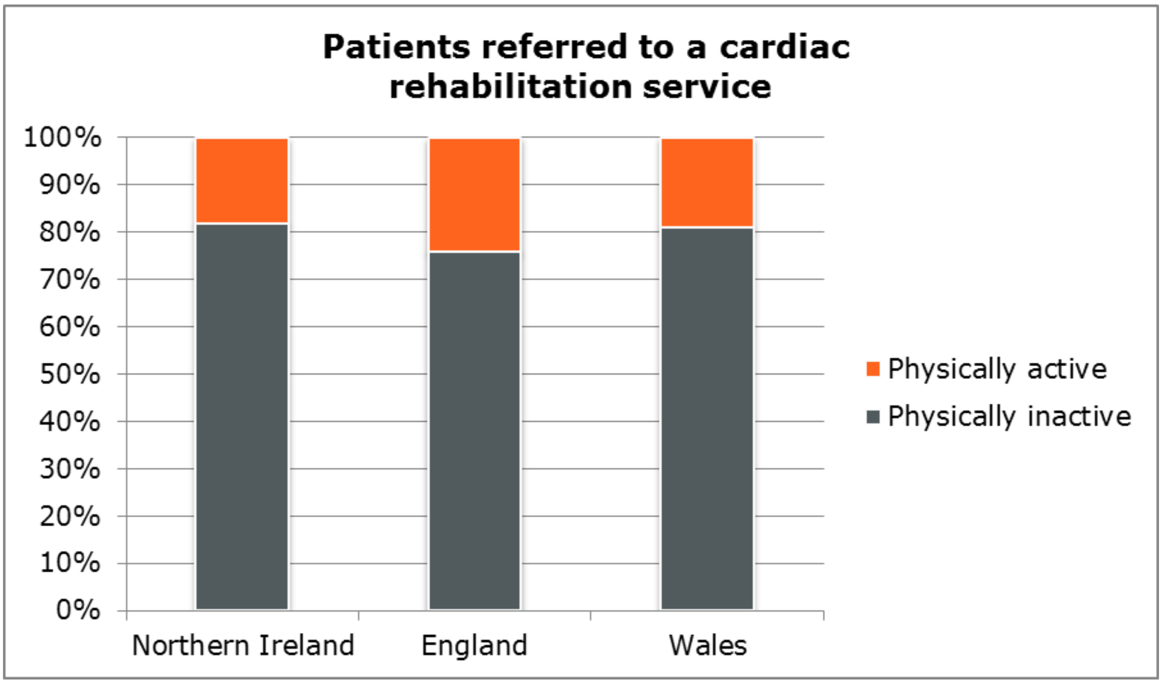


Figure 1: Percentage of the patients referred to a cardiac rehabilitation service, considered physically inactive or active (NACR, 2016)

5.2 Active commuting and health

5.2.1 Traditional modes of active travel and health

The results of a research project which aimed to investigate the link between active commuting and cardiovascular disease (CVD), all cause of mortality, and cancer incidence and mortality were published in 2017 (Celis-Morales & al., 2017). The study monitored 263,450 commuters in the UK over five years, divided into five transport mode groups, namely, non-active (used as reference group), walking, cycling, mixed including walking, and mixed including cycling. The data collected showed evidence that, regardless of gender, age, deprivation index, ethnicity, smoking habits, body mass index, leisure time, occupational and leisure physical activity, sedentary behaviour, and dietary intake:

- Both commuting by walking and by cycling were associated with a lower risk of CVD incidence and mortality; this connection was stronger for the cycling group
- Commuting by cycling was associated with the lowest risks of all-cause of mortality and cancer; the longer the mileage the stronger this relationship
- Mixed mode which includes walking was associated with a slight improvement in CVD incidence and mortality (no benefits were registered in the other categories)
- Mixed mode which includes cycling was associated with some benefits in all the categories.

More precisely, commuting by bicycle was related to a reduction of 41% in all causes of mortality, 52% in CVD mortality, 45% and 40% in cancer incidence and mortality, respectively. Table 2 summarise a comparison of the observed benefits for the four active commuting modes.

Table 2 Associations between commuting mode and prospective health outcomes for four active transport modes based on the statistical study of (Celis-Morales & al., 2017); the number is the average hazard ratio respect the non-active reference mode (between brackets, the 95% confidence interval), empty cells means that no significant association was observed.

Mode	All cause of mortality	CVD mortality	CVD incidence	Cancer mortality	Cancer incidence
Walking		**0.64** (0.45 -- 0.91)	**0.73** (0.54 -- 0.99)		
Cycling	**0.59** (0.42 -- 0.83)	**0.48** (0.25 -- 0.92)	**0.54** (0.33 -- 0.88)	**0.60** (0.40 -- 0.90)	**0.55** (0.44 -- 0.69)
Mixed-walking					
Mixed- cycling	**0.76** (0.58 -- 1.00)			**0.64** (0.45 -- 0.91	**0.68** (0.57 -- 0.81)

5.2.2 *E-bikes and health*

E-bikes can enable people who, for various reasons (e.g. because of physical impairments which make the use of a conventional bike challenging or impossible) have a sedentary life, to take up and maintain a more active life style.

In fact, even if the level of physical activity reached riding an e-bike is lower compared to a standard bicycle (s-bike), a number of studies have concluded that e-bikes can provide health benefits. Example of such findings are summarised in Table 3.

Table 3 Example of trials conducted to evaluate and compare the physical activity level reached when riding an e-bike and an s-bike

Study	Trial	Results
Physical activity when riding an electric assisted bicycle **(Berntsen & al., 2017)**	· 8 adults · Cycling on a conventional bicycle and an e-bike · Routes: one flat (8.2 km) and one hilly (7.1 km)	· In both cycling modes most time was spent in moderate and vigorous intensity physical activity · Fewer minutes were spent at moderate and vigorous intensity levels with the e-bike than with the s-bike (on hilly route: 26% lower, on flat route: 17% lower) · Fewer minutes were spent at vigorous intensity levels on the e-bike compared with s-bikes (on hilly route: 35% lower, on flat route: 15% lower)
Comparing physical activity of pedal-assist electric bikes with walking and conventional bicycles **(Langford & al., 2017)**	· 17 users of a bike-sharing system · Identical trips made by bicycle, pedelec and walking · Route: 4.43 km; hilly	· The energy required on e-bike is: ~ 24% energy required on s-bike ~ 64% energy required walking · Physical activity provided by E-bikes: - Moderate on flat and downhill segments (MET[7]>3) - Vigorous on uphill segments (MET>6)

[7] The estimated threshold for promoting/maintain health is 3 MET (Haskell & al., 2007). Guidelines indicate the range 3–6 MET as the moderate-intensity physical activity interval; while vigorous-intensity is reached over 6 MET.

Study	Trial	Results
The Electrically Assisted Bicycle An Alternative Way to Promote Physical Activity **(Louis & al., 2012)**	· 20 participants (ten trained and ten untrained in endurance) novice in the electrically assisted bicycle · 5 minutes cycling periods without electrical support, light support, or a high support · Three different speeds (16 km/h, 21 km/h, and freely chosen)	· All subjects reached the 3 MET threshold in all measured conditions · Vigorous intensity (>6 MET) was reached: - By the untrained group with no or light support at any speed - By the endurance-trained group at 21 km/h with the light support
Electric Bicycles as a New Active Transportation Modality to Promote Health **(Gojanovic & al., 2011)**	· 17 sedentary subjects · Four different modalities: walking, cycling an s-bike, and cycling an e-bike twice using two different power assistance settings · Routes: Walking - 1.7km uphill Cycling - 5.1km predominantly uphill	· All subjects reached at least 3 MET in all trials. · Vigorous intensity of physical activity (>6 MET) was reached cycling only, specifically by: - 47% subjects using high support - 88% subjects using moderate support - 100% subjects using s-bikes
Electrically Assisted Cycling: A New Mode for Meeting Physical Activity Guidelines? **(Simons & al., 2009)**	· 12 habitually active adults · Identical trips made by electrically assisted bicycle with three different level of support (no support, eco, and power support) · Route: 4.3 km on a flat track separated from motor traffic	· Moderate-intensity activity level (3–6 MET) was reached in all three conditions · Only cycling without support led to a mean intensity of at least 6.0 MET

5.3 Physical activity levels in the UK

The British Heart Foundation has compiled a report based on the latest health statistics (BHF, 2017), according to which:

- Around 39% of UK adults (i.e. around 20 million people) are failing to meet Government recommendations for physical activity
- Overall women in the UK are 36% more likely to be classified as physically inactive then men; around 11.8 million women are insufficiently active, compared to around 8.3million men
- In Northern Ireland almost half (46%) of the adult population (about 650,000 people) are physically inactive
- In Scotland almost two fifths (37%) of the adult population (1.6 million people) are physically inactive

- In Wales over two fifths (42%) of the adult population (over 1 million people) are physically inactive

The BHF also estimated that the average man and woman in the UK spends the equivalent of 78 and 74 days per year sitting, respectively. It is interesting noticing that roughly the equivalent of 64 days a year can be attributed to time spent watching TV (Ofcom, 2016).

It is noteworthy that it has been estimated that direct costs of illness as a consequence of physical inactivity (that is, the proportion of expenditure born by the NHS on diseases for which physical inactivity is a risk factor, such as ischaemic heart disease and stroke, and which is actually attributable to it (Scarborough & al., 2011) are almost £1 billion per annum to the NHS (in 2006-07 prices); while indirect costs (that is, those costs not directly attributable to the NHS, such as informal care, inferior physical and mental function, deficient physical and mental well-being, and loss of productivity due to sick leave) are around £8.2 billion per annum (2002 prices) (DfT, 2014).

The four Chief Medical Officers of the UK have issued a joint report intended *"for the NHS, local authorities and a range of other organisations designing services to promote physical activity".* Here below we report the recommendation on physical activity for adults (CMO, 2011):

- Adults should aim to be active daily. Over a week, activity should add up to at least 150 minutes (2½ hours) of moderate intensity activity in bouts of 10 minutes or more – one way to approach this is to do 30 minutes on at least 5 days a week
- Alternatively, comparable benefits can be achieved through 75 minutes of vigorous intensity activity spread across the week or combinations of moderate and vigorous intensity activity
- Adults should also undertake physical activity to improve muscle strength on at least two days a week
- All adults should minimise the amount of time spent being sedentary (sitting) for extended periods

Interestingly, from a survey conducted by BHF, it emerged that around 60% of adults are unaware of the Government's physical activity guidelines (BHF, 2017).

5.4 Economic impact of active travel

The benefits to society of increased physical activity are now recognised in DfT's Transport Appraisal Guidance (DfT, 2014). The suggested key indicators for the costs and benefits analysis (CBA) are:

1. Cycling and walking users
2. New individuals cycling or walking
3. Car kilometres saved
4. Commuter trips generated

These parameters are used to evaluate:

1. Social impacts, such as accidents, physical activity, security, severance, journey quality, option and non-use values, accessibility, and personal affordability.
2. Environmental impacts, such as air pollution, air quality, and noise pollution.

Transport accidents have a number of impacts on society, which need to be considered in appraisal, such as:

- Emotional impacts (pain, grief and suffering)
- Lost economic output from the people involved
- Medical and healthcare costs
- Material damage
- Police costs
- Insurance
- Legal and court costs

The magnitude of the impacts changes according to the severity of the casualties, that is, whether the outcomes of the accident were slight injuries, serious injuries or fatalities.

A significant proportion of benefits of active mode schemes derive from the increased physical activity in the population, which implies increased health and decreased mortality (see Section 5.1). The World Health Organisation (WHO) produced the Health Economic Assessment Tool (HEAT; see Section 6) for the economic assessment of the health benefits of walking and cycling. The tool estimates the monetary value corresponding to the reduced mortality associated to a certain increase of walking and cycling. Such benefits are also one of the parameters calculated by the DfT Active Mode Appraisal Toolkit (AMAT), which is a spreadsheet based tool designed for the appraisal of active mode scheme (Section 7).

Monetised health benefits of increased cycling and walking are so high that BCRs are higher than is the case for most transport infrastructure schemes. A study which TRL undertook for DfT and RSSB found a Benefit to Cost Ratio (BCR) of over 3:1 for investment in cycle parking at stations, with over two thirds of the benefits being from physical activity (RSSB, 2015).

Additional evidence of a positive impact on the economy has also been found in the higher productivity levels and in the fewer sick days of those commuters who walk and cycle (Hendriksen, 2010). Furthermore, it has been observed that the higher the frequency and the longer the distance travelled, the lower the absenteeism (Davis, A.; Jones, M., 2007).

Modal shifts which occur from private cars to active modes contribute to easing road traffic and reducing congestion; this implies savings in travellers' travel time, which, ultimately, translates into an indirect monetary benefit as well.

5.5 Summary

In response to the growing rates of obesity and health issues associated with sedentary lifestyles, Chief Medical Officers have issued guidance on recommended levels of physical activity. Active travel has been shown in to reduce the incidence and mortality associated with diseases such as cardio-vascular disease and cancer. Although less physically demanding than conventional bicycles, several studies have shown that riding an e-bike also provide health benefits. As well as health benefits, active travel also has economic benefits through social and environmental impacts.

6 Health Economic Assessment Tool (HEAT) for walking and cycling[8]

The idea of a tool for the economic assessments of the health impacts of walking or cycling started with Harry Rutter, from the London School of Hygiene and Tropical Medicine, in 2007. Since then several international groups and multidisciplinary experts, under the coordination of the World Health Organisation (WHO), have collaborated in the development and update of the tool, which is available on line for free (http://www.heatwalkingcycling.org/tool/).

The Health Economic Assessment Tool (HEAT) estimates the economic impact of the health improvements due to people who regularly walk and cycle. The evaluation is based on the corresponding mortality reduction in the adult population (more precisely, the age range is 20–74 years for walking, and 20–64 years for cycling). The health effects from road crashes and air pollution (AP) are also taken into consideration in the most recent versions, as well as the effects on carbon emissions.

Scope

The tool is capable of different types of assessment, such as, current/past levels of cycling or walking, comparisons over time or between specific scenarios (e.g. with or without measures taken), evaluation of new or existing projects, including benefit-cost ratio calculations. Example of the answers the tool is designed to answer are[9]:

- What would be the value if we doubled cycling in my city?
- What would be the value if we increased modal share for walking and cycling by x%?
- What would be the value if we cycled as much as – say - the Dutch?
- What would be the value if every adult in our town walked for 10 minutes more per day?
- What is the value of current levels of cycling/walking in my city?
- What would be the value of building a specific new bike path?
- What would be the value of a decrease in walking due to policy changes?

Out of scope

HEAT is designed to work on population sample and not on individuals; besides, it refers to habitual behaviours (e.g. cycling/ walking for commuting or regular leisure activities) and not to specific events. The tools statistics contain data about the adult population; therefore, children/adolescents are excluded from the calculations.

The model is not suited for population samples characterised by very high average levels of walking or cycling (e.g. bicycle courier); more precisely, the tool is not applicable to

[8] http://www.heatwalkingcycling.org/#homepage

[9] http://www.heatwalkingcycling.org/#examples

populations with average levels of cycling of about 1.5 hours per day or more, or of walking of about 2 hours per day or more.

Due to the type of default data available in the tool, calculations concerning air pollution cannot be performed for environments with very high levels of air pollution (i.e. significantly higher than 50 µg/m^3).

Assessment procedure

Figure 2 summarises the working structure of the tool. In the first stage of the modelling procedure the user is required to follow four steps (WHO, 2017):

1. **Define the 'use case', that is the scenario which needs to be modelled**: walking and/or cycling, time and geographic scale, whether it is about assessing one specific situation or a comparison between scenarios, and which impacts to assess (physical activity, air pollution, crash risk, carbon emission, etc.).
2. **Provide input data per person and day:** volumes of travel, duration, distance, trips and steps, frequency, modal share and shift, information about the population (e.g. size, age range).
3. **Provide information for data adjustments:** new versus reassigned, whether shifted from other modes, whether for transport or recreation, in or away from traffic.
4. **Review of calculation parameters**: the tool has both fixed and changeable default values (which are, for example, uptake period, trip or step length, speeds, mortality rate, air pollution concentration).

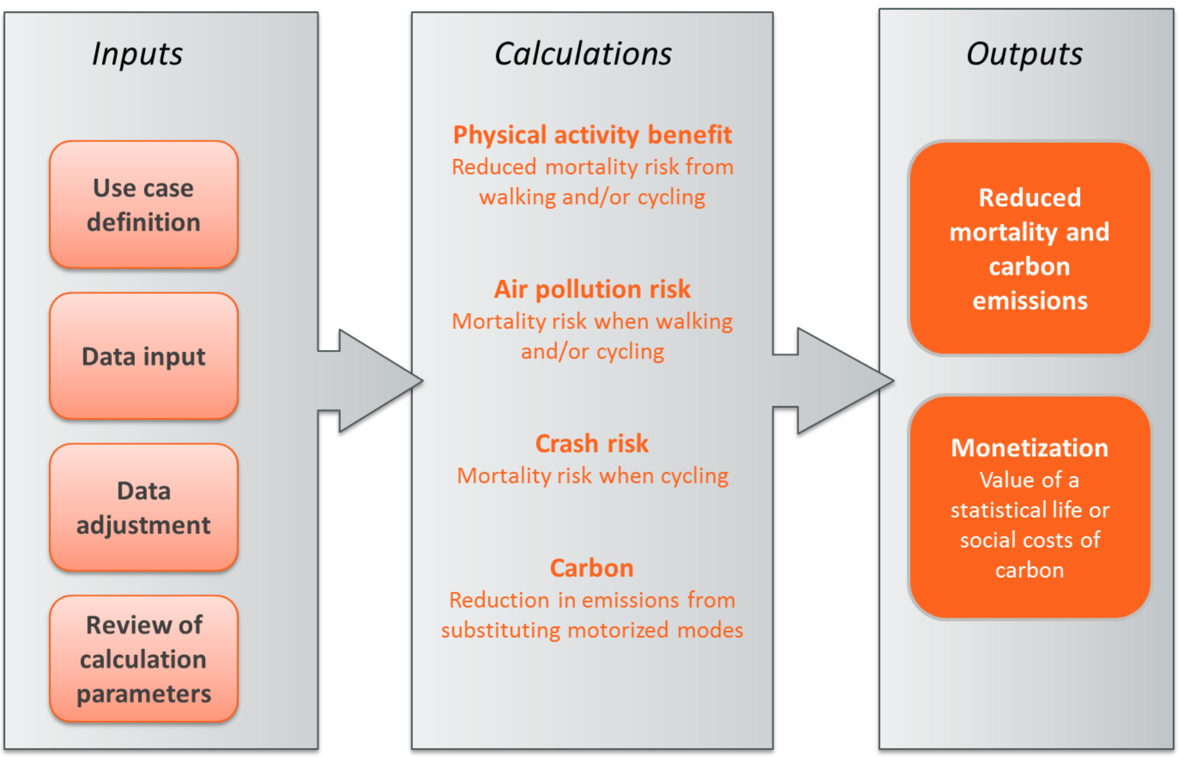


Figure 2 Schematics of the HEAT methodology (adapted from (WHO, 2017))

The calculation of the reduced mortality risk from walking and/or cycling due to health improvements is based on the formula:

$$(1 - RR_{death}) \times \left(\frac{Local\ volume\ of\ walking\ or\ cycling}{Reference\ volume\ of\ walking\ or\ cycling}\right)$$

Where, RR_{death} is the relative risk of death in underlying studies (walking: 0.89; cycling: 0.90).

The mortality risk associated to air pollution when walking and/or cycling is obtained from:

$$(1 - RR_{PM}) \times \left(\frac{AP\ exposure\ of\ active\ mode\ users}{Reference\ AP\ exposure}\right)$$

Where, RR_{PM} is the relative risk of death per 10 µg/m3 increase in $PM_{2.5}$ in underlying studies (1.07).

The mortality risk for involvement in a fatal crash when cycling is:

$$(Local\ volume\ of\ active\ mode) \times \left(\frac{Countrywide\ fatal\ crashes}{Countrywide\ volume\ of\ active\ mode}\right)$$

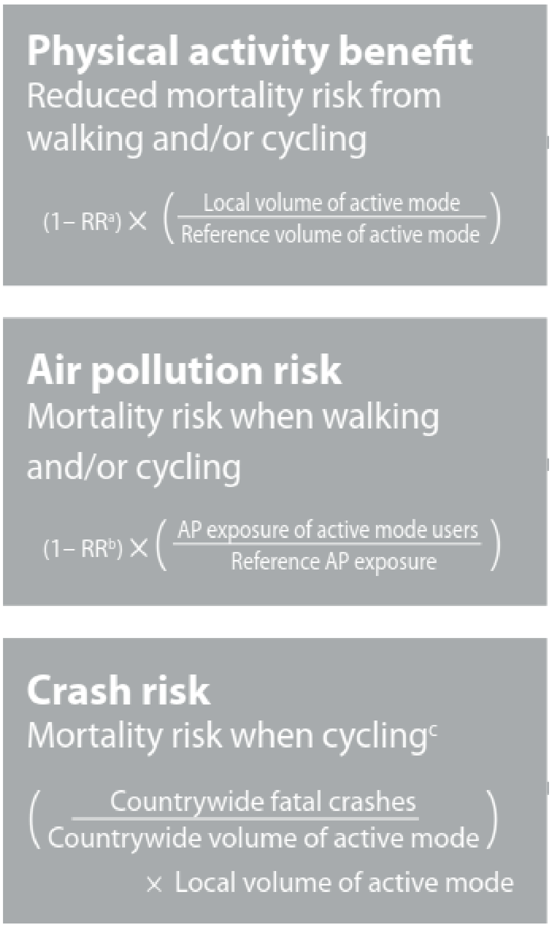
Note that the equivalent parameter for the walking scenario is still under development.

Finally, the reduction in the volume of carbon emission arising from modal shift from motorised transport to active travel is:

$$(Local\ volume\ of\ active\ modes\ shifted\ from\ motorised\ modes) \times (Carbon\ emission\ factors)$$

6.2 HEAT and the health impact assessment for e-bikes

HEAT is designed for assessment on a population level, aged between 20 and 74 years for walking, and between 20 and 64 years for cycling. The health effects are evaluated considering the physical activity involved (i.e. walking or cycling), road crashes and air pollution. Formulae used by the model are summarised in Figure 3.



[a]RR = Relative risk of death
[b]RR = Relative risk of death per 10 µg/m^3 increase in $PM_{2.5}$

Figure 3 Health assessment calculation in HEAT 4.0 (taken from the HEAT user guide (WHO, 2017))

6.2.1 Assumptions

The following key assumptions are used for the evaluation of health impacts (taken form the tool website[10] and the user guide (WHO, 2017)):

- The relative risk data from the meta-analysis, which includes studies from China, Europe, Japan and the United States, can be applied to populations in other settings.
- The tool applies a linear relationship between walking or cycling duration (assuming a constant average speed) and the mortality rate. Thus, each 'dose' of walking or cycling leads to the same risk reduction, up to a maximum of about 60 minutes of

[10] http://www.heatwalkingcycling.org/#assumptions

cycling or walking per day (447 minutes cycling and 460 minutes of walking per week).

- The mortality rate and air pollution exposure are related linearly
- The populations assessed do not disproportionately consist of sedentary or very active individuals. This could lead to a certain overestimation of benefits in highly active populations, or a certain underestimation of benefits in less active ones.
- Any walking assessed is of at least moderate pace, i.e. about 4.8 km/hour (3 miles/hour), which is the minimum walking pace necessary to require a level of energy expenditure considered beneficial for health; for cycling, this level is usually achieved even at low speeds.
- No thresholds of active travel duration have to be reached for health benefits.
- The relative risks of reduction in all-cause mortality from walking and cycling are the same in men and women.
- The relative risks of reduction in all-cause mortality from walking and cycling are the same across adult age groups (i.e. 20-74 and 20-64, respectively).
- A 5-year build-up time is needed for health benefits from regular physical activity to manifest in full, based on expert consensus. In a single-case assessment, a steady-state situation is assumed (i.e. active travel, and therefore physical activity took place in previous years already) and no build-up time for the health effects is applied.

Note that in scenarios where there is a modal shift from motor vehicles to active travel, HEAT does not consider the consequent pollution reduction for the calculation of health benefits.

6.2.1.1 Crashes

HEAT has a simplified approach to the assessment of road crashes; the generic estimate of road crash risk for cycling is based on national statistics, and it is obtained by dividing the total number of fatal cycling crashes by the total number of kilometres cycled for each country.

HEAT 4.0 does not consider variations in the exposure to motorized traffic; this is an option which might be available in a later version of the tool.

Moreover, HEAT does not consider injuries from road crashes since "*the currently available data sources and the lack of internationally standardized approaches to definitions and to collecting information on road injuries do not yet allow non-fatal outcomes to be included*". However, such assessment may be included in later versions.

6.2.2 Input data

The tool performs calculations based on three kinds of input data:

1) **Provided by the user**

These are necessary to define the use case, and include:

- The active travel mode to assess (either walking or cycling)
- Geographic scale (country, city, or sub-city level)
- Country (and city, when applicable)
- Single scenario or comparison of two scenarios
- Year of the reference case (and comparison case, when applicable)
- Number of years over which assess benefits
- Impacts to be assessed (physical activity, air pollution, crash risk, and carbon emissions)
- Choice of data for the motorised mode (default values or defined by the users)
- Data on the active travel modes selected (amount of time per person per day)
- Age range of the population
- Investment costs (if any).

Additional information on the active mode(s) under assessment can also be inputted; these are: proportion excluded, temporal and spatial adjustment, uptake time for active travel demand, proportion of new trips, proportion of reassigned trips, proportion of shifted trips, proportion in traffic, proportion for transport, traffic conditions, change in crash risk, and substitution of physical activity.

2) **Default values**, which are already available in the tool, but they can be overwritten by the user. These include (parameters which refer to cycling are in colour):

- Average number of trips per day using all likely modes (3 trips/person/day)
- Average walking speed (5.3 km/h)
- Average cycling speed (14.0 km/h)
- Average distance per walking trip (1.3 km)
- Average distance per bicycle trip (4.1 km)
- Time frame for calculating mean annual benefit (10 years)
- Average length of walking steps 72 cm)
- Reduction in crash rate over time (non-linear adjustment; 0% - HEAT advisory group decision)
- Mortality rates per country (based on the data collected by the World Health Organization (WHO, 2014); see an example of data extracted for the UK in Figure 4)
- Statistical life data (collected by The Organisation for Economic Co-operation and Development (OECD, 2012)).

Diagnosis	Crude death rate per 100 000	Number of deaths	% of all deaths
Pedestrian injured in collision with pedal cycle	0.0023	1	0.0005
Pedestrian injured in collision with two- or three-wheeled motor vehicle	0.016	7	0.0038
Pedestrian injured in collision with car, pick-up truck or van	0.178	78	0.0429
Pedestrian injured in collision with heavy transport vehicle or bus	0.0845	37	0.0203
Pedestrian injured in collision with railway train or railway vehicle	0.0571	25	0.0137
Pedestrian injured in collision with other nonmotor vehicle	0	0	0
Pedestrian injured in other and unspecified transport accidents	0.1872	82	0.0451
Pedal cyclist injured in collision with pedestrian or animal	0	0	0
Pedal cyclist injured in collision with other pedal cycle	0	0	0
Pedal cyclist injured in collision with two- or three-wheeled motor vehicle	0	0	0
Pedal cyclist injured in collision with car, pick-up truck or van	0.0388	17	0.0093
Pedal cyclist injured in collision with heavy transport vehicle or bus	0.0342	15	0.0082
Pedal cyclist injured in collision with railway train or railway vehicle	0	0	0
Pedal cyclist injured in collision with other nonmotor vehicle	0	0	0
Pedal cyclist injured in collision with fixed or stationary object	0.0114	5	0.0027
Pedal cyclist injured in noncollision transport accident	0.0411	18	0.0099
Pedal cyclist injured in other and unspecified transport accidents	0.0662	29	0.0159

Figure 4 Mortality by detailed cause of death in the UK in 2013 for the age group between 20 and 74 (WHO, 2014)

3) **Background figures**, which cannot be changed. These are based on numerous epidemiological studies, thus they are considered to be the best estimates available (see Table 4, Table 5, and Table 6).

Table 4 General background values based on HEAT consensus and core group

Description	value	unit
Time needed to obtain full health impacts in single case assessment	0	years
Time needed to obtain full health impacts in two cases assessment	5	years

Table 5 Background values regarding physical activity

Description	value	unit
Capped risk reduction for walking	30	%
Capped risk reduction for cycling	45	%
Relative risk for cycling	0.903	ratio
Relative risk for walking	0.886	ratio
Reference duration of cycling	100	minutes/person/week
Reference duration of walking	168	minutes/person/week
Relative risk for cycling without air pollution effect	0.899	ratio
Relative risk for walking without air pollution effect	0.883	ratio

Table 6 Background values about air pollution

Description	value	unit
Relative risk for PM2.5	1.07	ratio
Reference concentration for PM2.5	10	u/m^3
Conversion rate PM-exposure for walking	1.6	ratio
Conversion rate PM-exposure for cycling	2	ratio
Conversion rate PM-exposure for using a car	2.5	ratio
Conversion rate PM-exposure for using public transport	1.9	ratio
Minute ventilation for walking	1.37	m^3/hr
Minute ventilation for cycling	2.55	m^3/hr
Minute ventilation for car	0.61	m^3/hr
Minute ventilation for public transport	0.61	m^3/hr
Minute ventilation for sleep	0.27	m^3/hr
Minute ventilation for rest	0.61	m^3/hr
Activity duration for sleeping	480	minutes/person*day

6.2.3 Applicability to e-bikes

The tool calculates the health benefits involving cycling based on information about s-bikes; these data are:

- Average cycling speed (default data)
- Average distance per bicycle trip (default data)
- Mortality rates per country (default data)

- Relative risk for cycling (background data)
- Relative risk for cycling without air pollution effect (background data)
- Conversion rate PM-exposure for cycling (background data)
- Minute ventilation for cycling (background data)

The tool as such does not allow the user to model scenarios including e-bikes, since the only figures the user can overwrite are the 'default data'. To this is added the fact that this type of statistical data for e-bikes in the UK is still scarce.

Nevertheless, it is possible to explore to which extent the tool can be used to model scenarios which include e-bikes introducing a minimum level of approximations only.

> ***First assumption***
>
> *Road accident statistics are the same* for both s-bikes and e-bikes

An option can be focusing on that percentage of the people who do not cycle to work, but who would do it, if the effort required was lower; in other words, people who do not ride an s-bike to work, but would ride an e-bike. Under these hypotheses, we can assume that the average distance is the same travelled by standard and electric bicycles; the only difference is in the energy required for pedalling.

We also assume that road accidents involving e-bikes are equal, both in rate and outcome, to those concerning s-bikes (a condition that is not necessarily true, but the lack of data does not allow better inferences).

The two major impacts on the evaluation of health benefits would therefore involve:

[1] The level of physical exercise

[2] The level of inhaled carbon dioxide and air pollutants

> ***Second assumption***
>
> The average distance is the same for both s-bikes and e-bikes

6.2.3.1 Level of physical exercise on e-bikes compared to s-bikes

Even though smaller than those achieved cycling a conventional bicycle, health benefits obtained by riding e-bikes have been documented (Gerike, 2016; Berntsen & al., 2017). If we express the physical activity level reached riding an e-bike as a proportion of what is achievable by riding a conventional bike, we can 'simulate' the level of physical exercise reached on e-bikes by appropriately rescaling the distance which is contained as a standard value in HEAT. In other words, we can calculate the distance which, if travelled by an s-bike, would require the same amount of energy as for riding an e-bike for 4.1 km.

To this end, we could use the results published in the study ''Biomechanical, cardiorespiratory, metabolic and perceived responses to electrically assisted cycling" (Sperlich, 2012), where it is stated that they observed a reduction in the energy expenditure (EE) of about 36.5% in e-bike cyclists.

Based on this value, and assuming the relationship between EE and distance is linear, we can estimate that the EE of a cyclist riding 4.1 km on an e-bike which is equivalent to cycling 4.1 km - (36.5% x 4.1 km) on an s-bike; that is, 2.77 km.

However, despite what is declared in the user guide, neither the average distance nor the time spent travelling can be changed in HEAT. It is instead possible to overwrite the speed value. The default value for cycling speed is 14 km/s, which means that 0.298 hours is the commuting time considered in the tool, since:

Time = distance / speed = 4.1 km / 14 km/h = 0.298 hours

First adjustment

Speed changed to 9.3km/h (from 14km/h default value)

The user can then calculate the speed required to travel 2.77 km in 0.298 hour, i.e.:

Speed = distance/time = 2.77 km / 0.298 h = 9.3 km/h

That is to say, to simulate the EE of an e-bike commuter travelling 4.1 km in 0.298 hours, we consider an s-bike cyclist riding the same distance at 9.3 km/h.

6.2.3.2 Level of inhaled carbon dioxide and air pollutants riding an e-bike compared to riding an s-bike

The impact of air pollution depends on the inhaled dose of air and the concentration of pollutants in it. More specifically, it depends on the ventilation, the duration of the physical activity involved, and the exposure (WHO, 2015):

$$Inhaled\ dose\ \left(\frac{mg}{day}\right) = Minute\ ventilation\ (\frac{m^3}{h}) \times Duration(\frac{h}{day}) \times Concentration(\frac{mg}{m^3})$$

(Equation 1)

Assuming that the exposure is roughly the same for the two cycling modes, the difference is in the total ventilation for a given journey; this value depends on the duration of the journey and on the ventilation rate.

Compared to s-bikes, e-bikes enable quicker commuting journeys, besides lower volumes of inhaled air (Berntsen & al., 2017) (assuming that the e-cyclists are not maximising the effort), therefore the expectation is that the health impact of exposure to CO_2 and other pollutants is lower than using s-bikes. The evaluation of the magnitude of this difference is not trivial though, since the risk associated to the inhalation of pollutants is not linear, as shown by the formula (WHO, 2015):

$$Mortality\ due\ to\ exposure = Mortality\ rate\ in\ travellers \times \left[1 - \frac{1}{Exp\left[Ln(RR_{10}) \times \frac{Eq}{10}\right]}\right]$$

(Equation 2)

Where, the *mortality rate in travellers* is the proportion of mortality among travellers (i.e. the mortality rate in the city/region multiplied by the number of travellers); RR_{10} is the relative risk per each increment in 10 mg/m^3 of pollutant inhaled; and *Eq* is the Equivalent change in the pollutant concentration (expressed in mg/m^3), quantity which is directly proportional to the inhaled dose (Equation 1).

Since the figure for the ventilation is a background value in HEAT, i.e. it cannot be changed by the user, the adjustment necessary to simulate e-bikes needs to occur elsewhere. In particular, the users can change the figure relative to the $PM_{2.5}$ concentration, so that the product of this by the minute ventilation is the desired value.

For example, given that the background value for the ventilation while cycling on an s-bike is 2.55 m^3/hour (V_s) and that the default figure for the $PM_{2.5}$ concentration in Reading is 9.9157 $\mu g/m^3$ (C_R), we can calculate the concentration of $PM_{2.5}$ (c) such that:

$$c \cdot V_s = C_R \cdot V_e$$

Where, V_e is the ventilation riding an e-bike.

Assuming that the ventilation when riding an e-bike is proportional to the oxygen uptake[11], and using the result of a study which measured an oxygen uptake 33% lower for e-bikes than s-bikes (Sperlich, 2012), we have:

$$c = \frac{C_R \cdot V_e}{V_s} = 9.9157\mu b/m^3 \cdot 0.33 = 6.64\ \mu g/m^3$$

Second adjustment

Change $PM_{2.5}$ concentration to 6.64 $\mu g/m^3$

6.2.4 Assessment example

The scenario described in the previous section has been tested on the town of Reading. The sources used for the data are given in Appendix A.

6.2.4.1 Inputs

- Active travel mode assessed
  - Cycling
- Geographic scale
  - City level
  - UK
  - Reading
- Comparison and time scale
  - Two cases
  - Year for the reference case: 2018
  - Number of years the benefits are calculated for: 20
- Impacts
  - Physical activity
  - Air pollution

[11] Oxygen consumption or per kilogram of body weight

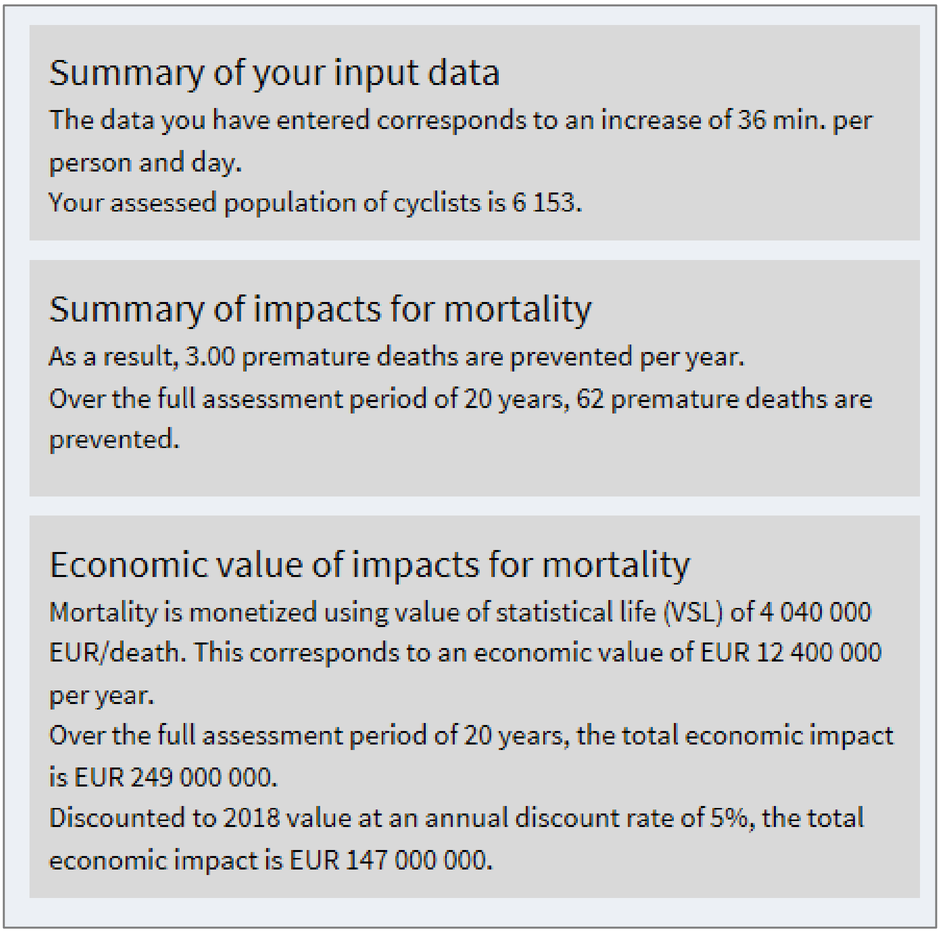
- Volume data active modes
    - Cycling data for the reference case: 0 min/day/cyclist
    - Cycling data for the comparison case: (25min * 2)*5 days/7 days ≅ 36 min/day/cyclist
- Population data
    - Population in the reference case of the cycling assessment: 6,153
    - Population in the comparison case of the cycling assessment: 6,153
- General adjustment
    - Proportion excluded: 0%
    - Temporal & spatial adjustment: 0%
    - Take-up time for travel demand: 0 years
- Contrast characteristics
    - Proportion for transport: 100%
- Other adjustment:
    - Proportion "in traffic": 90%
    - Substitution of physical activity: 0%
- Investment cost : 0
- Calculation parameters (default values changed)
    - Average cycling speed: 9.3 km/h
    - Pollution concentration changed to: to 6.64 μg/m3

6.2.4.2 Output

The results, which are summarised in the HEAT output Figure 5 below, indicate that in a medium-sized town, if availability of e-bikes led to 10% of the people who travel to work by motorised modes shifting to commuting by e-bike, the health benefits of improved physical activity would be equivalent to preventing 3 premature deaths each year, with a value of €12.4m per year (note that this calculation takes into account the health benefits from the increased physical activity only, but benefits could be higher if the corresponding lower levels of congestion and pollution are considered).

In economic terms, this implies that the cost of purchasing the e-bikes would be paid back within the first year, assuming a purchase cost of less than €2,000.

There are of course other economic impacts which are not taken into account in this assessment, such as the impacts of reduced congestion and emissions, and fewer public transport users, but it does indicate the scale of health benefits and rapid rate of return on investment in e-bikes. Moreover, a user who has purchased an e-bike may well use it as a means of transport other than for simple commuting, so that the benefit of additional exercise potential is even greater. This is a form of suppressed demand, where new transport methods encourage vehicle use.


Summary of your input data

The data you have entered corresponds to an increase of 36 min. per person and day.

Your assessed population of cyclists is 6 153.

Summary of impacts for mortality

As a result, 3.00 premature deaths are prevented per year.

Over the full assessment period of 20 years, 62 premature deaths are prevented.

Economic value of impacts for mortality

Mortality is monetized using value of statistical life (VSL) of 4 040 000 EUR/death. This corresponds to an economic value of EUR 12 400 000 per year.

Over the full assessment period of 20 years, the total economic impact is EUR 249 000 000.

Discounted to 2018 value at an annual discount rate of 5%, the total economic impact is EUR 147 000 000.

Figure 5 HEAT assessment output for the Reading example

6.3 Summary

The HEAT tool can be used to estimate the economic impact of health improvements among people who cycle or walk regularly. A shift to electrically assisted active travel will not make the same contribution to improving the health of the population as shifting to fully active modes. In the absence of robust data on the health benefits of e-bikes, the project developed a method for re-scaling the health benefits of cycling to apply to e-bikes using the difference in average speed. The results were similar to those achieved by a different calculation method based on oxygen uptake. In an example calculation for one town it was estimated that if 10% of people commuting by motorised modes switched to e-bike, the economic benefits would exceed the cost of buying the e-bikes within the first year. The technique developed could be used to adapt current tools to assess the benefits of e-bikes.

7 Active Mode Appraisal Toolkit (AMAT)

7.1 Scope

The Transport Analysis Guidance (TAG) Unit A5 published by DfT contains the guidelines for performing appraisals of interventions aimed at active modes (DfT, 2017). The key parameters considered for the appraisal are shown in Table 7.

Based on these recommendations, DfT have developed AMAT (Active Mode Appraisal Toolkit), a spreadsheet based tool[12], with the aim of helping scheme promoters with the appraisal of active modes (DfT, 2018). Figure 6 shows, as an example, the output page of the tool.

AMAT does not model other transport modes apart from walking and cycling; unlike HEAT which is applicable to the adult population only, AMAT considers all ages.

7.2 Benefits calculated by AMAT

The current version of the tool calculates the benefits based on the parameters of Table 7 (see subsections for further details).

Following the WebTAG A5.1 recommendation, AMAT provides the user with the possibility of including a 'decay rate' factor in the calculations, which represents the decreasing impact with time of a cycling scheme. The suggested assumption for infrastructure investments for active modes is 0% decay rate; whereas, for a revenue-funded initiative (e.g. cycle training or personalised travel planning) this percentage might be positive.

Table 7 Key indicators for the economic appraisal of active travel schemes indicated in TAG Unit A5.1 (Source: Table 2 in (DfT, 2017)**)**

Indicator	Used to appraise
Cycling and walking users	Journey quality
New individuals cycling or walking	Physical activity Journey quality
Car kilometres saved	Accidents GHG emissions Air quality Noise Indirect tax revenue Travel time (decongestion)
Commuter trips generated	Absenteeism

[12] The last version of AMAT was released in April 2018

7.2.1 Physical activity impacts

The health benefits as result of the increased number of active travellers are associated with a change in mortality, which can be considered to have a monetary value. The literature evidence which justifies this approach is the same as in HEAT.

The tool assumes that the new users (that is, the new cyclists and pedestrians) are not already active; therefore they receive the entire health benefit.

7.2.2 Absenteeism Impacts

The improved health from the increased physical activity can also impact the level of short term absence from work. For this evaluation, data on the number of new walkers and cyclists who are commuting, the time per day they will spend active, and average absenteeism rates and labour costs, are needed (TfL, 2004).

7.2.3 Journey quality impacts

AMAT includes empirical coefficients used for the evaluation of the impact that changes in the infrastructure would have on people who might consider walking or cycling to be a viable option for commuting short distances (7.5 miles or less)[13]. The aspects considered are:

- For pedestrians:
    - Street lighting
    - Kerb level
    - Crowding
    - Pavement evenness
    - Information panels
    - Benches
    - Directional signage
- For cyclists:
    - Off-road segregated cycle track
    - On-road segregated cycle lane
    - On-road non-segregated cycle lane
    - Wider lane
    - Shared bus lane
    - Secure cycle parking facilities

As recommended in TAG Unit A5.1, the ‘rule of a half’ is applied to the evaluation of the impact of improvements in journey quality; that is, current users fully benefit from the change, whilst new users experience half of benefits.

[13] This approach is one of the three mentioned for forecasting the levels of cycling and walking in Section 2 of the TAG Unit A5.1 document (the other two being, comparing with similar schemes; and Sketch Plan Methods, which are based on data set on demographics and factors (such as, car ownership, cost of travel by each mode, incomes and local policies) which can influence travellers’ choice.

7.2.4 *Environmental impacts*

The reduced number of vehicle kilometres corresponds to less noise and less emission of pollutants (which means, improved local air quality and less Green House Gases in the atmosphere).

Tag Unit A5.1 advises about considering also other environmental factors such as the impact on landscape and biodiversity; however, they are not included in AMAT.

7.2.5 *Accident benefits*

TAG Unit A5.1 states that in order to evaluate the benefits/disbenefits on accidents it is necessary to assess "*changes in the usage of different types of infrastructure by different modes and the accident rates associated with those modes on those types of infrastructure*"; however, the current AMAT version calculates the benefits due to the reduced vehicle kilometres only, and not the direct benefits of increased cycle safety.

7.2.6 *Travel time, Indirect tax revenue, and infrastructure impacts*

AMAT evaluates the impacts of the reduced vehicle kilometres in terms of the benefits due to decongestion and the correspondent reduction in the indirect tax revenue (fuel duty).

The tool also considers the benefits of reducing damage to infrastructure (e.g. road surfaces).

Not included in the tool, but part of the DfT guidelines, is the calculation of the benefits derived from the time saved by pedestrians and cyclists through the provision of quicker or shorter routes.

7.3 Summary

AMAT is an appraisal tool which enables a range of benefits to be calculated for interventions involving active travel modes and considers all age groups. In contrast, HEAT can also model other transport modes apart from walking and cycling but is applicable to the adult population only. The tool can assess the impacts of interventions aimed at walking and cycling on physical activity, absenteeism, journey quality, environment, accidents and reduced vehicle kilometre but does not calculate time savings from quicker or shorter routes.

Analysis of Monetised Costs and Benefits (in £'000s)	
Congestion benefit	173.98
Infrastructure	0.96
Accident	18.83
Local Air Quality	0.19
Noise	1.32
Greenhouse Gases	6.67
Reduced risk of premature death	3663.60
Absenteeism	904.94
Journey Ambience	1540.05
Indirect Taxation	-27.85
Government costs	3265.47
Private contribution	0.00
PVB	6281.72
PVC	3264.51
BCR	**1.92**

Benefits by type:

Mode Shift	174.10	2.8%
Health	4568.54	72.7%
Journey Quality	1540.05	24.5%

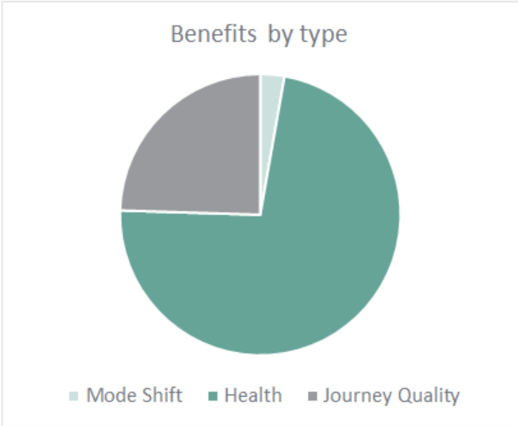


Figure 6 Example of AMAT output page

8 Review of the propensity to cycle tool

The review of the Propensity to Cycle Tool and associated datasets (www.pct.bike) is aimed at understanding classifications of the built environment in terms of their suitability for application to different active travel options.

8.1 Purpose of the tool

Funded by DfT, EPSRC and ESRC, the Propensity to Cycle Tool is designed to estimate cycling potential in geographically disaggregated areas of England and Wales to assist with prioritising investments and interventions to promote cycling.

It can be used as a strategic planning tool at a regional level or at a small scale for specific corridors.

The tool can be used to support business cases, e.g.

- To justify selection of areas and routes for cycling investment
- To estimate impact of new infrastructure that might cause or overcome severance of cycle desire lines
- To make direct estimates of benefits for health, economy and carbon reduction.
- To estimate other benefits not generated by the tool, e.g. congestion reduction and absenteeism

The tool is not intended to predict uptake in cycling following an infrastructure investment, but it can contribute to such estimates.

8.2 Core data

The core data consists of origin-destination pairs for travel to work in England and Wales from 2011 Census. This consists of the mode used for longest part of the journey by distance (data set disaggregates O-D pairs by mode). It is available for two 'levels' of area:

- Middle layer super output areas (MLSOA) - administrative regions with populations of 7500
- Lower layer super output areas (LLSOA) – administrative regions with populations of around 1560 (safeguarded dataset).

Enhancements to the core data

Data has been enhanced to include:

- Number of male and female commuters and number of male and female cyclists in each O-D pair
- Background mortality rates for new and existing cyclists under different scenarios
- Distance and gradient of the fastest route in each O-D pair (based on the fact that the tool is designed to help prioritise where to put new infrastructure), using a

routing algorithm developed by CycleStreets which finds the fastest route between points (defined by the shortest distance but taking account of hills) (see Section 8.3).

8.3 Modelling

For all O-D pairs with a fastest route distance <30km, the relationship between the proportion of commuters cycling and fastest route distance and route gradient is estimated. The model includes a distance decay term and an interaction effect to reflect the fact that steeper slopes are a stronger deterrent for people travelling intermediate distances. Data from the NTS and equivalent surveys in the Netherlands and Switzerland were used to develop model parameters.

CycleStreets – classification of the built environment

The CycleStreets journey planning algorithms which are the basis of selecting the fastest route between origins and destinations of cycle to work journeys in the Propensity to Cycle Tool take account of two key features of routes:

- Hills – routes have elevation profiles (presumably derived from OpenStreetMap data); the fastest route is calculated taking into account the delay of going uphill and the savings in time of coming downhill
- Quietness (cycle tracks and paths off road score 100%, quiet streets score 75% and shared-use facilities 80%, busy roads score 50% or less), with this percentage being used to 'extend' the route length (e.g. a 50% score on a link would lead to the length of that link being treated as twice a long); values are adapted with feedback from users but not yet taking account of variations with time of day

In the CycleStreets journey planner it is possible to obtain the quietest route, the fastest route and a 'balanced' route. However the Propensity to Cycle Tool uses the fastest routes generated by CycleStreets without taking account of quietness, because it is designed to prioritise where to put new infrastructure.

Scenarios

These are used to explore cycling futures in England and Wales, framed in terms of removal of different infrastructural, cultural and technological barriers to choosing cycling for short to medium distances. The impacts of those scenarios are estimated for mode shift, health benefits of physical activity and reductions in CO_2 emissions.

Zone level estimates and the route network

O-D pairs are aggregated to give zone-level results and to give bi-directional lines which are output in downloadable data files and in a visualisation tool (see Figure 7).

8.4 Extending the tool to include other active travel

The census data on which the tool depends records walking and cycling in cases where it is used for the longest part of the work journey, but not other active modes such as e-bikes, skateboards or scooters.

The O-D pairs are available as open access datasets at both MSOA and LLSOA level. The enhanced data produced within the project would be useful, but additional analysis of NTS and other data would be necessary to establish parameters for modelling scenarios on propensity to walk as the main mode. Similarly, additional parameters would need to be estimated or derived for other active modes such as e-bikes and scooters in order to actively reflect how features of an area influence propensity to use them.

Data downloads are available in files that can be read by 'R' software or GIS programs. These include the number of people commuting by each mode:

- Commuting data for local authorities (zones), MSOAs and LSOAs
- Commuting data for flows (MSOA and LSOA level) for different types of flow (all, centroids, straight lines, fast routes, quieter routes).

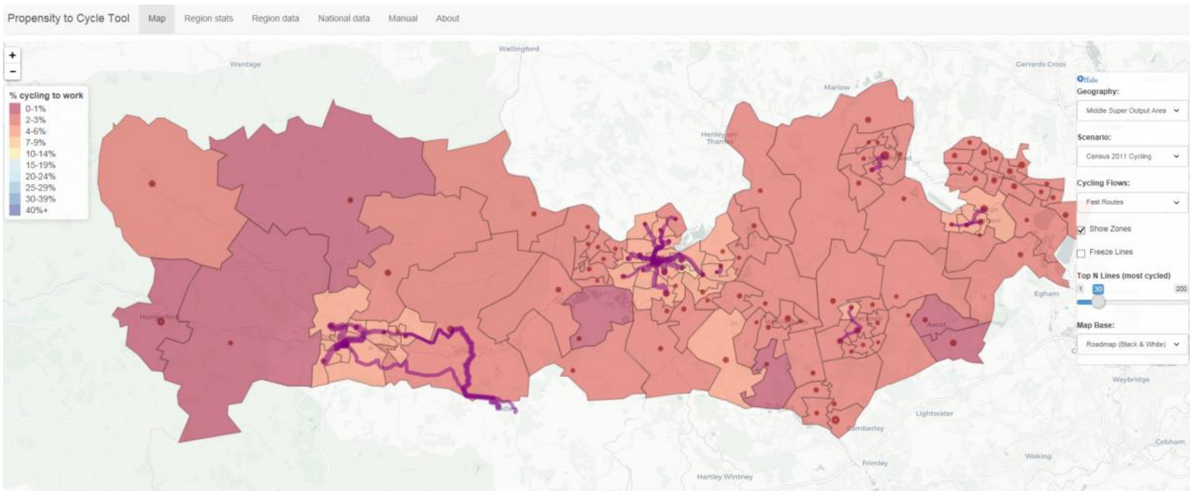


Figure 7 Example of the 'Propensity to Cycle Tool' output

8.5 Conclusions on classification of the built environment for active travel

CycleStreets 'Hilliness' and 'Quietness' are the two classification parameters on which the Propensity to Cycle Tool is based. They are clearly important parameters for classifying routes for other active travel modes.

The CycleStreets journey planner function could probably be extended to other active modes. However a 'quietness' parameter would need to be developed that is appropriate to each of those modes, taking account of two factors: whether or not there is a surfaced route suitable for that mode and if there is, whether that mode can legally be used there.

Thus to assist transport practitioners tasked with increasing use of active modes, it appears to be feasible for the Propensity to Cycle Tool could be adapted to assess the propensity to use other active travel modes.

9 TRL trial of microscooters

This section describes the findings from a survey of TRL personnel who trialled different microscooters for periods of between one and thirty days between April and September 2017. A total of 12 different people were involved with five trialling multiple models of scooters. There were a total of 18 responses to the survey.

9.1 Introduction

Microscooters have emerged in recent years both as leisure toys (mostly for children) and for active travel by adults. Advertisements suggest that a microscooter "*allows you to go anywhere, anytime or to complete the 'last mile' part of your journey quicker than walking and more reliably and enjoyably than public transport*".

To investigate the potential of microscooters for active travel, TRL contacted Micro Scooters Ltd (Micro Scooters Ltd, 2017). They provided TRL with four scooters from their range for initial evaluation:

1. Flex Classic 145 silver
2. Flex Deluxe 200 blue
3. Flex Deluxe 200 black
4. eMicro One black

Items in 1 and 4 have smaller (145mm diameter wheels) but 4 was battery assisted; while items in 2 and 3 were human powered but with larger 200mm diameter wheels.

9.2 Method

To gain initial impressions on the utility of microscooters for active travel from a range of potential users, the four microscooters were offered to TRL staff on a flexible basis.

Before the trial began, several steps were undertaken:

- An initial review of potential legal and safety issues
- Discussions with the TRL Compliance Manager and development of a Health & Safety briefing note
- A participant consent form
- A Temporary Loan record sheet
- Development of a short experience survey questionnaire using Smart Survey (Appendix D)

An opportunity to trial the range of scooters was offered to TRL staff through an Intranet announcement and the scooters were collected on a "first come first served" basis. Each participant was required to read the H&S briefing and to sign a consent form. They were then shown the basic operation of the scooter (folding/unfolding, etc.) and the loan was signed out. .

On return, the scooters were inspected for damage and signed back in. Some deterioration in condition was noted even with relatively short and light usage (Figure 8) so the condition was recorded in the sign in/out sheet.

9.3 Results

The survey ran in the spring/summer period and involved 12 people; there were a total of 18 responses to the survey. Many tried more than one scooter with the electric one being most popular; the manual scooter with small wheels was trialled twice, the manual scooter with big wheels was trialled eight times and the electric powered scooter was trialled ten times (Figure 9). Several hardware issues were noted:

- The small wheeled scooter's forks became loose (such that the wheel turned independently of the handlebars); this was tightened and then appeared to be OK
- The pop-out button securing the extensible handle failed (but the scooter could be extended using the locking bracket)
- One electric scooter developed a battery fault (and was replaced by Micro Scooters Ltd)
- Some deterioration in condition was noted particularly to the rear tyres and the small stand

Figure 8 Example of minor condition damage to one of the scooters

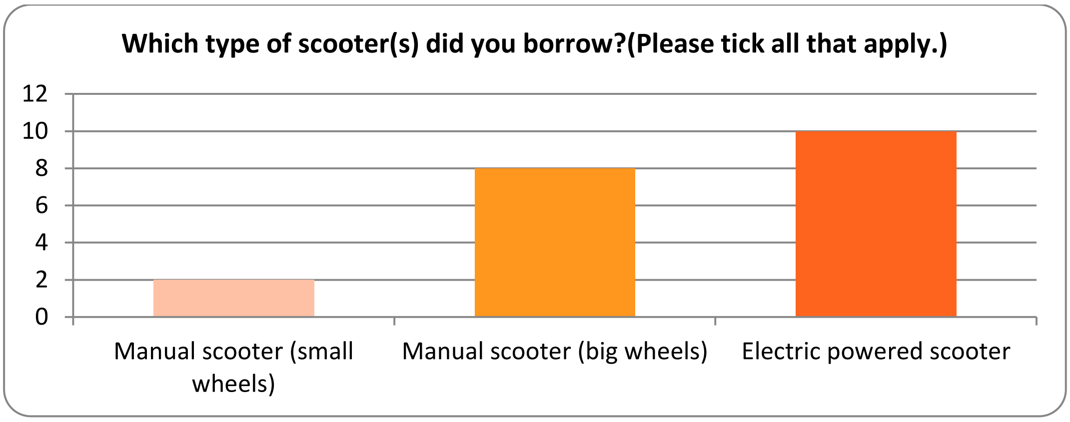


Figure 9 Types of microscooters used in the trial

9.3.1 What did people use scooters for?

The majority of people indicated that they used the scooter for recreational use (83%) while some also indicated that they used the scooter they borrowed for particular journeys (44%). The eight people who specified that they used the scooter for a particular journey indicated that they used the scooter(s):

- To travel to and from work;
- To run errands around town;
- On site visits, for travelling to and from the car; and
- To travel to and from the gym.

Distances specified for these journeys ranged from 600 metres up to 3 miles. There were no differences in use between the different types of scooters.

9.3.2 Would people use a scooter as an alternative to other modes?

When asked whether they would use a scooter instead of other forms of travel for particularly journeys if they had one available on a regular basis, five people answered ‘yes’, ten answered ‘maybe’ and three answered ‘no’ (see Figure 10).

Eight people indicated that using a scooter could replace walking; with a further three suggesting that they might use a scooter for short journeys. This was a response noted for all of the different types of scooters.

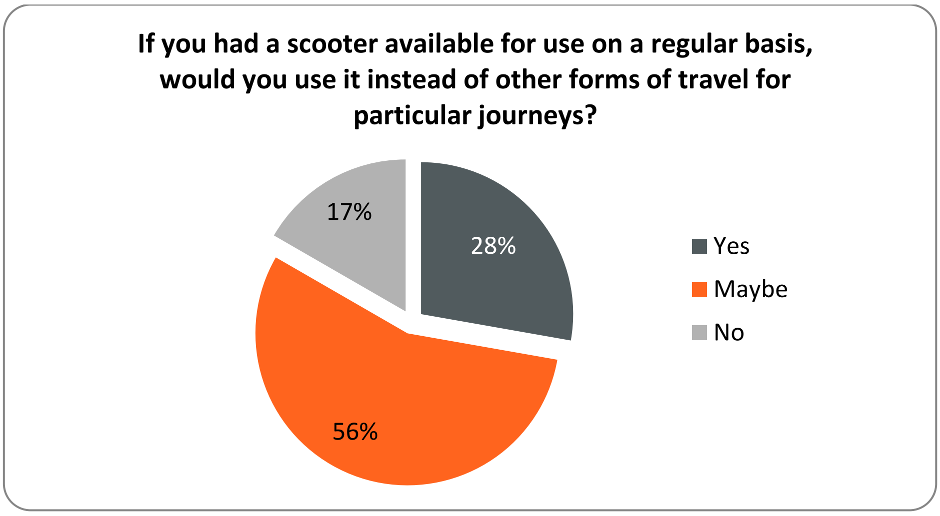


Figure 10 Opinion of the respondent about using microscooters as alternative vehicles

Some examples of comments included:

- *"Definitely any walking journey that would take 5-45 minutes. I would also consider replacing journeys typically taken by bicycle. The electric scooter (as seen on videos online - the e-micro scooter) would be particularly beneficial with its powered motor, quick charge time, and portability".*
- *"For trips to school with the children (they have their own scooters) or short distances with children."*
- *"I would journey to and from work by scooter instead of walking, as it allows for faster travel and exercise. In addition, it can be compactly stored on the train under the seat or in the baggage rack. I would prefer the manual scooter with big wheels, however, due to the rural roads being quite rough."*
- *"Instead of walking to local shops/post office/bank."*

Three people observed that the small wheels on the electric microscooter resulted in a lot of vibrations and discomfort:

- *"It is fun to drive and very nice for recreational activities but not suitable for regular commuting on particular journeys (i.e. go to the office). The reason is that whereas the e-assistance is fairly adequate, the small wheels cannot provide acceptable comfort. On any rough surface, it is impossible to use the scooter without having significant vibrations."*

One person questioned the legality of the electric microscooter for use on roads and pavements:

- *"I don't think this scooter is legal on the road or on the pavement so the only regular journey would need to be in a car park/private land/factory site or similar. I don't have such a need personally, but could see some potential niche use."*

9.3.3 *Would a scooter increase physical activity?*

Out of those who took part in the trial, two thirds (66.7%) said that if they had a scooter available to them, they thought it would increase the amount of physical activity they would do (Figure 11); this would result from using the scooters for replacing short car journeys, or for recreation, leisure and fitness purposes.

Of those who responded yes, six had trialled the electric microscooter (out of 10 people), five had trialled the manual microscooter with big wheels (out of eight people), and one had trialled the manual microscooter with small wheels (out of only two people).

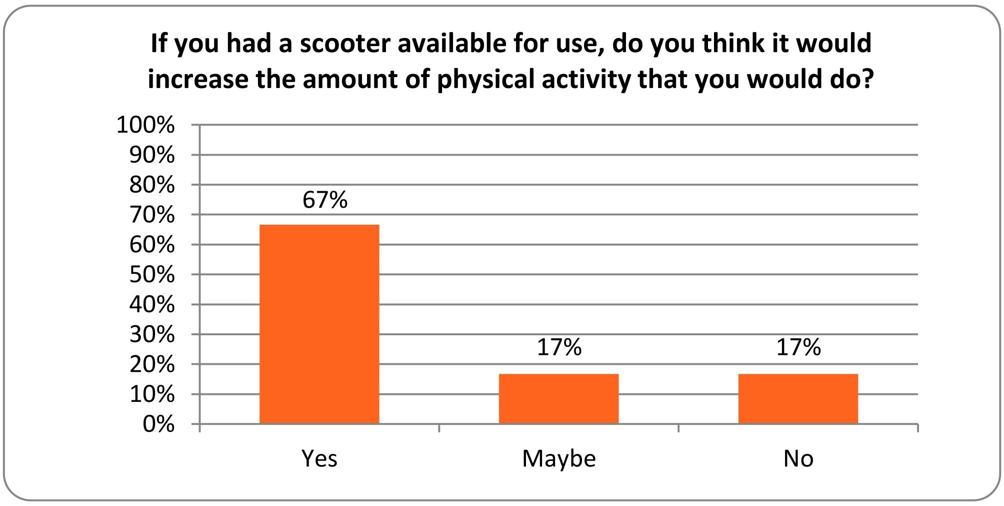


Figure 11 Would a scooter increase physical activity?

9.4 Attitudes towards scooters

9.4.1 *Advantages*

One of the most popular advantages recognised by the respondents is that not only microscooters offer a quicker alternative to walking, but they are also easily accessible and portable. Compared to bicycles they are smaller and lighter, characteristics that makes them easy to store and to take on the bus, train or in a car.

Around half of the respondents underlined the enjoyability of riding a scooter and the opportunity it offers to share fun moments with their children:

- "*Making commutes has been more enjoyable, I quite often get bored when making regular journeys via foot or car but there is always an element of fun while riding a scooter*"
- "*Can enjoying recreational journeys with my children at the same speed that they travel*!"

9.4.2 Disadvantages

The main drawback identified in the survey is that microscooters cannot be ridden on rough surfaces, and vibrations can cause discomfort and also pain; facts that greatly penalises their usability. Furthermore, it has been recognised by various respondents that these vehicles are not appropriate to use in rainy weather; one participant pointed out that electric scooters cannot be used when raining.

- "*Depending on the size of wheels a small piece of wood may flip your scooter, which can be very painful. With this specific one ... I had quite a bumpy ride at times, so yes it can be very annoying to use where the surface is not appropriate. It is not really high - so again have to be careful for bumps on the road ahead and try to avoid the markings for blind people (which is impossible) , so go with super caution through them.*"

Hilly environments represent another challenge for microscooters; although electric ones may offer a solution at least uphill.

- "*[…] going downhill at high speeds makes the scooter unstable*"

Another disadvantage is that they need to be carried with you all the time.

- "*Because of the scooter value I'd be concerned about leaving it unattended*"

A quarter of the respondents were concerned about the poor social image that riding a scooter can give ("*Perceived "uncoolness" / social stigma*"). One respondent highlighted the lack of clarity over legality of its use.

9.4.3 Safety

Participants were asked whether there were any particular safety issues or hazards that they encountered when using the scooter.

About a third of the respondents declared that they did not find any particular serious safety issue. The most mentioned risk (seven responses in total) regards the surface condition; if the pavement is wet, icy or bumpy (the last one in particular for scooters with small wheels), the vehicle is unstable and the brakes are not reliable. For two respondents brakes are also a concern when downhill.

Three respondents declared that they did not feel safe riding the electric scooter in the moment when the sport mode kicked-in.

- "*The electric scooter was occasionally unpredictable when the motor kicked in. I would not allow younger children to use it (and they will want to!)*"

9.4.4 Attractiveness

The main characteristics which have been judged as important in evaluating the attractiveness of a microscooter:

- Model – electric scooters are preferred
- Structure – foldable, compact and light for commuters use

- Wheels – large and possibly with suspensions; anti-mud design
- Brake – it must have an efficient brake system; the brake should be designed to prevent rear wheel lock

9.5 Conclusions from microscooter initial experience trials

The trial shows that there was a good level of interest in trying the microscooters, especially the electric model.

Scooters were judged as safe and enjoyable to use for short recreational trips; however, the inappropriate road infrastructure (hard/uneven surfaces) and the particular characteristics of the scooter (solid wheels and lack of suspension) are likely to be obstacles to their take-up.

Making the riding experience more comfortable might encourage the use of microscooters; for instance electric scooters with bigger wheels and some sort of suspension, like pneumatic tyres.

One person summarised the experience of the majority of participants:

- "*good fun to use, difficult to justify practically*".

10 Activity monitoring technology

One of the objectives of this project is to better understand the health impacts of different active travel options. To do this, the project undertook a review of available techniques for monitoring and evaluating human activity levels.

Two categories of equipment are readily available – those which are on-board the vehicles and those which are personal to the vehicle user.

10.1 Instrumented vehicles

Instrumented bicycles have been developed by a number of research groups including, for example, Southampton University (Kaparias & Miah, 2017). Typical research applications are cycling safety and biomechanical investigation for optimising cycle design.

The advantages of instrumented vehicles are:

- Modest space and weight restrictions
- Ability to use standard hardware and sensors
- Broad range and multiple sensors can be fitted

The disadvantages from the perspective of measuring activity are:

- Instrumentation not readily transferrable
- Has to be custom-designed for each vehicle type
- Costs (when equipping multiple vehicles)
- Comparison of energy expenditure between vehicles is difficult.

10.2 Personal activity monitoring devices

There is a growing range of technological solutions that could be used to measure the health and fitness benefits of the different active travel solutions by direct monitoring of the participants using vehicles (or just walking). To rapidly access knowledge in this area, an intranet request identified a number of TRL staff with recent experience of using personal activity monitoring devices.

TRL staff were invited to express an interest in taking part in a short survey about fitness tracking technologies via an Intranet announcement. In total, 12 people volunteered. A 10-minute interview was carried out with each of them to find out about the fitness tracking devices they use, how they use them, identify suggestions for devices to use in a trial and their willingness to take part in a trial. The results are summarised in this section.

10.2.1 Fitness tracking devices and how they are used

Data collected in the survey are summarised in the tables in Appendix C. Table 21 lists the devices used by the respondents. Four people use more than one device. The combinations of devices used are:

- Heart rate monitor and fitness band
- Smartphone apps and fitness band
- Cycle computer and smart watch
- Cycle computer and fitness band

Most people use their tracker to record steps when walking and to monitor progress towards targets, as Table 22 in Appendix C shows. Several people monitor their heart rate (either regularly, or occasionally for interest) and several monitor sleep patterns (either regularly or for interest). Some monitor cycling and some monitor running. A few monitor other forms of exercise (gardening, football and golf) and one monitors their calorie intake.

A few specifically mentioned setting goals and monitoring when they are met and a few compare their performance with previous occasions or with other people (either known or unknown).

The GPS feature is used for mapping and route finding in some cases. A few use their devices for purposes not related to fitness: as a watch, or to identify incoming messages and phone calls through the link to their smartphone.

Table 23 in Appendix C shows that half of the respondents wear a device all the time and a quarter wear one throughout the day but take it off when sleeping. The heart monitoring band, apps and cycle computers were only used during exercise.

10.2.2 Popular features of specific devices

The features which users particularly liked on each model of device are listed in Table 8. These varied with the variety and complexity of the uses being made of the devices. In some cases the features mentioned were not relevant to either fitness or exercise (such as customisable appearance and receiving notifications of activity on their phone).

10.2.3 Additional desirable features

Users were asked whether there were any additional features that they would like to see in their fitness tracker. In most cases, these were features that are available in a different make or model as Table 9 shows. There were however a few features that may not be currently available on any devices:

- Automatic connection with gym equipment
- Connection to cycle odometer
- Link exercise done to options presented when ordering groceries online
- Near Field Communications to enable the device to be used for payment services

10.2.4 Recommendations for devices to use in a TRL trial

Respondents were asked to recommend possible trackers for use in a TRL trial involving active travel (walking, cycling, scooting etc.) in two scenarios: ‘low cost’ and ‘cost is no barrier’.

Several people had done little or no research into fitness trackers, having been given theirs as a gift. Some identified the features that would be important rather than naming a specific model. The requirements identified were:

- Distinguish between the different active travel activities (possibly automatically)
- Able to identify and map location (depending on the nature of the trial)
- Able to measure heart rate
- Good battery life, depending on the duration of the trial

These features are not all available on low cost fitness tracking devices and indeed some thought GPS was not a basic requirement for a trial.

The specific suggestions received for low cost and 'cost is no barrier' options are listed in Table **24**.

Table 8 Popular features of devices used

Types of tracker	Model	Popular features
Fitness band	**Fitbit Flex**	▪ Tracking progress over time - graphs showing trends for day, week, month, year and sleep tracking ▪ Step counter ▪ 'Rewards' when reach milestones ▪ Community - league table to compare steps with friends ▪ It buzzes when daily goal reached ▪ Notification on phone when nearly reach daily goal ▪ Send encouraging messages to friends when they're doing well
	Fitbit Charge2/HR	▪ Step counter ▪ In-depth sleep analysis ▪ Heart rate monitor ▪ Smart phone notifications - phone is ringing and who is calling
	Garmin Vivo Smart	▪ Good web site to monitor health tracking, heart rate etc. ▪ Sync with phone so mobile app shows stats
	Jawbone	▪ Sleep tracking ▪ Vibrates after period of inactivity to remind you to move around
Smart watch	**Samsung Galaxy Gear 2**	▪ Heart rate monitor ▪ Sleep tracking ▪ Step counting ▪ Exercise tracking ▪ Smart phone notifications of texts and calls (but not for texts or calls)
	Garmin Vivo Active HR	▪ Step tracker linked to GPS so can't cheat ▪ Exercise tracking speed, time, distance

Types of tracker	Model	Popular features
		▪ Link with apps on smartphone so can see route on map ▪ Notification of email, text, phone calls ▪ Garmin app good - can add widgets such as compass, calculator and weather to the device ▪ Track heart rate, calories, steps ▪ Bluetooth sync to phone ▪ Web site display of data and charts ▪ Can display different watch faces and details about activities ▪ Waterproof
	Garmin Fenix 5X	▪ Swim tracking ▪ Heart rate monitor ▪ Maps and navigation built in (don't need app) ▪ Steps ▪ Sleep tracking
	Garmin Forerunner 735XT	▪ Tracking multi-sports (e.g. doing triathlon) ▪ Heart rate interesting, but not sure how reliable ▪ Customisable appearance
Smartphone app	**Strava**	▪ GPS logging ▪ Tracking progress over time on the web site
	Collection of iPhone apps for sleeping, pedometer, UnderArmour (food & fitness),	▪ Location tracking when walking ▪ Sleep tracking
	MyfitnessPal (calorie counter)	▪ Link between weight goals and achievement
Cycle computer	**Garmin Edge 810**	▪ Helps with navigation when cycling - don't have to stop to check route ▪ Small ▪ Has 1:50,000 OS map so can use for navigation when cycling or walking ▪ Accurate GPS
Heart rate monitor		

In making these recommendations, some people made other points that should be borne in mind when planning the trial:

- One person who had carried out TRL trials using GPS devices warned that unless using a standard circuit, there could be data protection limitations prohibiting the use of GPS tracking in a trial.

- Some noted that it may not be possible to track scooting automatically on any of the devices available, although it may be possible either to add extra activities to the app or to use one which records a range of activities and set it to monitor another activity (such as snowboarding) while scooting (e.g. Garmin Vivo Active).

- One person had researched heart rate monitoring capabilities and concluded that none seem to be particularly accurate in the way they are linked with calories used.

Table 9 Additional features desired

Types of tracker	Model	Additional features desired
Fitness band	Fitbit Flex	▪ Record cycling as well as walking
	Fitbit Charge2/HR	▪ Connect automatically to gym equipment instead of using heart band ▪ Prefer a smarter appearance
	Garmin Vivo Smart	▪ Altimeter for mountaineering
	Jawbone	▪ Heart rate monitor
Smart watch	Samsung Galaxy Gear 2	▪ Heart rate monitor could be improved to monitor more often and during exercise
	Garmin Vivo Active HR	▪ Touch screen could be improved so that it doesn't respond to moving in water (this causes it to change settings, etc.) ▪ NFC for Android Pay ▪ Connect to cycle odometer to measure wheel speed rather than speed from GPS as it currently does
	Garmin Fenix 5X	▪
	Garmin Forerunner 735XT	▪ Tracking gym sessions e.g. weights, even if it involves making a manual entry to classify the activity
Smartphone app	Strava	▪
	Collection of iphone apps for sleeping, pedometer, UnderArmour (food & fitness)	▪ Link exercise done to food ordering from supermarket for next week to block out unsuitable foods depending on the exercise recorded this week
	MyfitnessPal (calorie counter)	▪ More granularity e.g. food content
Cycle computer	Garmin Edge 810	
Heart rate monitor		

10.2.5 Devices available for use in a TRL trial

Most people volunteered to take part in a trial (10 in total) and all of these were happy to use their devices in the trial. The devices that would be available for the trial are shown in Table 25.

Nine people offered the use of their devices for others to use in a limited trial (for example during part of a working day) but were generally not happy for them to be used over a longer period as this would mean they would not have it available themselves, and the trial data would 'contaminate' their own exercise data. The devices available are listed in Table 26.

One person pointed out that their device is extremely expensive and would only consider lending it if it were for one person to use.

The Garmin Forerunner 10 is no longer being used by the owner so would be available unconditionally for as long as required for a trial.

10.3 Small scale trial on wearable technology

A small scale trial was designed to investigate the use of wearable technologies to measure health and fitness, in order to understand the technologies and their suitability for a future research trial. The wider aim of the potential larger trial would be to understand the potential of fitness tracking devices to encourage a shift away from car use by promoting the health and fitness benefits of active travel modes.

TRL staff were invited to participate and among those who showed interest in the project, five completed the trial in their spare time. Participants were asked to choose one single circuit familiar to them, at least one mile long, and two active modes of transport (e.g. walking at a brisk pace, cycling, riding an e-bike, riding a kick scooter); they recorded information about the circuit and the readings obtained from their device about their heart rate, for each trip around the circuit (the survey sheet is in Appendix E). Information about the general climate conditions were also requested in order to be aware of any relevant external factor which could have altered the participant's performance in one of the two trips (e.g. one trip performed in a very dry and warm day and another in extremely cold or wet weather).

10.3.1 Methodology

The trial aimed to investigate the different levels of exercise which each mode offers, in terms of average number of heart beats per minute and maximum heart rate. This approach considers the fact that increasing the heart rate during physical activity not only enables general health and fitness improvements, but it also maximises the cardiovascular benefit.

The methodology employed for assessing the intensity of the exercise during the trial is based on the Maximum Heart Rate (MHR)[14] and the 'Training Zone' concept. The MHR is an

[14] https://www.bhf.org.uk/get-involved/events/training-zone/walking-training-zone/walking-faqs

indicator of how hard to work the heart to develop either aerobic or anaerobic fitness, and it is defined as:

$$MHR = 220 - age$$

Based on this parameter we have the following 'training zones':

1. **Endurance training**: 50%-69% MHR - Low to medium intensity zone, where a higher percentage of calories are burned from fat.
2. **Aerobic training**: 70%–84% MHR
3. **Anaerobic training** (improve cardiovascular fitness): 85%-100% MHR - High-intensity exercise, which improves performance and speed.

Therefore, by considering the data collected by the participants through their devices, together with the participant's age, the intensity of the exercise undertaken was identified.

MHR is approximate; in fact thresholds may differ according to personal levels of activity and fitness. Considering that the focus of this trial was in developing a methodology and not the analysis of the results, a parameter adjustment was considered out of scope and therefore not introduced in the calculations.

10.3.2 Survey design

In addition to age and heartbeat rate, additional questions were asked in order to obtain a picture of the physical fitness of the participants and their propensity to use active transport for commuting.

A high level qualitative exploration of how people make choices when different modes are available to them was included in the survey. In particular, participants were asked at the end of each trip whether they would consider that mode for daily commuting and if the circuit used in the trial was similar to the actual route from home to work. The preference of one mode over another is dictated by what a person values more in that specific circumstance.

This approach was chosen in consideration that there will always be a trade-off between effort and speed, which may vary between the modes and individual participants. For instance, some people will use an e-bike to reduce the effort involved for the same journey (perhaps to avoid the need for a shower at work), others to go faster or further for the same effort, or to go on steeper roads than they would be prepared to cycle on. Moreover, even if somebody is particularly interested in leading a life as active as possible, it is not obvious that a mode would be chosen just because it offers a higher training level; for example because the amount of time required is significantly larger.

Moreover, the explicit request to the participants to go at a pace they feel comfortable, and not to look at the HRM during the journey, was introduced in order to avoid a potential bias in the data collected. In fact, participants could have used the HRM to achieve similar levels of effort with both their trial modes, which would have led to the conclusion that both modes involve similar levels of effort.

10.3.3 Trial results

Participant sample

Five people participated in the trial, three men and two women, aged between 28 and 58 (Table 1). All the participants regularly include physical activity in their weekly routine; more specifically, three people spend between 2.5 and 5 hours on physical activity per week, and two reported spending over 5 hours per week.

The participants chose three modes, namely walking, cycling and running. Three participants did the circuit once walking and once cycling; one participant opted for walking and running; one person chose cycling and running. The chosen circuits complied with the length request of being over 1 mile long (Table 11).

Table 10 Participants' age and corresponding MHR

Participant's age	MHR
28	192
35	185
48	172
50	170
58	162

Table 11 Summary of the circuit length and modes selected by the participants

Circuit length (miles)	Mode 1	Mode 2
2.1	Walking	Cycling
2.3	Walking	Cycling
4	Cycling	Running
4.2	Walking	Cycling
4.2	Walking	Running

Table 12 Commuting distances which participants would consider for cycling or walking

Which commuting distance would you consider feasible by…?	Up to 1 mile	Up to 2 miles	Up to 3 miles	Up to 5 miles	Up to 10 miles	Over 10 miles
cycling				2	3	
walking		3		2		

All the participants would consider commuting by cycling for distances up to 5 miles (Table 23); even longer distances would be considered by three of the participants (up to 10 miles). A length up to two miles is considered by all the participants to be a walking distance that is acceptable for commuting; two of the respondents would even consider distances up to 5 miles.

However, also other characteristics of the route play a decisive role in the choice of the transport mode (e.g. the height difference, the pavement/road surface conditions, lighting and perceived safety of the area, traffic, etc.), but they have not been considered here.

Training zones reached

The ratio between the maximum pulse rate (PR) recorded during the trip and the MHR have been calculated and reported for each participant and each mode in Table 13. These figures, expressed in terms of percentages, are used to identify which training zone has been reached during the physical activity. Note that these are the upper limit the participants experienced; the time interval during which the PR reached the maximum rate has not been recorded, therefore, the higher training zone reached could have occurred as a single event during the journey or have lasted for several minutes. To have an indication of the overall effort put into the physical activity, the same calculation has been repeated using the average PR as well (also reported in Table 13).

Table 13 Calculation of the training zone reached during each trip – Zone 1 and Zone 3 are in light and dark green, respectively; Zone 2 is in a middle shade green.

	Mode 1			Mode 2		
	Average PR /MHR	Maximum PR /MHR	Maximum PR /Average PR	Average PR /MHR	Maximum PR /MHR	Maximum PR /Average PR
1	83%	97%	1.16	87%	106%	1.22
2	63%	80%	1.27	60%	81%	1.34
3	46%	59%	1.27	77%	82%	1.07
4	48%	77%	1.60	54%	63%	1.18
5	58%	63%	1.09	75%	85%	1.14

Results show that in all the trips the endurance training level was reached (Zone 1) at least once. Moreover, according to the maximum heartbeats recorded, all the participants reached the aerobic training zone at least once with at least one of the two modes.

Two participants experienced the anaerobic training zone as well; besides, the corresponding training zone calculated using the average PR was also situated in the aerobic or anaerobic range, meaning that the high exercise level was maintained for an extended interval of time and not just briefly reached once.

Figure 12 shows the training zones reached by each participant in each of the two runs they did according to the maximum PR recorded by the wearable devices; different symbols specify the transport mode employed. The personal type of approach to different active modes of transport mentioned in the Section 'Survey design' (page 59) can be identified in these results. For example, despite both participants 4 and 5 choosing walking and cycling, they did not reach the higher training zone with the same mode. Another approach entirely is shown by participant 2, who also cycled and walked, but who reached the same training level with both options.

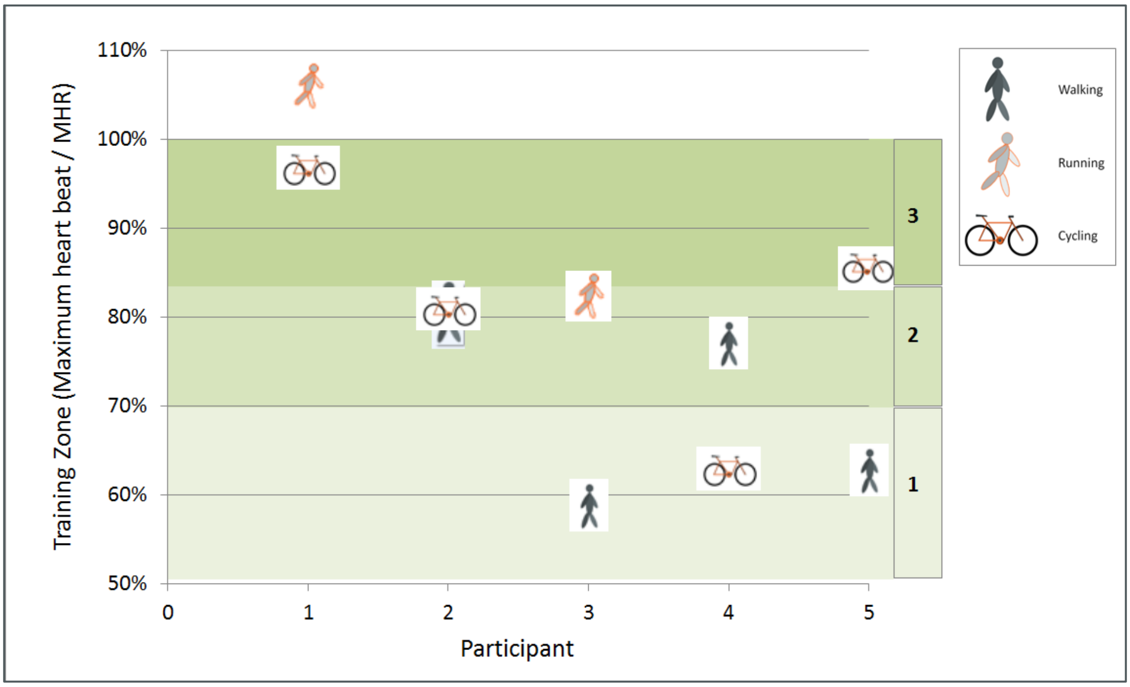


Figure 12 Training zone reached by each participant for each mode chosen

10.4 Conclusions on activity monitoring devices

The trial of activity monitoring devices was designed to be on a small scale for the purpose of developing a methodology, rather than for obtaining data on potential health impacts of active travel. The methodology developed in the trial was shown to be suitable for identifying the level of effort exerted by participants using different active modes, which can be considered as a proxy for the health impact of these modes. Although the trial involved only walking, cycling and running, the method developed is also suitable for use when using new active modes such as microscooters and e-bikes.

These devices offer a low-cost and more accessible option for monitoring activity levels compared with instrumented vehicles.

The trial has provided TRL with an understanding of the issues involved in planning, implementing and analysing results which can be used to design a further more in-depth investigation.

Before further use in a more in-depth investigation, it is recommended that the method is enhanced in two ways:

- To enable the calculation of training zones reached by participants to take account of personal levels of activity and fitness
- To record the time during which the PR reached the maximum rate to provide data on duration of such events during the journey

These enhancements would improve the sophistication of the indicator for intensity of activity and provide an indicator of the duration of activity.

On a large scale, with a representative sample of users of active modes, this enhanced version of the methodology could be used to derive values for the health benefits of active modes for application in the evaluation of interventions to encourage active travel.

11 Impacts on travel behaviour

This section analyses data on mode use to provide an indication of the current levels of use and potential future for active travel modes in Great Britain.

11.1 Current use of active travel

The National Travel Survey provides data on the percentages of trips by distance and main mode in England in 2016 (DfT, 2017) – see Table 14. It is worth noticing that almost a quarter of all car trips as a driver are shorter than 2 miles, and that more than half of car driver trips are less than 5 miles (56%). These distances are generally considered manageable by bicycle; in fact, we can see from figures in Table 14 that 79% of the bicycle trips are shorter than 5 miles, and in particular that almost the half are between 2 and 5 miles. It is therefore reasonable to wonder whether the increasing availability of active travel modes, particularly those which benefit from the support of an electric motor, might encourage modal shift from cars to active transport modes.

It is necessary, however, to keep into consideration that also a shift from an active mode, such as walking or riding a traditional bicycle, to a 'less active' mode, such as riding an e-bike or an e-scooter could occur; such a shift would not contribute to the same degree of improvement the health of the population.

Table 14 Cumulative percentage of trips by length and main mode in England (DfT, 2017)

	Cumulative percentage						
Main mode	**Under 1 mile**	**Under 2 miles**	**Under 5 miles**	**Under 10 miles**	**Under 25 miles**	**Under 50 miles**	**Under 100 miles**
Private:							
Walk	74%	96%	100%	100%	100%	100%	100%
Bicycle	14%	43%	79%	93%	99%	100%	100%
Car / van driver	6%	23%	**56%**	78%	94%	98%	99%
Car / van passenger	7%	26%	60%	80%	93%	97%	99%
Motorcycle	3%	11%	35%	66%	90%	97%	100%
Other private transport	9%	23%	48%	69%	87%	93%	97%
Public							
Bus in London	4%	27%	80%	97%	100%	100%	100%
Other local bus	2%	16%	64%	88%	99%	100%	100%
Non-local bus	0%	0%	0%	3%	3%	24%	69%
London Underground	0%	3%	26%	62%	98%	100%	100%
Surface Rail	0%	0%	9%	31%	70%	87%	95%
Taxi / minicab	3%	24%	72%	89%	98%	100%	100%
Other public transport	2%	9%	52%	82%	96%	96%	96%
All modes	23%	18%	26.6%	15.5%	11.5%	3.1%	1.3%

The relationship between the choice of travel mode and the distance to commute has also been analysed in a study conducted in Cambridge in 2013 (Dalton & al., 2013). The project aim was to understand the link between the mode of travel and some characteristics of the physical environment, such as street network connectivity, urban design, land use, infrastructure for walking or cycling, and the availability of or access to public transport. The research used cross-sectional data obtained from a sample of commuters taking part in the Commuting and Health in Cambridge study in Cambridge in 2009; the final sample used for the analysis included 1,115 commuters.

As expected, results showed that the longer the distance to cover, the more unlikely was the choice of cycling or (even more markedly) going on foot; more precisely, for each additional kilometre between home and work the estimated likelihood of cycling or walking was 1.3 times and 3.9 times lower than driving, respectively. That cycling is considered a valid alternative to driving for short trips only (less than 3 miles) is also the conclusion of a survey conducted in Germany (Technische Universität Dresden, 2013); however, they also observed a trend to cycle for longer distances associated with an increase in the number of e-bikes. An on-line survey conducted in the Netherlands in 2008 concluded that the average commuting distance was about 56% higher for people who cycled an e-bike than for people who used an s-bike (9.8 km and 6.3 km, respectively) (TNO, 2008).

Cycling represents a means to access public transport as well. That cycling is often part of multi-modal journeys is highlighted in the German study by the fact that greater distances to a railway station corresponded to a smaller proportion of commuters using a bike; besides, people who live in neighbourhoods with fewer bus services were also less inclined to cycle.

The importance of cycling as a means of access to rail emerges also from the high number of rail journeys involving a bicycle in Great Britain; these figures, obtained using data from the National Rail Passenger Survey (Transport Focus, 2015) and the Office of Rail and Road statistics (ORR, 2015) are shown in Figure 13

Since the subject is relatively recent, trends are not well documented yet. In particular, the literature review found a lack of studies on travellers' behaviour and e-scooters/microscooters. Findings concerning e-bikes are reported in Section 11.2 and Section 11.3. Conventional travel surveys do not yet collect data on innovative active travel modes specifically.

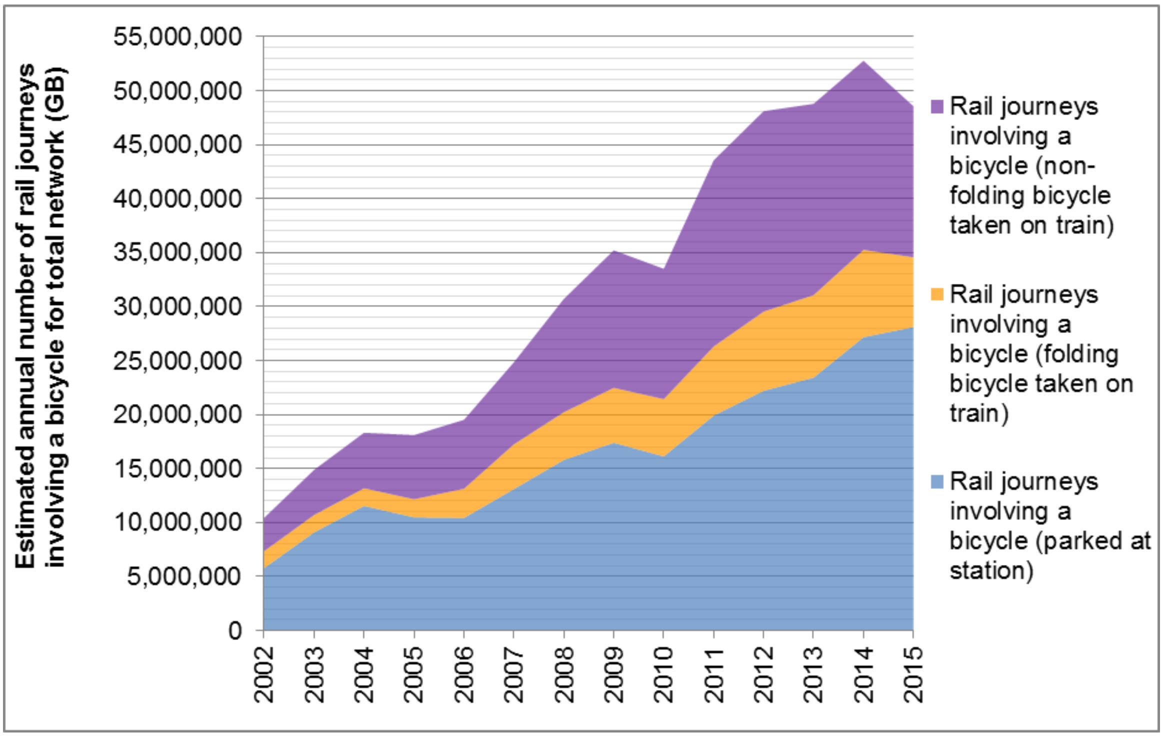


Figure 13 Estimated annual number of rail journeys involving a bicycle (TRL, 2016)

11.2 Cycling trends in Great Britain

As shown in the left chart in Figure 14 bicycle sales decreased from the over 3.9 million units in 2006 to figures between 3.3 and 3.6 million units in the following ten years, before falling further to about 3 million units (CONEBI, 2017). The CONEBI (Confederation of the European Bicycle Industry) justified the small fluctuations which occurred until 2015 as natural variability; it seems that the significant decrease in 2016 (-13% compared to 2015, with import figures falling to 2.8 million, that is around 20% down respect to the previous five-year average) cannot be attributed to a single cause. CONEBI lists among the possible impact factors “a correction for over-supply in previous years, substitution of sales of children’s bikes by in-fashion scooters, and Brexit concerns” since the vast majority of cycles are imported.

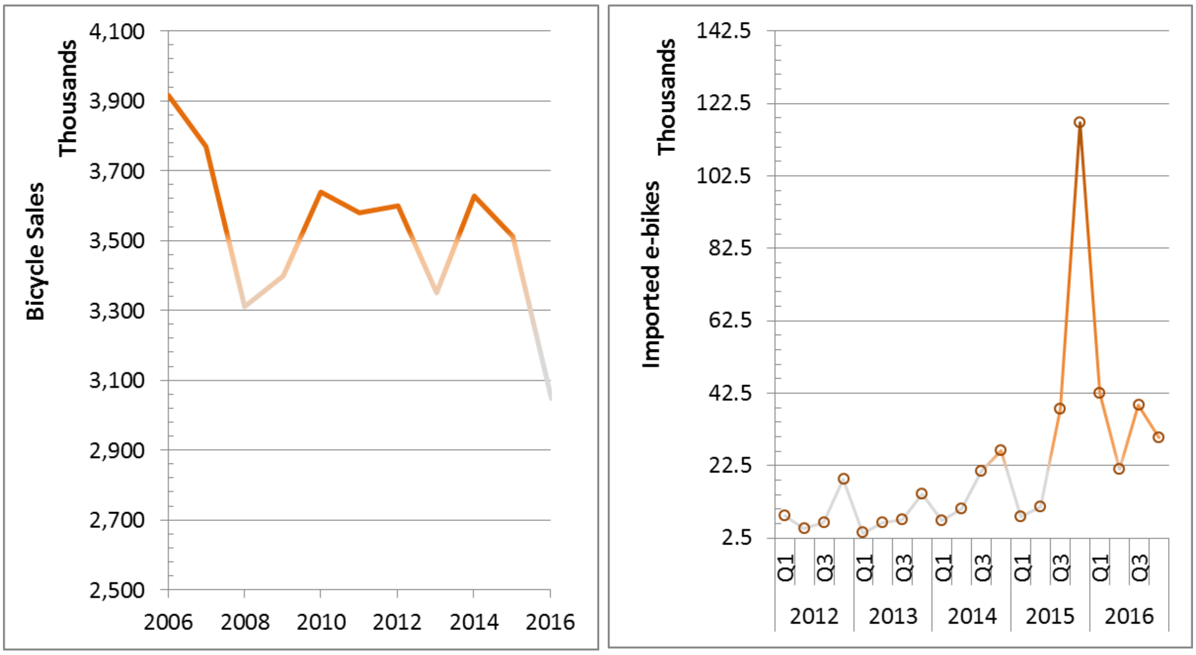


Figure 14 Cycle market trends in Great Britain between 2006 and 2016; (on the left) bicycle sales (CONEBI, 2017); (on the right) Number of e-bikes imported (SQW, 2017)

Sales of electrically assisted pedal cycles are increasing, even if they still represent a small portion of the cycle market, with roughly 75,000 units sold in Great Britain in 2016 (CONEBI, 2017). However, it is not possible to draw a specific trend, since reliable data for the previous years are not available. The figures contained in the official import statistics published by Her Majesty's Revenue and Customs (HMRC) do not match those provided by the industry; in particular, sales declared between the end of 2015 and the beginning of 2016 appear anomalously high (right-hand chart in Figure 14). The cause of this inconsistency is attributed to mis-categorisation of the items.

Halfords, one of the UK's cycling retailers, stated that, according to their insights, approximately 1 in 25 adult bikes currently sold in the UK is an e-bike; they also expect that the proportion will increase to 1 in 15 in the near future (Halfords, 2017). The retailer's estimates that e-bikes will lead to an additional 320,000 people cycling to work in cities.

Despite the slightly negative bicycle sales trend, the overall bicycle traffic in Great Britain has increased in the past nine years (Figure 15). As expected, most cycling takes place on minor roads (83%), in particular in urban environments (55%) (DfT, 2017). Some cities have seen a significant increase in cycling; this is the case, for example, in London, where the daily average cycle trips[15] went from 0.39 million in 2005 to 0.6 million, and the cycle stages[16] from 0.41 million to 0.67, in 2015 (TfL, 2016).

[15] Cycle trip is defined as a one-way movement to achieve a specific purpose that is conducted entirely by bike

[16] A cycle journey stage includes cycle trips as defined in footnote 15, and shorter cycle legs undertaken as part of a longer trip using another mode

According to Halfords the number of people over the age of 65 using this technology will significantly increase, adding 140,000 bicycles to the circulating bike fleet; moreover, the 55-64 age group would see an additional 2.1 million people cycling (Halfords, 2017). However, the retailer has also warned that if the Directive of the EU Court of Justice issued in 2014[17] which states that "some non-road-traffic motoring activities must be covered by third party liability insurance" is enacted as initially intended by the EU (the European Commission has expressed the intention to review the Motor Insurance Directive (DfT, 2016)), it might turn away thousands of potential cyclists.

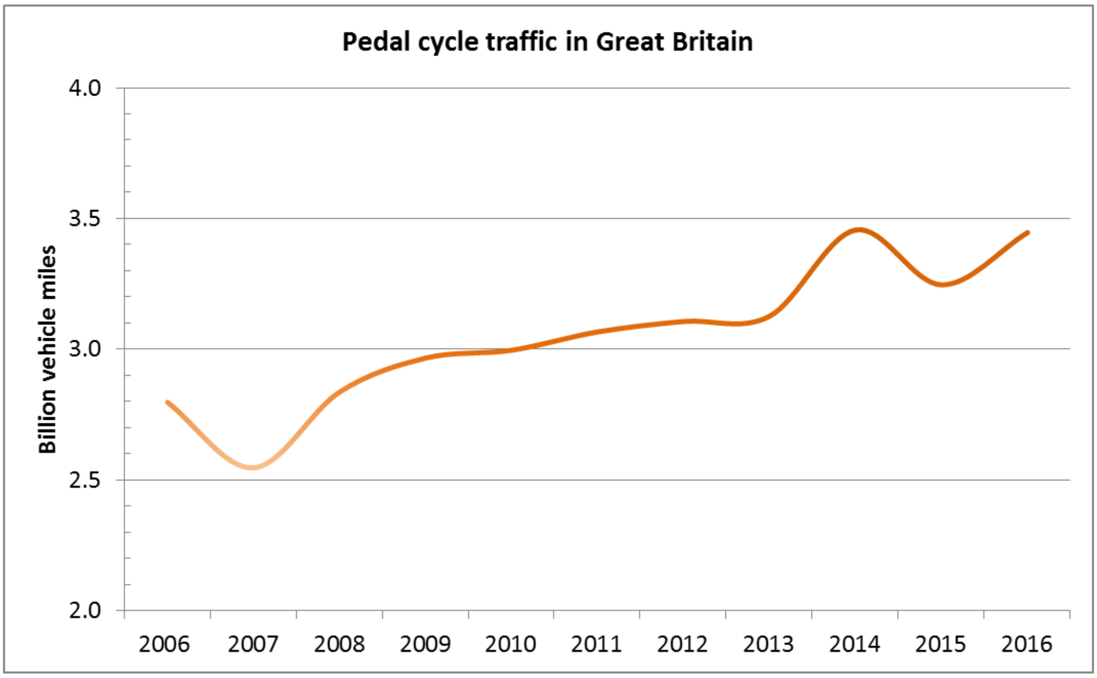


Figure 15 Pedal cycle traffic (DfT, 2017)

11.3 Shift to cycling

As mentioned in Section 2 new types of vehicles such as e-scooter and hoverboards are gaining popularity as a recreational activity not only among children, but also in the adults' market. However, bicycles and e-bikes remain the favourite means of transport, after walking, both among new and experienced active travellers.

Policies and measures implemented in various British cities have encouraged travellers to opt for cycling; in particular, offering the possibility of using e-bikes for a certain period of time has proven to be an effective way to promote modal shift. An example of this is the outcome of a series of trials conducted in Brighton, where 80 employees were loaned an electrically-assisted bike for a 6–8 weeks (Cairns & al., 2017). During that period the average usage was 15–20 miles per week, which led to an overall reduction in car mileage of 20%. At

[17] Damijan Vnuk v Zavarovalnica Triglav d.d. C-162/13 (the 'Vnuk judgment')

the end of the trial, 38% of the participants expressed the intention to cycle more in future, and at least 70% declared that they would like to have an e-bike, and that they would cycle more if this was the case.

In this context, observations by TfL about the relationship between cycling growth and the use of other modes (TfL, 2016) are relevant. In the document dated 2016 'Travel in London', they highlight the following characteristics of different categories of travellers in terms of propensity towards cycling:

- Bus and Underground users share similar overall cycle trip rates; cycle trip rates for car users tend to be higher overall – suggesting a higher potential among car users.
- Cycle trip rates among Underground users have grown especially among frequent users of the Underground, suggesting that this group are particularly susceptible to change.
- However, cycle trip rates among car users have hardly grown at all among frequent car users, but there has been very strong growth among less-frequent car users.
- Growth in cycle trip rate has been fairly uniform across all categories of bus user. This tells us that there are no strong features of 'being a bus user' that affect propensity to take up cycling – although the overall rate of growth is comparatively low across the board for people in this category.

Conclusions similar to those reached in the Brighton trials have also been drawn from other experiences in Europe. A literature review of European studies reported in the paper "*Electrically-assisted bikes: Potential impacts on travel Behaviour*" (Cairns & al., 2017) reveals that a number of trials demonstrated not only that when e-bikes are made available they get used, but also that a proportion of e-bike trips is actually an alternative to driving. Furthermore, many people who take part in the trials showed interest in future e-bike use, or in cycling more generally.

As mentioned in Section 11.1, since e-bikes enable longer and faster journeys, also in hilly environments, they offer a valid transport option in a wider range of circumstances than a traditional bike. Also, they offer the opportunity of being active travellers to a larger group of people, including who don't wish to, or cannot ride a conventional bike. These expectations have been confirmed in the frame of the Shared Electric Bike Programme, which installed e-bikes in eleven schemes across England and studied how these bikes were used in a twelve month period (Carplus Bikeplus, 2016). The outcome of the project can be summarised by the following points:

- Shared e-bikes attract new riders to begin to cycling:

  One in three participants rarely or never cycled before they started using shared e-bikes. Besides, the programme reached a wider demographic than the standard bike user group; in particular, 45% of the participants were women (compared to 25% in the standard cyclist population), and the range of ages was wider (25-65 years old).

- E-bikes represent a practical transport means on a larger number of occasions than traditional bikes:

  The average length trip increased from 3 miles for the traditional bikes to 5 miles; besides, e-bikes enabled 33% of participants to cycle up hills which they would not have cycled with a standard bike.

- E-bikes can effectively be considered an alternative to cars:

  In one commuter scheme 46% of regular shared electric bike trips were previously made by car; moreover, in the follow-up survey 22% of riders confirmed that the e-bike reduced their car travel.

To verify whether increasing the active travel in the population would lead to a decrease in recreational physical activity, a research group (Sahlqvist & al., 2013) used longitudinal data from 1,628 adult respondents in the UK-based iConnect study[18]. The meta-analysis concluded that, even if the time spent in recreational physical activity had decreased, the overall weekly physical activity in adults increased proportionally to the increase in active travel.

11.4 Last mile deliveries

The logistics sector has the potential to significantly contribute to increase the traffic of e-bikes and e-scooters in urban areas. This has been shown by the European research project PRO-E-BIKE, where the great majority of the 40 businesses (across seven countries) involved in a trial of these vehicles for last-mile deliveries decided to continue using them after the pilot phase, even without any financial support (PRO-E-BIKE, 2017).

It is reasonable to expect higher interest in active travel where measures and policies offer the appropriate conditions, such as adequate infrastructure and a safe environment. In the case of urban deliveries, it is also necessary to redesign the logistic planning system, since the smaller load capacity of bicycles and scooters results in a different pattern of trips. The route optimisation could consider, for example, loading/unloading points in less peripheral areas, with ease of access, but not causing traffic disruptions. Such planning needs of course to be tailored to the local context.

11.5 Summary

Pedal cycle traffic has shown a steady increase over the past decade. Looking simply at distance travelled and ignoring any other constraints on choice of mode, around a quarter

[18] From http://www.iconnect.ac.uk/: *"The iConnect study aimed to measure and evaluate the changes in travel, physical activity and carbon emissions related to Sustrans' Connect2 programme, which was an ambitious UK-wide project that transformed local travel in more than 80 communities by creating new crossings and bridges to overcome barriers such as busy roads, rivers and railways, giving people easier and healthier access to their schools, shops, parks and countryside."*

of car trips are less than two miles and two-fifths are less than five miles, distances which are generally considered to be manageable by bicycle. The increasing availability of electrically assisted active travel modes could encourage a shift from car for such distances, while in the logistics sector trials have demonstrated the potential for e-bikes to replace motor vehicles for last mile deliveries. As well as encouraging non-cyclists, e-bikes enable riders to travel longer distances and on hillier routes, thus extending the range of current active mode users. Some small scale trials and local schemes have shown the potential for e-bikes to encourage a shift from car travel, while a series of shared e-bike schemes attracted new riders as well as being used on longer trips. Even small increases in the distance travelled will extend the 'active mode catchment area' of facilities such as the rail network. However it is not yet possible to quantify these statements due to the limited data available on patterns of use of scooters, microscooters and e-bikes.

12 Issues

The growth in bicycle traffic raises the need for redesigning or improving the current road infrastructure, in order to support policy objectives for continuing such growth. Furthermore, the presence of Personal Mobility Devices (PMD; e.g. skateboards, kick-scooters, electric scooters, hoverboards, e-wheels, etc.) opens a series of questions about how to regulate road and non-road traffic.

12.1 Road regulations

As reported in Section 4 electric vehicles such as e-scooters and hoverboards are allowed neither on road, nor on public pavement, a circumstance that decisively contributes to limit their take up as modes of travel rather than for leisure activities on private land. It could be instructive to observe and learn from the experience of those countries where some permits have been granted.

This is the case, for instance, in Singapore, where the interest in similar mobility devices is so high that the government decided to revoke the ban on their use in certain areas (Singapore Government, 2017). Since 2018 they are allowed on footpaths, cycling paths, and shared paths as long as the speed is kept below 25km/h on the former two, and 15km/h on the latter. They still are not allowed on roads and pedestrian-only paths though, where the risks are understandably high -- as demonstrated, for example, by the fact that during the first six months of 2017 the majority of approximately 90 accidents involving active transport vehicles (which caused four deaths and about 90 injuries) took place on roads. The rules and code of conduct related to sharing of paths among pedestrians, cyclists, and e-scooters riders is however still under review by the Singapore Government, which has involved the population in the process through an on-line survey (until 30 April 2018).

In Singapore, anyone who is caught breaking the law may receive a fine up to S$2,000, or be imprisoned for up to 3 months, or both. Repeated offences are treated even more severely, with fines up to S$5,000, or imprisonment up to 6 months, or both. The idea is that when there is a clear code of conduct, a set of rules and a strict enforcement regime, it is possible to have a safe shared space for active travellers and a more efficient way of moving around the urban environment.

12.2 Infrastructure

The infrastructure plays a key role in the choice of transport mode. Some critical aspects are summarised in the following list:

- Together with the lack of cycling and pedestrian infrastructure, also its inadequacy where it exists is a barrier to the take-up of active modes.

  In planning the infrastructure a number of aspects need to be addressed, starting with basic requirements, such as for example, an adequate riding/walking surface (as discussed in Section 9.3 uneven surfaces and potholes are a major concern when riding a vehicle with small wheels, such as microscooters), and lighting, which might be more even more important for e-cyclists than traditional bicycle riders due to their higher speed of travel (Dozza & al., 2016).

The quality of the infrastructure is also linked to the width of the lanes, the presence of steps and physical barriers. These aspects strongly influence the propensity to use active transport means, and in certain circumstances they can be decisive factors.

This is the case, for example, with disabled people, who might use non-standard bikes and e-bikes, which are often wider, longer and heavier than standard bicycles. Accessibility can also be reduced for disabled cyclists who ride on two wheels but who may not be able to lift, carry or walk their cycle. As revealed by a UK survey, the infrastructure is the biggest barrier for disabled cyclists (Wheels for Wellbeing, 2017). According to TfL, in London 15% of disabled people use a cycle to get around occasionally or often (compared to 18% of non-disabled people) (DfT, 2015). This percentage could be higher if the infrastructure facilitated it; in fact, as the experience of the charity 'Wheels for Wellbeing' shows, the will to use vehicles for active transport is present in the disabled community, for whom the benefits of active transport are even more important than for non-disabled people since they are more likely to be physically inactive and socially isolated (Wheels for Wellbeing, 2017).

- Connectivity plays an important role in modal choice, as concluded by a study which found that walking and cycling were less common in areas with low junction density (Dalton & al., 2013). The study, which was based on the analysis of 1,155 questionnaires from the 'Commuting and Health in Cambridge study' in 2009, conducted on commuters working in Cambridge and living within 30 km of the city, found that in the least connected areas only 35% of commuters chose walking or cycling, against the 70% in the most connected areas.

- Safe storage is a serious issue. Police recorded almost 200 thousand cycle thefts in England and Wales from October 2015 to September 2017 (Office for National Statistics, 2017). The availability of facilities for safe storage, such as lockers or attended parking options, is particularly important when using expensive bicycles and e-bikes (e.g. an average e-assist recumbent trike costs over £2,000 (Wheels for Wellbeing, 2017)).

Figure 16 Vehicle theft and vandalism are often a deterrent to the use of personal active transport vehicles as utility transport means

- Robust storage is also an issue with e-bikes given that they are heavier than s-bikes. Some current designs of cycle parking are not suitable for the weight of e-bikes (for example the upper tier of two-storey cycle racks or those designed to hold one wheel in place).

- Damaged batteries and chargers can cause fires. There is anecdotal evidence of this but no statistics have been found to indicate their incidence. The infrastructure where batteries are stored and charged, either private or public, needs to meet safety standards to prevent these hazardous events.
- If charging stations for e-bikes and other personal vehicles were available at least at busy public transit stops (such as universities, hospitals, businesses, and hotels), this would encourage the use of personal electric transportation for commuting.

In addition to these specific issues there is a more comprehensive problem concerning street space allocation. Even though vehicles in this new group do not belong to the motor vehicle category, they cannot either be considered like traditional bikes or like pedestrians, since their higher speed changes the way that riders interact with other road users. As shown in one study (Huertas-Leyva & al., 2018), cyclists on e-bikes encounter more difficulties in predicting the movements of the surrounding road users, and consequently they brake abruptly more often to avoid collisions, compared with those cycling on traditional bicycles. From the model developed by Bai et al. (Bai & al., 2017) it emerged that:

- Increasing the average speed of e-bikes by 1% leads to an increase in the number of rear-end conflicts between e-bikes and bikes of 1.48%
- An increase of 1% in the speed difference between e-bikes and bikes corresponds to 0.16% increase in the expected number of rear-end conflicts between e-bikes and bikes.

As highlighted in 'Streetscape Guidance' (TfL, 2017) "*Streets need to manage a wide range of road users and their competing demands by providing clear but flexible spaces, with consistent and legible features that acknowledge where, when and how users should interact. Priorities should be applied to best provide for efficient and safe movement of people, goods and services, while reflecting and enhancing the character of the plac*e". However, a single solution suitable in all traffic environments is not conceivable; street design should rather be adapted to meet the user requirements in different situations. It can be assumed as a general rule that bicycles and scooters could share the route with motor vehicles where traffic is slow, such as in town centres; while next to major roads they could use segregated spaces. However, it is necessary to analyse the characteristics of each specific street and area in order to understand which modes need to fit together and, therefore, which space configuration is the most appropriate.

A possible approach is designing the infrastructure according to the main role of the specific streets. The Roads Task Force (RTF), which was set up by the then-Mayor of London in 2012 to "*tackle the challenges facing London's streets and roads*" (TfL, 2012), identified six requirements that streets and public areas need to meet (see Figure 17 for the definitions).

RTF also suggested a practical street categorisation in order to set priorities at specific locations. The nine 'street families', represented in the matrix in Figure 19, are defined according to the 'place' and 'movement' functions they currently serve or could perform in future.

Each of these street categories can be associated with a group of road users which is prioritised there, and, subsequently, to a type of infrastructure. For instance, in a street in a residential area, which mainly fulfils a 'place' function (M1/P3 in Figure 19), priority would be given to pedestrians; a 'Woonerf' style street could be implemented in this scenario, where all modes share the space but motor vehicles are restricted to walking pace. Table 15 is an illustration of how different user groups can be mapped against the different infrastructure design approaches recommended for each street category. Modes share space with the other modes shown in the same colour. It is important to note that the design geometries used for conventional bicycles, i.e. minimum required passing distances, turning radii, design speeds and stopping distances, may need to be reviewed for consistency with e-bikes. One example of street design where bicycles are the primary and preferred mode of transport is the 'Fietsstrook' (cycle-street), which has wide cycle lanes but only a single lane for motorised vehicles which are allowed as long as they do not crowd out the cyclists (Figure 18).

Functions roads/Public spaces	**Example**
Moving	Helping people get from A to B, providing for efficient and reliable movement by different transport modes and supporting access to jobs and services
Living	Providing good places that support vital economic, cultural and social activity, bustling high streets, successful neighbourhoods, thriving town centres and world-class destinations
Unlocking	Increasing accessibility and connectivity of growth areas to unlock the development potential that will create the homes, jobs, and new economic sectors that London needs as it grows.
Functioning	Ensuring essential access to premises for deliveries and servicing, effective use of kerb space to support activities in town centres and upgrading utilities under the roads.
Protecting	Reducing collisions, particularly for vulnerable users, and helping to ensure that streets are places where people feel secure
Sustaining	Reducing emissions on the road network, supporting greener, cleaner, quieter streets and a healthier, more active city.

Figure 17 Roads and public spaces functions according to the RTF's categorisation (RTF, 2013)

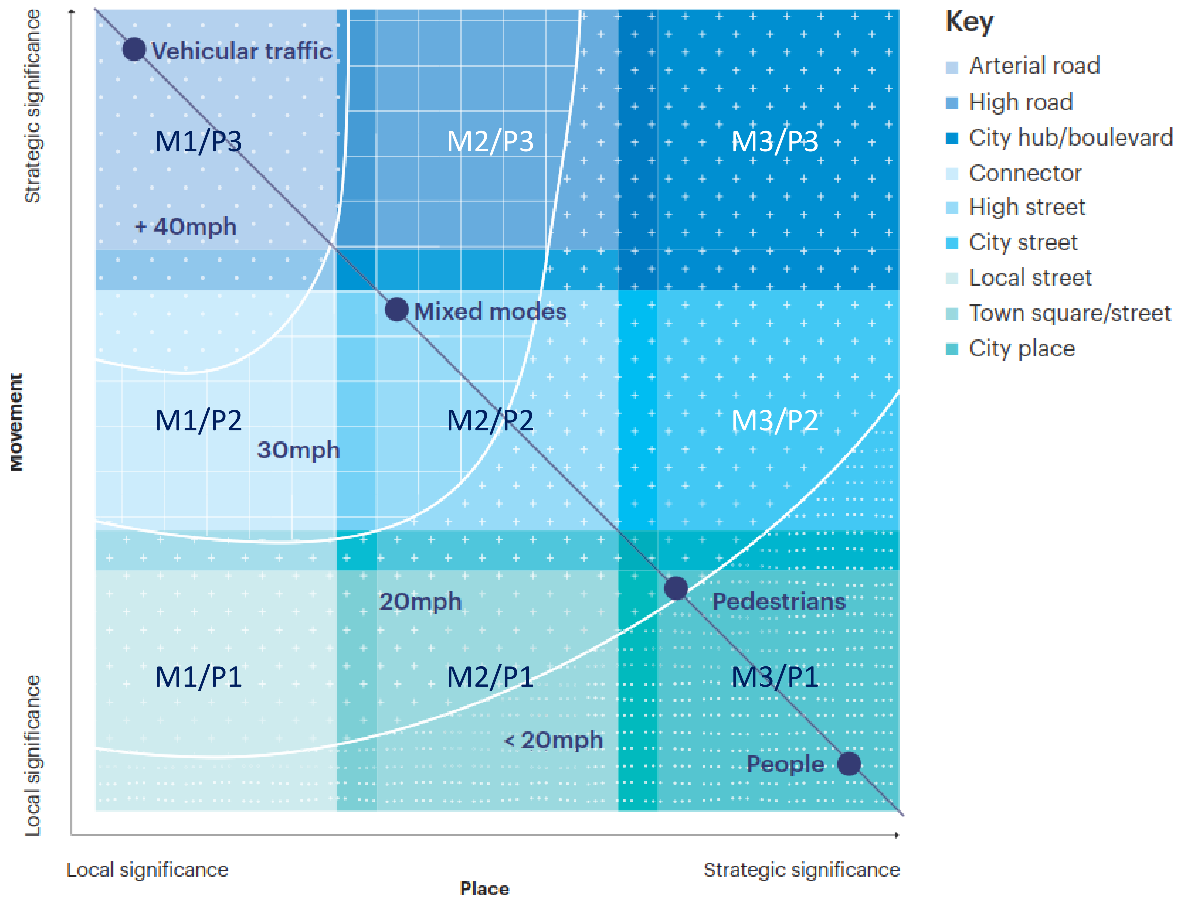


Figure 19 Street types matrix (from (RTF, 2013))

Table 15 Example of road design based on the street family. Groups of users sharing the same space are indicated by the same colour of the marker.

Street Family	M1/P3	M1/P2	M1/P1	M2/P3	M2/P2	M2/P1	M3/P3	M3/P2	M3/P1
Example	City Place	Town Square	Local street	City street	High street	Connector	Boulevard	High Road	Arterial/ CoreRoad
Standard / e-bikes	● (orange)	● (orange)	● (orange)	● (orange)	● (orange)	● (orange)	● (orange)	● (orange)	
Pedestrians	● (orange)	● (dark grey)	● (orange)	○	○	○	○	○	
e-scooters	● (orange)	● (orange) ● (dark grey)	● (orange)	○	○	○	● (orange)	● (orange)	
Public transport	● (orange)	● (orange)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)
Motor vehicles	● (orange)	● (orange)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)	● (dark grey)
Model	Home zone (Woonerf): all modes; motor vehicles at walking pace	Cycle Boulevard/ cycle street and Contraflow Cycle Street. Motor vehicle share road with other vehicles, and maintain low speed. Pedestrians have dedicated sidewalks at the same road level.	Motor vehicles have dedicated lanes; active modes share the space which is at the same road level.	Conventional cycle lanes separate non-motor vehicles* from sidewalks and main road.	Buffered cycle lanes separate non-motor vehicles from motor-vehicles road. Pedestrian share sidewalks with e-scooters.	Protected Cycle Track for conventional non-motor vehicles and e-bikes	Protected Cycle Track for conventional non-motor vehicles*	Protected cycle lanes separate non-motor vehicles* from motor-vehicles road	Motor vehicles only. Alternative road network for non-motor vehicles*

*Including vehicles battery assisted

12.3 Riders

The adoption of new electric vehicle types, such as pedelec and electric kick scooters, should be accompanied by adequate information for users about the technology and the risks involved. This would be advisable for example in relation to the following:

- Riding heavier and faster e-bikes increases the rate and severity of road accidents (Poos & al., 2017; Gross & al., 2018; Siman-Tov & al., 2016); therefore, it would desirable to initiate education and road safety training for users.
- Lack of proper vehicle maintenance and repair is a safety risk.
- Anyone who uses or borrows the vehicle (family members, friends, etc.) needs to be aware of the safety rules (for example, which charger goes with which bike).

Education and/or rider training is especially important for vulnerable categories, such as e-bike returners, who may be older and frailer, have little or no road sense, and become hazards to themselves, as shown for example by a study conducted in Australia (Johnson & Rose, 2015).

12.4 Insurance

Insurance for electric vehicles such as e-bikes, e-microscooters and e-scooter is currently not required in Great Britain (see Section 4 for the precise requirements on the vehicles); however, there are countries where it is mandatory for certain personal mobility vehicles. For instance, a moped licence, vehicle registration, corresponding tax payment and insurance, are needed to ride an e-bike in Northern Ireland (GOV.UK). Another example comes from Singapore, where the Government, as consequence of the several accidents involving personal mobility devices, approved the mandatory registration of e-bikes starting from August 2017 (Land and Transport Authority, 2017), and of e-scooters used on public paths from the second half of 2018 (Land Transport Authority, 2018).

There are not sufficient records about PMD involved in accidents to predict whether such requirements will become necessary in Great Britain. Vehicle owners may eventually be forced to have third-party insurance, which might slow down the take-up of new active transport modes.

12.5 Environment

The main environmental concern regarding electric personal vehicles, such as e-bikes, is about the battery disposal. The life span of the batteries currently on the market is a few years (depending on various factors, such as the type of battery, its use, etc.), after which they need to be replaced. If exhausted batteries are not properly disposed of, the harmful materials they contain (which can be metals such as zinc, copper, manganese, lithium and nickel) eventually leaks and contaminates the environment.

At European level the collection of batteries is regulated by the 'battery directive' 2006/66/EC (EU, 2006), where it is stated that:

"In order to protect the environment, waste batteries and accumulators should be collected. For portable batteries and accumulators, collection schemes achieving a high collection rate should be established. This means setting up collection schemes so that end-users can discard all waste portable batteries and accumulators conveniently and free of charge."

Schemes for battery recycling, treatment and disposal are also in place in Member States following the directive, which also sets minimum collection and recycling targets for Member States.

The collection rate in the UK was slightly below the target in 2017 (44.88%, instead of 45%) (Environment Agency, 2018); nevertheless, the increasing number of devices, among which personal vehicles, equipped with this technology could require further efforts.

It might also be important to raise the users' awareness about the implications for the environment of the inconsiderate disposal of hazardous waste.

12.6 Summary of issues

The growth in use of cycles, e-bikes and personal mobility devices raises issues for safety, the environment and the design of current infrastructure and the legislative framework governing their use. Issues associated with regulations, street design, provision of charging points and secure and appropriate storage/ parking when personal mobility devices, cycles and e-bikes are 'parked' which affect the take-up and use of these modes have been identified. Safety risks are not yet well understood and there are environmental concerns over the extent to which batteries used to power these new types of device are being disposed of correctly. These issues can be used to identify areas for further work, as set out in Section 13.

13 Proposal for further work

From this wide-ranging review of developments in innovative active travel, the potential benefits of three different areas of further investigation have been identified.

- Legal and regulatory aspects
- User experiences
- Support for practitioners.

13.1 Legal and regulatory aspects

This would involve discussions with policy makers and manufacturers to investigate the potential for clarification and possibly simplification of the legal position on use of new active modes.

This would involve a more detailed review of where the various modes are currently allowed to be used, and consideration of where their use could be permitted in the future. Different types of location would be considered, such as: in the carriageway with normal traffic; in the carriageway where normal traffic is restricted (for example pedestrian zones); in cycle lanes or tracks, but not pedestrian footways.

There appears to be a case for a more flexible view of how roads are defined from the point of view of which modes can be used where. For example in residential streets with low speed limits and in shared spaces and home zones, there is a case for use of scooters, Segways and mobility scooters to be legal, although these would not be considered safe on a busier road, or with 40mph traffic. One specific aspect to be investigated would be the definition of new categories of road that would enable wider use of active modes.

13.2 User experiences

Measures aimed at improving user experiences to make active travel more attractive and safer are proposed, covering vehicle design, street design, safe use of shared space and secure and suitable storage. To inform decisions on planning and implementing such measures, user research would also be needed.

13.2.1 User research

Innovative active travel modes, particularly those with electric power, can be expected to be associated with longer distances and use of hillier routes than traditional cycling and walking. This research would assess the characteristics of these new active modes of travel, the behaviour of their users and how use of these modes interacts with other modes (for example to access or replace other modes).

Such data would provide an understanding of how parameters used to model 'thresholds' for use of active modes vary with innovative active travel mode, and particularly e-bikes.

This user research could either be carried out by designing bespoke surveys, or by expanding the categories of mode type which are used when collecting data in large scale routine and one-off travel surveys.

It would also be helpful to investigate the physical characteristics of new modes and how they interact with other traffic, e.g. speeds, acceleration and stopping distances, comfortable turning radii, effective width when travelling- the dynamic envelope. This information would inform infrastructure design guidance.

13.2.2 Improved street design to take account of the requirements of these modes

On the basis of the understanding gained from the user research (in Section 13.2.1), this would involve a review of current highway design guidance to identify any changes that might be required to take account of the different characteristics and behaviours of users. This review would also take into account requirements for and positioning of charging points for e-bikes and other powered personal modes.

13.2.3 Investigate need for awareness raising over safe use of shared space

Using the faster modes of active travel in shared spaces such as footways and other areas designated primarily for pedestrians increases risk and potential conflicts. The extent to which such conflicts occur and the circumstances of such conflicts could be investigated to provide evidence and examples to support an awareness raising initiative to encourage safe use of shared space.

13.2.4 Design and provision of secure storage

Safe storage, such as lockers and attended parking is particularly important for e-bikes but is also an issue for other active modes. This piece of work would investigate the options for secure storage identify the key design features and the costs involved, with a view to encouraging take up of such modes.

User research could also be carried out to identify the extent to which lack of suitable storage acts as a deterrent in practice, potentially as part of the user research described in Section 13.2.1.

13.2.5 Improved design of microscooters

The limited trial carried out in this project indicated that the solid wheels and lack of suspension were likely to make them unattractive as regular modes of travel. One potential avenue for further work would be to share the findings with manufacturers of micro scooters with a view to collecting more systematic data that could be used to make the case for improved design (such as larger wheels and pneumatic tyres).

13.2.6 Investigate need for awareness raising over safe battery disposal

Safe disposal of batteries at the end of their life is crucial to ensuring active modes do not result in detrimental impacts on the environment. At present there appears to be little information available on how batteries are disposed of.

This investigation would identify the measures which users, retailers and manufacturers are taking to ensure safe disposal of batteries and then assess the need for awareness raising to ensure that batteries are disposed of appropriately.

13.3 Support for practitioners

In order to identify the potential for active travel modes, and to make the case for interventions to encourage innovative active travel, practitioners would benefit from a range of additional pieces of work.

13.3.1 Data on accidents and near misses

Data would be gathered on accidents and near misses to identify the involvement of these active modes specifically, to improve the understanding of relative risk. This could either be done using a bespoke study, or by changing the categories used to record modes in routine data collection.

13.3.2 Health impacts of active travel

To improve the data used by practitioners to assess the potential benefits of innovative active travel interventions, a more refined version of the trial methodology developed in this project could be used in a larger scale study. This would measure the health impacts of active travel modes including new active modes amongst a representative sample of users of a range of active modes.

In the short term, before data is available on widespread e-bike use, the method developed here for assessing the health benefits of e-bikes could be used to assess the health benefits of e-bike use, when assessing the potential benefits of interventions involving e-bikes. Amongst other things this would take account of a potential trade-off between intensity of exercise and duration and frequency, if electrically assisted modes encourage greater usage at lower levels of effort.

13.3.3 Conversion of assessment methods to accommodate e-bikes

The ‘thresholds’ affecting mode choice decisions for different active travel modes could be estimated on the basis of user research outlined in Section 13.2.1. Such information could then be used to define factors to be used for converting assessment methods so that they are appropriate for these new modes.

13.3.4 Adapting the Propensity to Cycle Tool

In order to adapt the Propensity to Cycle Tool for use with other active modes, some of the user research identified in Section 13.2.1 would be needed to understand how parameters used to model ‘thresholds’ for use of active modes vary for innovative active travel modes.

Additional data would also be needed on presence of surfaced off-road routes and which modes can legally be used on them.

13.3.5 Other implications of innovative active travel for traffic and demand modelling

If e-bikes or other powered active modes make it easier to travel further, they effectively extend the effective catchment area for facilities. In transport modelling terms, this will effectively reduce the value for time for users. Thus these modes have implications for the values used in transport modelling and appraisal. This is particularly important when considering multi modal journeys, e.g. cycling to a railway station, where the ability to cycle and ride can make rail travel more competitive with driving for the door to door journey. More research is therefore needed to improve demand modelling techniques and scheme assessments.

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Appendix A Data used for the test

The data used for simulating a medium sized urban scenario are those relative to Reading; they are available at the website http://www.reading.gov.uk/jsna/transport (accessed in April 2018).

Reading population

According to the Active People Survey [19] results, reported on the webpage http://www.reading.gov.uk/jsna/physical-activity (accessed in April 2018), the population in Reading is characterised as follows:

- 70,100 Active
- 25,400 Insufficiently active
- 32,700 Inactive

From these figures we obtain a total number of 128,200 adult residents.

Method of travelling to work

Data used for the transport mode proportions are from the Census 2011, which involved 36,229 residents, aged between 16 and 75.

Table 16 Method of travelling to work in the Local Authority of Reading (Census 2011)

Car or van	Motorcycle	Train	Bus	Cycle	Walking
30.6%	0.4%	6.4%	7.4%	2.8%	11.2%

Table 17 Proportion of working age population in Reading travelling to work by different methods (Census 2011)

Working at home	Driving	Public Transport	Active transport	Not in employment
6%	34%	14%	14%	32%

Using the figure for the total adult population in Reading calculated in A.1, we have:

<u>Commuters in Reading using car or public transport</u>: (34%+14%)*128,200 = <u>61,536</u>

Assumption for the calculation exercise: 10% of the commuters who drive or use public transport shift to riding e-bikes, that is, 6,153 new cyclists (e-bikes).

[19] "The Active People Survey (APS) is the largest sport and active recreation survey ever established. It is a telephone survey for adults living in England (aged 14 years and over). It identifies how participation varies from place to place and between different groups in the population." (Sport England, 2017)

Casualties on Reading roads

Also available on the web site http://www.reading.gov.uk/jsna/transport:

- Number of pedestrian and cycle accidents on A-Roads in Reading

"People reported killed or seriously injured on Reading's roads between 2012 and 2014 was 28.3 per 100,000 people (note: England average of 39.3 and the rate of 41.5 per 100,000 amongst Local Authorities with similar levels of deprivation)."

Physical activity in the adult population in Reading

From the website http://www.reading.gov.uk/jsna/physical-activity:

"While the largest number of people in the population are meeting the threshold (more than 70,000), some 32,700 do no physical activity at all, while 25,400 people don't reach the recommended level."

In percentages (Figure 20):

- Active (i.e. at least 150 minutes of moderate activity a week): 54.7%

    Of which, 63% were doing between 150 and 599 minutes

- Inactive (i.e. less than 30 minutes of moderate activity per week): 25.5%

    Of which, ~ 20% were doing between 30 and 149 minutes

Using an approximate weighted average from the above figures, we have:

- Average number of minutes per week: 216
- Average number of minutes per day: 31

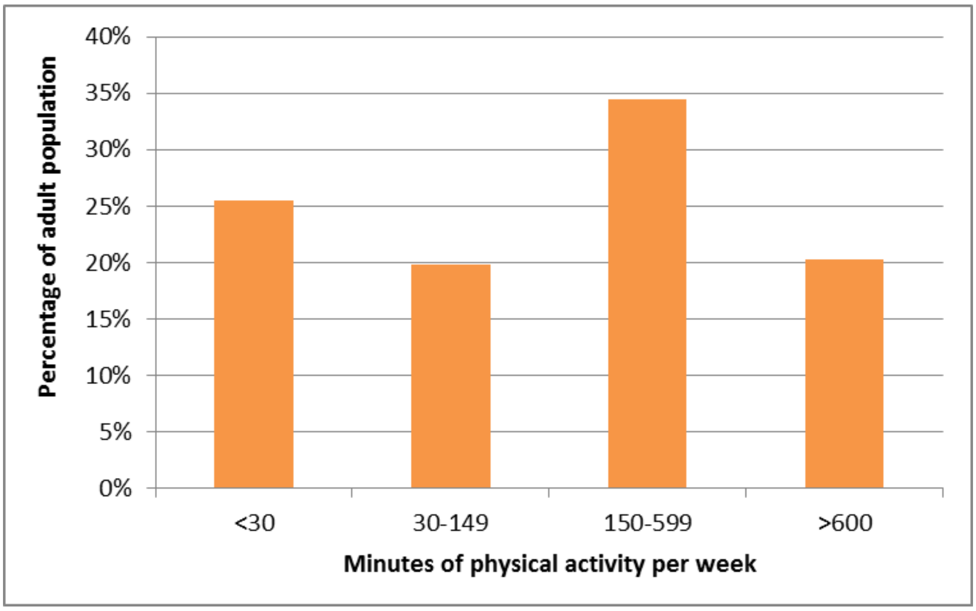

Figure 20 Physical activity in the adult population in Reading

Appendix B Quadricycles

Four-wheeled microcars include light (L6e) and heavy (L7e) quadricycles. Table 18 summarise the limitations for electric quadricycles in terms of weight, power and speed which define the two categories according to the Directive 2002/24/EC.

The Directive 2006/126 (3rd Driving Licence Directive) establishes that light and heavy quadricycles comply with the same requirements applied to three-wheeled mopeds of category L2e and L5e respectively (including the minimum driving age, i.e. 16 years and 17 years), unless differently specified in separate Directives. The Directive 168/2013 EU defines several subcategories (reported in Table 19 and Table 20) and contains the administrative and technical requirements the vehicles must comply with.

Table 18: Technical features of light and heavy quadricycles

Category	Technical feature	Classification criteria
L6e	Maximum design vehicle speed	≤ 45 km/h
	Mass in running order	≤ 425 kg
	Engine capacity	≤ 50 cm^3 if a Positive Ignition (PI) engine or ≤ 500 cm^3 if a Compressed Ignition (CI) engine forms part of the vehicle's propulsion configuration or ≤ 4 kW continuous rated power if electric
	Seats	Maximum of 2 seating positions (including the driver's seat)
L7e	Maximum design vehicle speed	≤ 90 km/h
	Mass in running order	≤ 450 kg for transport of passengers ≤ 600 kg for transport of goods
	Net rated engine power	≤ 15 kW continuous power

Table 19: Light quadricycle sub-categories according to the Regulation No 168/2013 EU

Sub-category		Supplemental sub-classification criteria
L6e-A	Light on-road quad	L6e vehicle not complying with the specific classification criteria for a L6e-B vehicle and maximum continuous rated or net power ≤ 4 kW.
L6e-B	Light quadri-mobile	Enclosed driving and passenger compartment accessible by maximum three sides and maximum continuous rated or net power ≤ 6 kW
		Sub-sub-classification criteria in addition to the sub-classification criteria of a L6e-B vehicle

L6e-BP	Light quadri-mobile for passenger transport	L6e-B vehicle mainly designed for passenger transport and L6e-B vehicle other than those complying with the specific classification criterion for a L6e-BU vehicle
L6e-BU	Light quadri-mobile for utility purposes	Exclusively designed for the carriage of goods with an open or enclosed, virtually even and horizontal loading bed that meets the following criteria: (a) $length_{loading\ bed} \times width_{loading\ bed} \geq 0.3\ Length_{vehicle} \times Width_{vehicle}$ or (b) an equivalent loading bed area as defined above in order to install machines and/or equipment and (c) designed with a loading bed area which is clearly separated by a rigid partition from the area reserved for the vehicle occupants and (d) the loading bed area shall be able to carry a minimum volume represented by a 600 mm^3

Table 20: Heavy quadricycle sub-categories according to the Regulation No 168/2013 EU

Sub-category		Supplemental sub-classification criteria
L7e-A	Heavy on-road quad	L7e vehicle not complying with the specific classification criteria for a L7e-B or a L7e-C vehicle and vehicle designed for the transport of passengers only and maximum continuous rated or net power ≤ 15 kW and
		Supplemental sub-classification criteria
L7e-A1	A1 heavy on-road quad	Maximum two straddle seating positions, including the seating position for the rider and handlebar to steer
L7e-A2	A2 heavy on-road quad	L7e-A vehicle not complying with the specific classification criteria for a L7e-A1 vehicle and maximum two non-straddle seating positions, including the seating position for the driver
		Supplemental sub-classification criteria
L7e-B	Heavy all terrain quad	L7e vehicle not complying with the specific classification criteria for a L7e-C vehicle and ground clearance ≥180 mm
		Supplemental sub-classification criteria
L7e-B1	All terrain	Maximum two straddle seating positions, including the seating position

	quad	for the rider and equipped with a handlebar to steer and maximum design vehicle speed ≤ 90 km/h and wheelbase to ground clearance ratio ≤ 6
L7e-B2	Side-by-side buggy	L7e-B vehicle other than a L7e-B1 vehicle and maximum three non-straddle seats of which two positioned side-by-side, including the seating position for the driver and maximum continuous rated or net power ≤ 15 kW and wheelbase to ground clearance ratio ≤ 8
L7e-C	Heavy quadri-mobile	L7e vehicle not complying with the specific classification criteria for a L7e-B vehicle and maximum continuous rated or net power ≤ 15 kW and maximum design vehicle speed ≤ 90 km/h and enclosed driving and passenger compartment accessible via maximum three sides and:
		Sub-sub-classification criteria in addition to the sub-classification criteria of a L7e-C vehicle
L7e-CP	Heavy quadri-mobile for passenger transport	L7e-C vehicle not complying with the specific classification criteria for a L7e-CU vehicle and maximum four non-straddle seats, including the seating position for the driver
L7e-CU	Heavy quadri-mobile for utility purposes	Exclusively designed for the carriage of goods with an open or enclosed, virtually even and horizontal loading bed that meets the following criteria: (a) $length_{loading\ bed} \times width_{loading\ bed} \geq 0.3\ Length_{vehicle} \times Width_{vehicle}$ or (b) an equivalent loading bed area as defined above designed to install machines and/or equipment and (c) designed with a loading bed area which is clearly separated by a rigid partition from the area reserved for the vehicle occupants and (d) the loading bed area shall be able to carry a minimum volume represented by a 600 mm^3 and maximum two non-straddle seats, including the seating position for the driver

Appendix C Personal activity monitoring devices – Collected data

Data collected during the survey about personal activity monitoring devices (whose discussion is the subject of Section 10).

Table 21 Types of fitness tracker used

Types of tracker	Model	No.
Fitness band	Fitbit Flex	2
	Fitbit Charge2/HR	2
	Garmin Vivo Smart	1
	Jawbone	1
Smart watch	Samsung Galaxy Gear 2	1
	Garmin Vivo Active HR	2
	Garmin Fenix 5X	1
	Garmin Forerunner 735XT	1
Smartphone app	Strava	1
	Collection of iphone apps for sleeping, pedometer, UnderArmour (food & fitness), MyfitnessPal (calories counter)	1
Cycle computer	Garmin Edge 810	2
Heart rate monitor		1
Total		16

Table 22 How devices are used

Uses	No.
Walking - count steps and monitor progress towards target	10
Monitor sleep	6
Track cycling	5
Track running	5
Monitor heart rate at rest and during exercise	5
Track swimming	3
Manually enter activities that are not recorded automatically	3
Monitor performance compared with previous occasions on the route	2

Uses	No.
Turn by turn navigation and mapping	2
Watch	2
Football	1
Golf	1
Monitor exercise and whether need to go to the gym	1
Monitor whether eating or drinking too much	1
Set exercise goals	1
Identify whether daily target met	1
Measure daily and weekly exercise and 'intensity minutes'	1
Compare performance with others (unknown) on the same route and maintain league table	1
Recording location of route	1
Record distances and speed	1
Alarm 'clock' set to go off at appropriate point in sleep cycle	1
Notification of incoming emails, texts and phone calls	2

Table 23 Times when devices are worn

Time when the device is worn	Number
All the time, or almost all the time	6
Almost all the time apart from when asleep	3
When exercising/ days when exercising	6
Varies	1

Table 24 Suggested devices for use in TRL trial

Suggested devices for use in trial	Number
'Low cost' option	
The most basic Fitbit that can distinguish required activities and linked to an app	2
The most basic Fitbit that can distinguish require activities and monitor heart rate	1
The most basic Garmin Vivo that can distinguish required	1

Suggested devices for use in trial	Number
activities and linked to an app	
Garmin Vivo Fit or Active with add-on for running	1
'Cost is no barrier' option	
Garmin Vivo Active HR	2
Apple watch	1
Garmin watch Fenix 5X	1
Smart watch with heart monitor, activity and sleep tracking	1
Multi-sport smart watch	1
Device with GPS tracking	2

Table 25 Devices available for trial if used by owner

Devices available for use by owners in a trial		Respondent reference
Fitness band	Fitbit Flex	[1]
	Fitbit Charge 2	[3]
	Fitbit Charge HR Available for a trial on a specific circuit but does not do active travel	[7]
	Garmin Vivo Smart	[12]
	Jawbone	[4]
Smart watch	Garmin Fenix 5X	[9]
	Garmin Forerunner 735XT	[10]
	Garmin Vivo Active HR One of these people will be out of action for October and first half of November; if outside this time would need a specific circuit as cycling is the only usual active travel	[8, 11]
Running watch	Garmin Forerunner 10	[10]
Running app	Strava	[2]

Table 26 Devices available for others to use in trial

Devices available for others to use in a trial		Respondent reference
Fitness band	Fitbit Flex	[1]
	Fitbit Charge 2	[3]
	Fitbit Charge HR	[7]
	Garmin Vivo Smart	[12]
	Jawbone (but need iPhone]	[4]
Smart watch	Garmin Fenix 5X (available if trial is one person)	[9]
	Garmin Forerunner 735XT (if limited session)	[10]
	Garmin Vivo Active HR	[11]
Running watch	Garmin Forerunner 10	[10]

Appendix D Survey Form

<u>TRL MICRO-SCOOTERS</u>

This survey is to get your feedback on the micro-scooter that you borrowed recently, in preparation for a potential TRL reinvestment project to look at their potential as a means of travel.

The survey consists of one page of questions - these have all been made compulsory (to avoid people accidentally missing questions), but feel free to put n/a if you do not wish to answer.

This work is being led by Alan Stevens and Sally Cairns. Notably:

Individually identifiable survey responses will be kept confidential to Alan, Sally and any other members of TRL who work in this area.

However, text provided may be used as an anonymous quotation in a future report.

We may contact you in the future, to clarify what you have said.

1. I understand that I am providing information on this basis *

☐ Yes

2. What is your name *

3. What is your email address? *

4. When, and for how long, did you borrow the scooter(s)?(e.g. please use the reply format 'Monday 27th March - Friday 31st March 2017') *

5. Which type of scooter(s) did you borrow?(Please tick all that apply.) *

☐ Manual scooter (small wheels)
☐ Manual scooter (big wheels)
☐ Electric powered scooter

☐ Other (please specify):

6. What types of activity did you use the scooter for? *

☐ Recreational use

☐ Particular journeys

If used for particular journeys, what type of journeys? (i.e. in terms of purpose and distance)

7. If you had a scooter available for use on a regular basis, would you use it instead of other forms of travel for particular journeys? *

☐ Yes

☐ Maybe

☐ No

☐ Don't know

If you might do so, please indicate what type of journey, what mode of travel the scooter would replace, and why you would use the scooter instead

*8. If you had a scooter available for use, do you think it would increase the amount of physical activity that you would do? **

- ☐ Yes
- ☐ Maybe
- ☐ No
- ☐ Don't know

Any other comments:

9. What do you see as the main advantages of using the scooter(s)? *

10. What do you see as the main disadvantages of using the scooter(s)? *

11. Were there any particular safety issues or hazards that you encountered when using the scooter(s)?

12. Any comments on the attractiveness of the different types of scooters? *

13. Any other comments? *

Appendix E Survey form for the trial on wearable technologies

1) Please answer the following questions by either typing in the box or copying this: ✓ into the relevant box

a. How old were you on your last birthday?		☐
b. Gender	Male	☐
	Female	☐
c. How much time do you spend on physical activity during a typical week?	< 30 mins	☐
	≥ 30 mins, <2.5 hours	☐
	≥ 2.5 to <5 hours	☐
	≥ 5 hours	☐
d1. Which commuting distance would you consider feasible by cycling?	☐ d < 1 mile	☐
	☐ 1 mile ≤ d < 2 miles	☐
	☐ 2 miles ≤ d < 3 miles	☐
	☐ 3 miles ≤ d < 5 miles	☐
	☐ 5 miles ≤ d < 10 miles	☐
	☐ d ≥ 10 miles	☐
d2. Which commuting distance would you consider feasible by walking?	☐ d < 1 mile	☐
	☐ 1 mile ≤ d < 2 miles	☐
	☐ 2 miles ≤ d < 3 miles	☐
	☐ 3 miles ≤ d < 5 miles	☐
	☐ d ≥ 5 miles	☐
d3. (Optional) Which commuting distance would you consider feasible using other active modes (fill in)…?	………………………………..	

Please answer the following questions about your trial circuits by typing in the boxes

a) Circuit length:

b) Estimate of height difference

c) Weather condition trial 1 eg: extremely cold, cold, sunny and warm, raining, …

d) Weather condition trial 2

e) Weather condition trial 3

Trial number	Mode	Average heart beat	Max heart beat rate	Time (min)	If the circuit used in the trial were similar to the actual route home/work, would you consider this mode for the daily commuting? If not, why?
1	………..	…..	…..	..:..	………..
2	………..	…..	…..	..:..	………..
(3)					

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TRL would like to thank Alison Jackson of Micro Scooters Ltd for providing the scooters and being an enthusiastic supporter of our research.

Innovative active travel solutions and their evaluation

Recent developments in power-assisted active travel solutions have the potential to encourage mode shift away from cars and provide health benefits for users. However, the understanding of legal and safety issues associated with using these modes is limited. Moreover, little research has been done to evaluate their health impacts, while current tools for appraisal of transport interventions do not take account of the different health impacts of assisted active travel.

This report investigates the nature of innovative active travel solutions, how this area is developing, and it gives insights on related issues. The techniques available for the monitoring and evaluation of health impacts of different active travel options are explored, as well as the tools for the economic appraisal associated to health benefits of active transports (HEAT, AMAT), and for the evaluation of the propensity to cycle (Propensity to Cycle Tool).

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