May 2021

ADEPT Live Labs

Last Mile Mobility

In-depth Feasibility Study

Buckinghamshire Council

Background

Buckinghamshire Council have been leading the £4.5m **'SMART Connected Community: Live Labs'** project since 2019. It is part of a £23m programme, funded by the Department for Transport, and led by the Association of Directors of Environment, Economy, Planning and Transport (ADEPT). The project is built around four themes: **Smart Materials, Smart Communication, Smart Energy, and Smart Mobility.** The Connected Places Catapult (CPC) has delivered this Last Mile Mobility: In-depth Feasibility Study as part of the Smart Mobility theme.

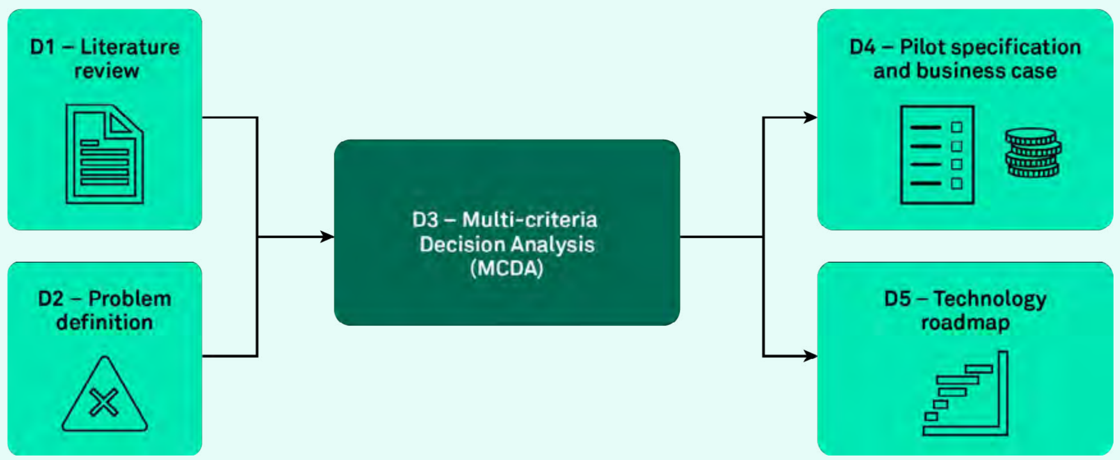
The in-depth feasibility study was undertaken to investigate the current first and last mile mobility landscape, including the movement and people and goods, and determine the benefits of introducing new technological solutions for Buckinghamshire and other similar local authorities.

Oveview

Innovative last mile mobility solutions present an opportunity to transform the mobility landscape and offer sustainable options in line with strategic aspirations for improving air quality and reducing the over-reliance on private vehicles and delivery vans for short journeys.

This document presents the outputs of the in-depth feasibility study which are made up of the following five deliverables:

- **D1 Literature Review:** explores the existing, emerging and future last mile mobility solutions for moving people and goods.
- **D2 Problem Definition:** uses interviews with key stakeholders to define a set of targeted problem statements.
- **D3 Multi-Criteria Decision Analysis:** evaluates the different last mile options against a defined set of criteria and identifies a short-list of solutions that satisfy defined needs.
- **D4 High Level Pilot Specifications:** outlines options for piloting the shortlisted last mile solutions in a sub-urban setting.
- **D5 Roadmap Report:** defines the evolutionary path for realising the full potential of last mile solutions and identifies the associated infrastructure and technology requirements.



D1 - Literature Review

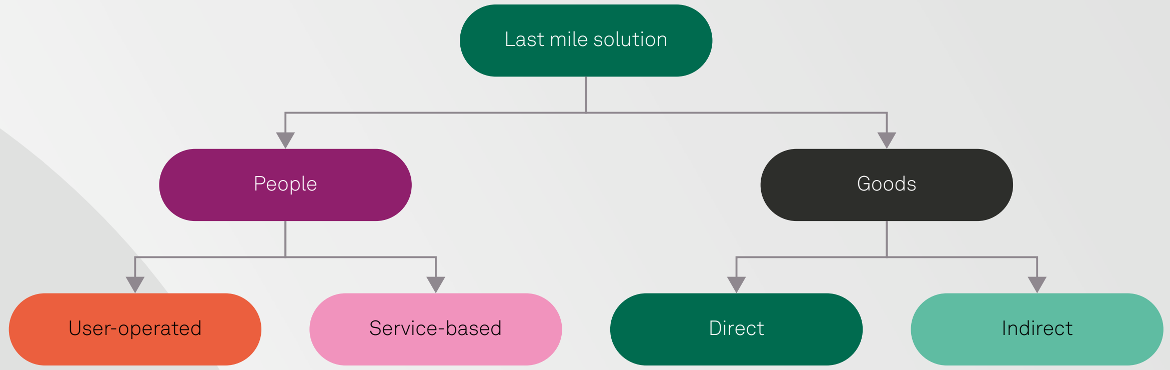
The literature review (Appendix D1) outlines the urgent need for change in how Buckinghamshire in particular and the UK in general, move goods and people over the last mile to meet Net Zero targets, reduce congestion, and improve air quality. The growth of diesel vans and internal combustion engine cars for short journeys were highlighted as key priorities for targeted modal shift.

For the purpose of this study we have defined last mile mobility as follows:

> First or last mile mobility is the movement of goods or people over short distances to facilitate either;
>
> a) end-to-end short journeys between a precise origin and destination, or;
>
> b) modal connections as part of a longer journey.

The literature review was conducted to explore the state-of-the-art of last mile mobility solutions and determine their relative merits. Information such as cost to user, occupancy/payload limits, maturity of technology, required infrastructure, cost to implement and the general benefits and limitations are provided within the report's appendices.

The solutions were categorised as shown in the flow diagram below.



As shown in the flowchart, the **people-based solutions** are subcategorised into user-operated and service-based solutions with the following definitions:

- **User-operated solutions:** require active engagement from the user for the duration of the journey.
- **Service-based solutions:** operated by a paid operator and/or automated technology and do not require active engagement from the user.

The **goods-based solutions** are subcategorised into direct and indirect solutions with the following definitions:

- **Direct solutions:** allow for goods to be delivered to the precise end destination directly.
- **Indirect solutions:** improve efficiency of delivering goods but require a direct solution for journey completion.

The literature review can be used as a reference when evaluating the best last mile solutions to be trialled or deployed in a specified location. The full list of the solutions can be found in the table above. Solutions from this table were added to the 'longlist' where they were further analysed for their suitability for a pilot in Aylesbury using multi-criteria decision analysis.

People		Goods	
User-operated	Service-based	Direct	Indirect
Car	Bus	Van	Amazon lockers
Walking/ wheelchair	Taxi	Cargobike	Consolidation centres
e-scooter	Flying Taxis	CAV[1]	Magway
Car club	Water bus	Private car	Delivery to car
Bicycle	On-demand ride hailing	Drones	3D printing
Docked share scheme	CAV[1]	Motorcycle	
Motorcycle	Cable car	Automated delivery robots	
e-bicycle	DRT[2]		
Dockless share scheme	Segregated CAV[1]		

1 CAV: Connected and Autonomous Vehicle
2 DRT: Demand Responsive Transit

D2 - Problem Definition

The problem definition report (Appendix D2) outlines the last mile mobility challenges experienced by local authorities and the barriers they face when attempting to diversify and decarbonise their last mile mobility ecosystem. Through a series of interviews and workshops with members of Buckinghamshire Council, the following eight problem statements were developed:

Problem statements

1. Investment in active travel is restricted by public and political perception.
2. Heavy Goods Vehicles are routed through towns and villages.
3. Reliance on diesel vans to fulfil low density last mile deliveries.
4. On-demand delivery vehicles cause traffic disruption.
5. Powerful lobbying from car users perpetuates driving dominance.
6. New housing developments are not setting best practice.
7. Public transport is inefficient over the last mile.
8. Long-term change is difficult to plan and implement.

These challenge statements were used to develop the multi-criteria decision analysis framework, whereby solutions which work to overcome these challenges scored more highly.

D3 - Multi-criteria Decision Analysis

The longlist of solutions identified and explored in the literature review were scored and ranked using a multi-criteria decision analysis (MCDA) framework – see Appendix D3 for more details. The developed MCDA framework considered the solutions' current maturity and costs of implementation in addition to benefits such as environmental and political and challenges such as public perception and infrastructure requirements. Solutions which are unlikely to reduce carbon emissions compared with a car or diesel van were discarded and discounted from the rankings.

The top five solutions for the movement of people and goods are presented in the tables below.

Movement of people

Rank	Solution (People)	Total score (-34 to 78)
1	Walking	64
2	e-bicycle	48
3	Bicycle	46
4	e-scooter	44
5	Docked shared bike scheme	43

Movement of goods

Rank	Solution (Goods)	Total score (-26 to 63)
1	(e-)cargobike	38
2	Automated robots	36
3	Collectplus	33
4	3D printing	30
5	Drones	29

D4 - Pilot Specification and Business Case

Three pilot proposals were developed which showcase different combinations of the shortlisted solutions from the MCDA analysis. Each pilot tackles a different challenge, has different objectives, and supports the decarbonisation of the last mile as well as the wider mobility ecosystem. They are therefore not directly comparable, but could all be deployed simultaneously if desired without competing or significantly impacting each other’s baseline data. Details of pilot proposals are in Appendix D4.

Appendix D4 has been omitted from this document as it contains commercially sensitive information

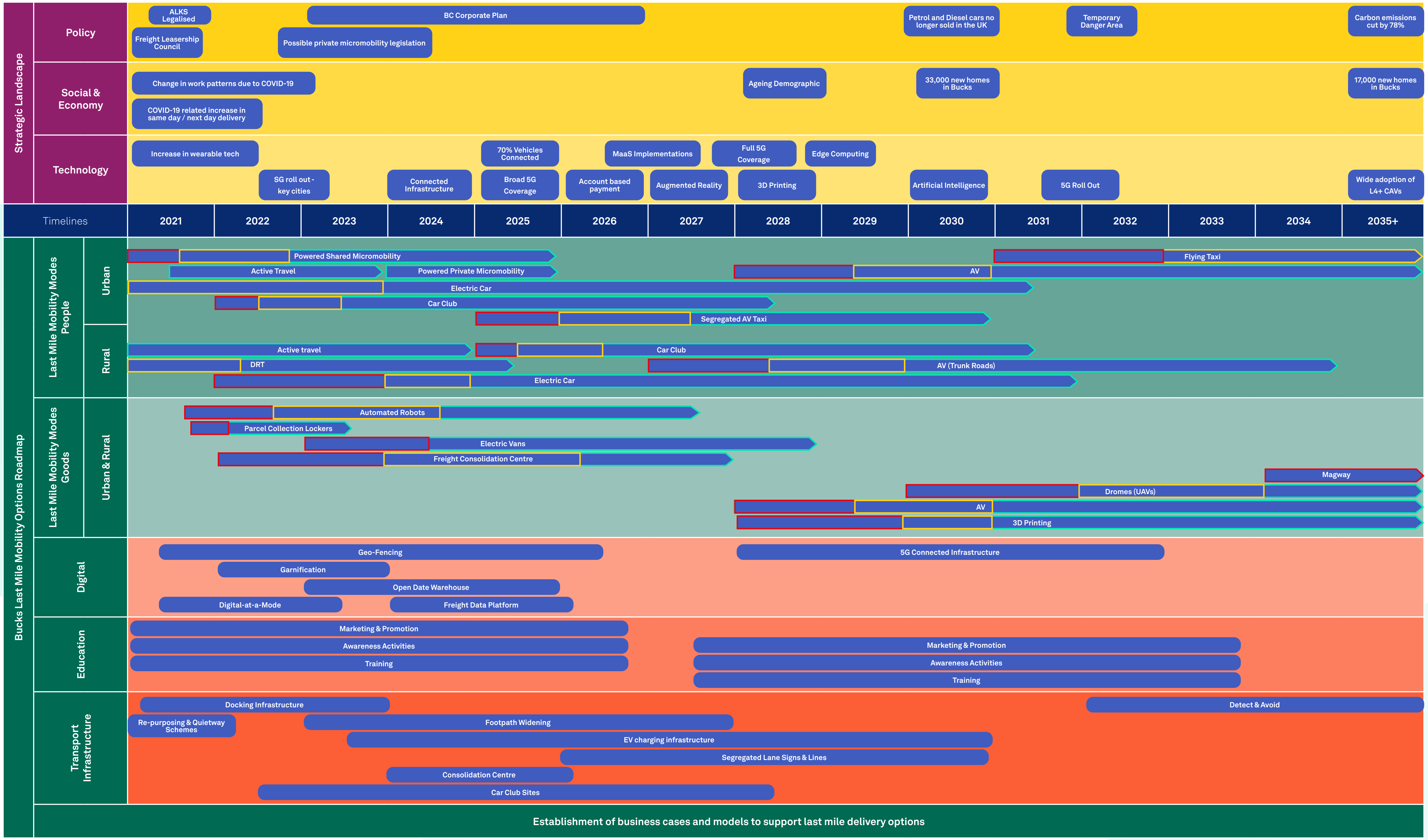
D5 - Technology Roadmap

The last mile mobility technology roadmap (Appendix D5) presents the changes that are on the horizon between 2020 and 2035, beyond which there is too much uncertainty to make reasonable assumptions. It outlines enabling activities that need to be undertaken to lay the foundations for last mile mobility modes to be delivered in line with Buckinghamshire Council's objectives. This roadmap builds upon the literature review, problem statement and multi-criteria decision analysis (MCDA), and last mile mobility pilot options activities.

The roadmap considers the key changes that are going to take place from a strategic, regional, local, technological and political lens. It sets a direction of travel and will need to be reviewed and refreshed on a continual basis throughout its term as new technologies will emerge that haven't been foreseen and changes may come more quickly or be delayed against current expectations. This roadmap should then support the more detailed planning, design, business case development, procurement and implementation of last mile mobility modes.

The Last Mile Mobility Roadmap (shown below) offers Buckinghamshire and similar local authorities with a view of a range of innovative and cutting-edge transport modes to address the four problem areas; **congestion, sedentary lifestyle, poor air quality and carbon emissions.** Whilst it provides a holistic view of multiple available modes it should not be seen as essential to deliver all of the last mile mobility solutions. Each solution will deliver incremental benefits and contribute towards delivery of the overall objectives and as such, there is a need to closely monitor and evaluate the success of any implementation.

Last Mile Mobility Feasibility Study



Notes

- The development phases are shown as linear for clarity, however for some options there maybe overlap between the phases. For example, the powered shared micromobility option pilots may form part of the ongoing feasibility.
- The key to the right groups the development cycle into three board phases for the purposes of clarity with the roadmap. Should Bucks take forward any option there are likely to be a number of additional phases such as design.
- Powered micromobility includes a subset of options which follow a broadly similar implementation paths such as e-scooters and e-bikes.
- Active travel includes a subset of options which follow broadly similar implementation paths such as walking and cycling.

Key

Feasibility = feasibility of the option for Bucks or similar area (not when the option becomes a feasible solution in general i.e. the option may be feasible at an earlier state for testbeds and urban conurbations such as London)

Pilot = trial of the option and assessment of benefits before potential scaled rollout

Rollout = scaled roll out of the option before embedment into BAU

Conclusion

The Connected Places Catapult's Last Mile Mobility In-depth Feasibility Study has highlighted the urgent need for change in Buckinghamshire to make last mile mobility more efficient and meet the current and future needs of residents. We found that there are many challenges experienced by local authorities as they strive to improve last mile mobility in line with their social, economic and environmental objectives. These challenges include geographical limitations such as available road network infrastructure, human behaviour and perception and the resistance to change, operational inefficiencies and not making the most of available technologies or lessons learned.

There are many potential benefits to be gained from implementing new last mile mobility options for the movement of people and goods. All of the solutions we took forward to consider for a pilot had the potential to reduce carbon emissions relative to the combustion engine car and van but the ones with the most significant reductions include active travel modes (walking, cycling, cargobikes) and electrification of vehicles (e-scooters, electric delivery robots, e-cargobikes). Active travel modes have the added benefit of health benefits to the user, zero particulate production leading to better air quality and wider societal benefits from the improved public health resulting from both. Solutions which remove the need for travel completely such as 3D printing may also contribute significantly to reduced carbon emissions once the technology rises in maturity to be able to manufacture a wider range of goods. Beyond our shortlisted options, quicker wins such as transitioning from diesel vans to electric vans should be considered but understanding that this will not tackle the wider system problems of congestion.

The success or failure of implementing new mobility solutions is very sensitive to contextual factors. As such, it is critical that a thorough trial with a measurable baseline and sufficient monitoring and evaluation is conducted before rolling out the technologies further. In Aylesbury, we suggest launching one, two or three of the pilot specifications set out in D4; electrifying pedal power, estate of the art or gamification of active travel as the findings will be replicable in many similar semi-urban areas. Elsewhere our multi-criteria decision analysis framework (MCDA) can be modified to meet the context and objectives of other authorities looking to implement last mile solutions.

Our last mile mobility roadmap demonstrates the importance of considering external factors when determining the feasibility of disruptive technologies or behavioural change in the last mile mobility system. Enabling technologies such as 5G networks and automation should be continually reviewed to check whether their maturity is sufficient to unlock new mobility solutions. In addition, legislative changes and policy interventions such as clean air zones should be treated as important potential levers for fostering innovation in last mile travel and to accelerating the transition to a greener transport network.

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May 2021

Appendix D1

Literature Review

ADEPT LIVELABS Transforming Local Places

Buckinghamshire Council

Executive Summary

There is an urgent need to diversify the last mile mobility landscape to reduce the over-reliance on passenger cars and delivery vans for conducting short journeys. Innovative last mile solutions have the potential to revolutionise local movements of people and goods and help to meet sustainability targets.

The delivery of goods and people over the first and last mile is a vital part of the logistics supply chain and an important component of daily life. The speed, efficiency and cost of last mile travel have an impact on productivity and local economic growth. Currently, there is an overreliance on vehicles powered by internal combustion engines to fulfil short journeys which has caused overcrowding on the road network leading to high congestion levels in urban areas and at peak travel times. Heavier congestion levels result in longer and less reliable travel times by road and can lead to more road traffic collisions.

According to the Department for Transport (DfT), car usage has been increasing steadily with vehicle miles travelled (VMT) growing by 29.8% in the 25-year period between 1994 and 2019. Vans have experienced a much more significant growth of 106.2% VMT and an increase in stock of 93% over the same time period. Meanwhile, bus VMT dropped by 16.4% suggesting that consumer appetite for larger shared modes has reduced[1]. The growth and dominance of private motorised transport has negative environmental impacts due to the high levels of carbon emissions and the release of nitrogen oxides and other pollutants which lead to poor air quality.

There are a range of last mile modes and solutions which can provide alternatives to car and van travel and help local authorities to achieve their sustainability goals while also improving productivity and public health. For the transport of people there are user-operated modes such as cars, bikes and e-scooters which require the full engagement of the user at all times to complete the journey. Alternatively, service-based solutions enable more productive travel time by replacing user engagement with a driver or automated system. The last mile delivery of goods can be carried out by direct solutions which complete the entire last mile journey leg such as vans, cargobikes and automated delivery robots while indirect solutions can improve the efficiency or user experience by consolidating destinations or deliveries, or reducing travel demand altogether.

1 Department for Transport, Road Traffic Estimates: Great Britain 2019, September 2019 accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/916749/road-traffic-estimates-in-great-britain-2019.pdf]

Alternative last mile modes can bring benefits to the user, such as more reliable travel times, reduced cost of travel and increased fitness levels, as well as to the local authority by increasing productivity levels, improving air quality and helping to achieve sustainable goals. However, there are also barriers and limitations to introducing new modes or building on existing ones such as high cost of investment, user perception on safety and unfamiliarity with the operation of new modes. In addition, modal shift requires a change in human behaviour which can be very challenging to promote, achieve and sustain. Some last mile solutions are best introduced alongside enabling technologies such as electrification and policy interventions such as ultra-low emission zones to fully realise their benefits. A range of these technologies and interventions are explored in more detail within the report.

This literature review is designed to be used as a reference when determining the best last mile solutions to be trialled or deployed. The report is produced as part of the ADEPT's Live Lab program in Buckinghamshire with the aim of disseminating the findings to similar authorities.

Contents

1 Introduction

There are many opportunities to improve the efficiency of transporting goods and people over the last mile. These opportunities have the potential to significantly reduce congestion, improve air quality, lower carbon emissions and lower the cost of travel.

The transport sector has been subject to a spate of innovations in recent years; from disruptive technologies such as ride-hailing apps revolutionising the taxi industry to the introduction of new modes such as dockless e-scooters which are set to improve the accessibility of active travel. Despite an increasing abundance of choice and better access to travel information, road passenger transport is still dominated by privately owned combustion-engine vehicles and the last mile delivery of goods is dominated by fleets of diesel vans. This reliance on motor vehicles has led to heavy congestion, poor air quality and significant levels of carbon emissions in urban areas across the UK.

Last mile mobility considers the transport of goods or people over short distances to complete end-to-end journeys or provide a modal connection between an origin or destination and a transport hub. While named after the final leg, last mile journeys in the context of this report can occur at the start, middle or end of a longer journey and can also occur more than once. Completing last mile journey legs can be time consuming and expensive due to the difficulty of consolidating short journeys with many different start and end points. There are, however, many existing last mile mobility solutions and enabling technologies which have the potential to reduce the environmental, social and economic impacts of last mile travel. Furthermore, emerging and future solutions such as automated vehicles, flying taxis and drone logistics have the potential to completely revolutionise the way we move people and goods.

This report provides a review of the state-of-the-art last mile mobility modes, including established, emerging and future technology solutions. In future work packages, this information will be used to consider interventions to improve the convenience, reliability and accessibility of last mile travel and alleviate the detrimental aspects of travel demand growth within towns such as Aylesbury, Buckinghamshire.

1.1 Background and Motivation

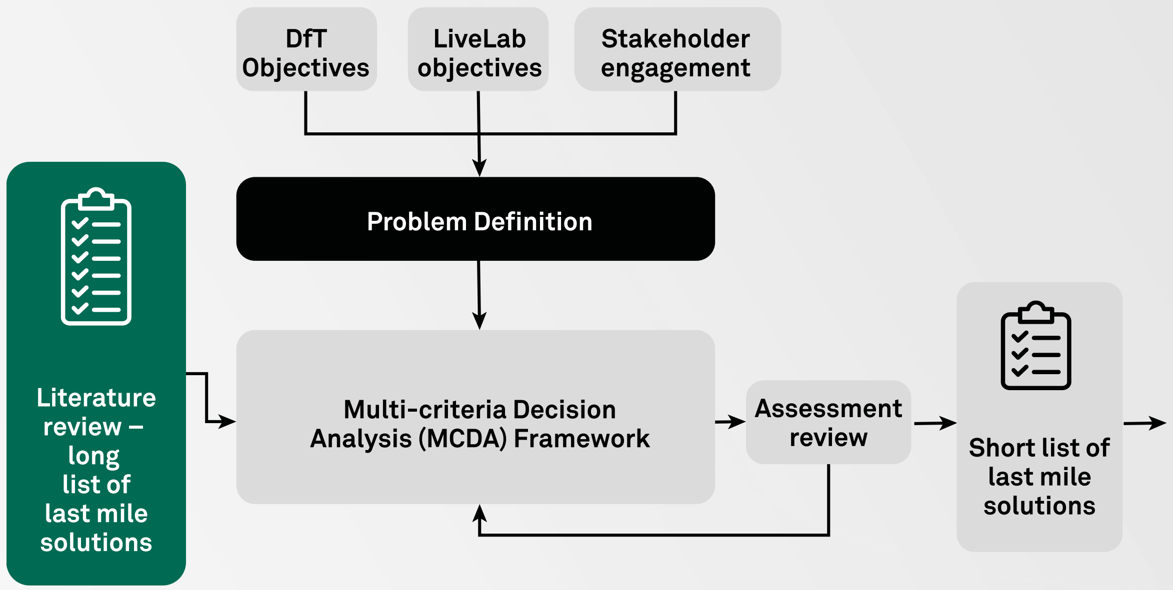
Buckinghamshire Council is leading the delivery of the £4.5m 'SMART Connected Community: Live Labs' project which is part of a £23m programme, funded by the Department for Transport, and led by the Association of Directors of Environment, Economy, Planning and Transport (ADEPT). The project is built around four themes: **Smart Materials, Smart Communication, Smart Energy, and Smart Mobility.** Within the Smart Mobility theme, the Connected Places Catapult (CPC) is delivering a feasibility study into last mile mobility solutions.

This literature review provides a summary of the last mile mobility solutions available in the marketplace and those in earlier stages of development and discuss their potential benefits and limitations.

1.2 Overview of Work Packages

The literature review is a single work package in a much larger scope of works being conducted by Connected Places Catapult. It provides a long list of last mile mobility solutions to give an overview of the current landscape and demonstrate the art of the possible. **Figure 1** demonstrates that the literature review and the problem definition task will feed into a multi-criteria decision analysis (MCDA) framework. The MCDA represents the success criteria and will be used to filter down to a short list of appropriate last mile solutions for further consideration. The problem definition is being developed in parallel to the literature review through stakeholder engagement with members of Buckinghamshire council.

Figure 1: Relationship between work packages



Ultimately solutions within the short list will be considered for their suitability to run a pilot in Aylesbury with the intention of disseminating the lessons learnt to similar towns around the UK.

2 Defining the Scope

2.1 Last Mile Definition

The definition of last mile mobility can vary depending on the context. For this literature review last mile mobility is defined as:

> The movement of goods or people over short distances to facilitate either;
>
> a) end-to-end journeys between a precise origin and destination, or;
>
> b) modal connections as part of a longer journey.

Figure 2 provides some examples of last mile journey legs in the context of end-to-end journeys. The last mile legs are highlighted in orange.

Figure 2: Examples of last mile journey

2.2 Last Mile Mobility Landscape

Car travel is a popular modal choice for passenger transport and the dominance of privately owned vehicles to complete short and long journeys has led to high car dependency, poor air quality, heavy congestion, high levels of carbon emissions and significant land use dedicated to parking cars across much of the UK. In 2019 the UK had 32.9 million licensed cars, over 17% higher than in 2000[2]. Walking is the most popular modal choice in England for journeys under 1 mile, but beyond that motor vehicles are used to complete the vast majority of passenger trips making up over 60% of journeys between 1 and 2 miles in 2017[3]. Private cars are inefficient at network level due to their low utilisation rates; they typically spend 95% of the time stationary and therefore require lots of land for parking. Cars are typically powered by internal combustion engines (ICE) which contribute to carbon emissions and poor air quality and private vehicles have a slow rate of fleet renewal which lessens the impact of improved fuel efficiency in newer models. The average occupancy of car journeys in the UK is just 1.6, a figure which has remained constant since 2002[4]. This suggests that car usage is dominated by single and dual-occupancy trips which increases the impact of cars on traffic congestion. Furthermore, car usage contributes to a sedentary lifestyle which leads to negative health implications over time. While car use is popular due to its privacy and perceived convenience in addition to versatility of journey purpose, there are many limitations for the user which can be leveraged to encourage modal shift to more sustainable modes. Firstly, cars require a high initial investment which can encourage excessive usage to justify the sunk costs and lead to an underestimation of the true cost of car ownership. Secondly, cars require full engagement from the driver for the duration of travel and therefore are not conducive to productive travel time. Thirdly, journey time reliability can be poor due to congestion, especially at peak times and the private ownership model places responsibility on the owner/driver to refuel, locate parking and see to maintenance and repairs. This report considers alternative ownership models and alternative modes to cars to create a more diverse transport ecosystem for last mile travel.

Last mile delivery of goods is currently dominated by the diesel van in the UK. Light Goods Vehicle (LGV) van miles have grown by 70% over the last 20 years and are the fastest growing sub-category of vehicle with over 4 million already on the road[5]. The increase in demand can be linked to a growth of e-commerce and home deliveries and these markets are predicted to rise further; the Department for Transport (DfT) forecast a further 108% growth in LGV miles between 2015 and 2050. An increase in diesel van miles is problematic for local authorities since each mile travelled contributes to increased carbon emissions, poor air quality and increased congestion on the road network which has a negative impact on the movement of people. This report considers alternative last mile solutions which could prevent the expected growth in LGV miles and limit the negative impacts of increased freight demand.

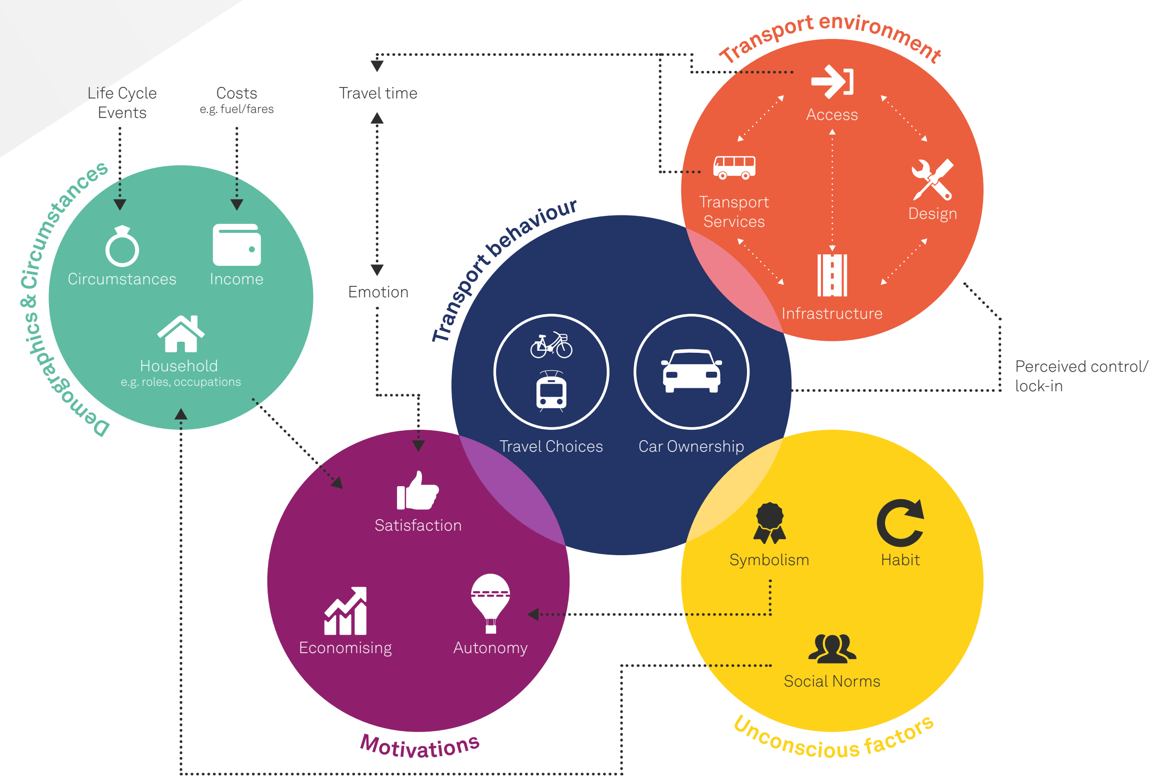
Last mile travel is an inefficient component of any journey due to the difficulty of consolidating unique origins or destinations of a person or product. Vans conducting last mile deliveries are likely to require many stops which can be miles apart and are likely to have a low drop rate[6]. The duplication of journeys can also add to travel demand with different logistics providers delivering to the same addresses at different times on the same day. According to the Capgemini Research Institute, 41% of the cost of product delivery is spent on transporting goods over the last mile. The transportation of people over short distances also suffers from similar challenges, especially in low density areas where public transport services are difficult to make financially viable. Improving efficiencies within the last mile of transport and increasing user satisfaction can result in large improvements to the whole transport ecosystem and reduce overall journey costs.

2 I. Wagner, Number of cars on the road in the United Kingdom (UK) 2000-2019, July 2020, accessed from: [https://www.statista.com/statistics/299972/average-age-of-cars-on-the-road-in-the-united-kingdom/]
3 Department for Transport, NTS0308: Average number of trips by trip length and main mode: England, July 2018, accessed from: [https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/1487/148705.htm]
4 Department for Transport, NTS0905: Car occupancy, England: since 2002, last updated August 2020, accessed from: [https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy]
5 Department for Transport, Domestic Road Freight Statistics: 2016 report, July 2017, accessed from [https://www.gov.uk/government/statistics/road-freight-statistics-2016]
5 S. Dolan, The challenges of last mile delivery logistics & the technology solutions cutting costs, May 2018, accessed from: [https://www.businessinsider.com/last-mile-delivery-shipping-explained?r=US&IR=T]

2.3 Influencing Modal Shift

Multiple factors influence mobility decision making, including demographics and circumstances, motivations, unconscious factors, transport behaviours and the transport environment, further details for each factor are presented within Figure 3[7]. Convenience and cost remain key drivers for selection of mode though environmental awareness is increasingly growing and maybe considered more highly in the future[8]. Considerations of the multitude of these factors, and the inter-relationships of these must be considered when exploring and understanding transport mode preference and acceptance.

Figure 3: Factors Influencing transport user's decision-making[9]



Unfortunately, many of the population still turn to the car as a predominant mode of travel, significant number of drivers still feel they have little choice but to rely on their car given the lack of other viable transport options[10]. Others can only accept what modes are available to them. In subsequent work packages, the drivers for modal shift in the context of towns like Aylesbury, will be explored in more detail so that the potential success of the last mile solutions described in the literature review can be evaluated.

7 C. Whittle et al., Government Office for Science, Decision-Making in the UK Transport System, January 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/773667/decisionmaking.pdf]
8 M. Smith, YouGov, Concern for the environment at record highs, June 2019, accessed from: [https://yougov.co.uk/topics/politics/articles-reports/2019/06/05/concern-environment-record-highs]
9 C. Whittle et al., Government Office for Science, Decision-Making in the UK Transport System, January 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/773667/decisionmaking.pdf]
10 RAC, Dependency on the car is increasing, February 2020, accessed from: [https://www.rac.co.uk/drive/features/rising-car-dependency-2019/

3 Last Mile Solutions

3.1 Categorisation of Solutions

Last mile mobility modes and solutions vary in type and purpose. They have been categorised in this report so that comparisons can be drawn more easily. **Figure 4** displays the categorisation process of the last mile solutions considered within this literature review.

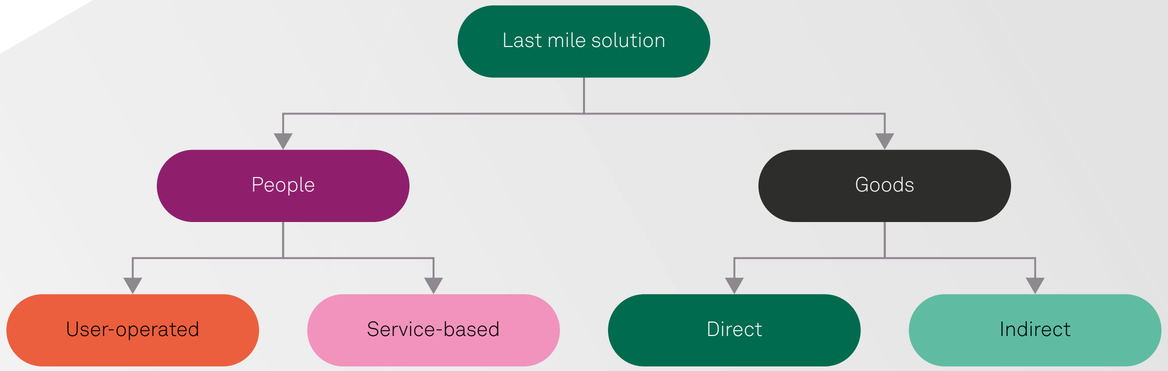


Figure 4: System for categorising last mile solutions

First, the solutions were categorised into whether they are designed predominately for the transportation of people or goods. Where a mode or solution applies to both, they are considered separately for each context.

The **people-based solutions** are subsequently categorised into either user-operated or service-based solutions. The definitions of each can be found below:

- **User-operated solutions:** require active engagement from the user for the duration of the journey
- **Service-based solutions:** operated by a paid operator and/or automated technology and do not require active engagement from the user

The implications to the user of whether something is user--operated or service-based include:

- Productivity of travel time
- Responsibility for parking, operation or maintenance
- User requirements such as licences, minimum age and medical certificates

The **goods-based solutions** are subcategorised into direct and indirect solutions. The definitions of which can be found below:

- **Direct solutions:** allow for goods to be delivered to the precise end destination directly
- **Indirect solutions:** improve efficiency of delivering goods but require a direct solution for journey completion

3.2 People-based Solutions

A last mile transport network designed for the movement of people must cater for a wide range of demographics whom have varying needs. There is no one-size fits all solution and as such a successful system relies on the availability of a range of modal choices. **Figure 5** shows an overview of the people-based solutions considered within the literature review split into user-operated and service-based categories.

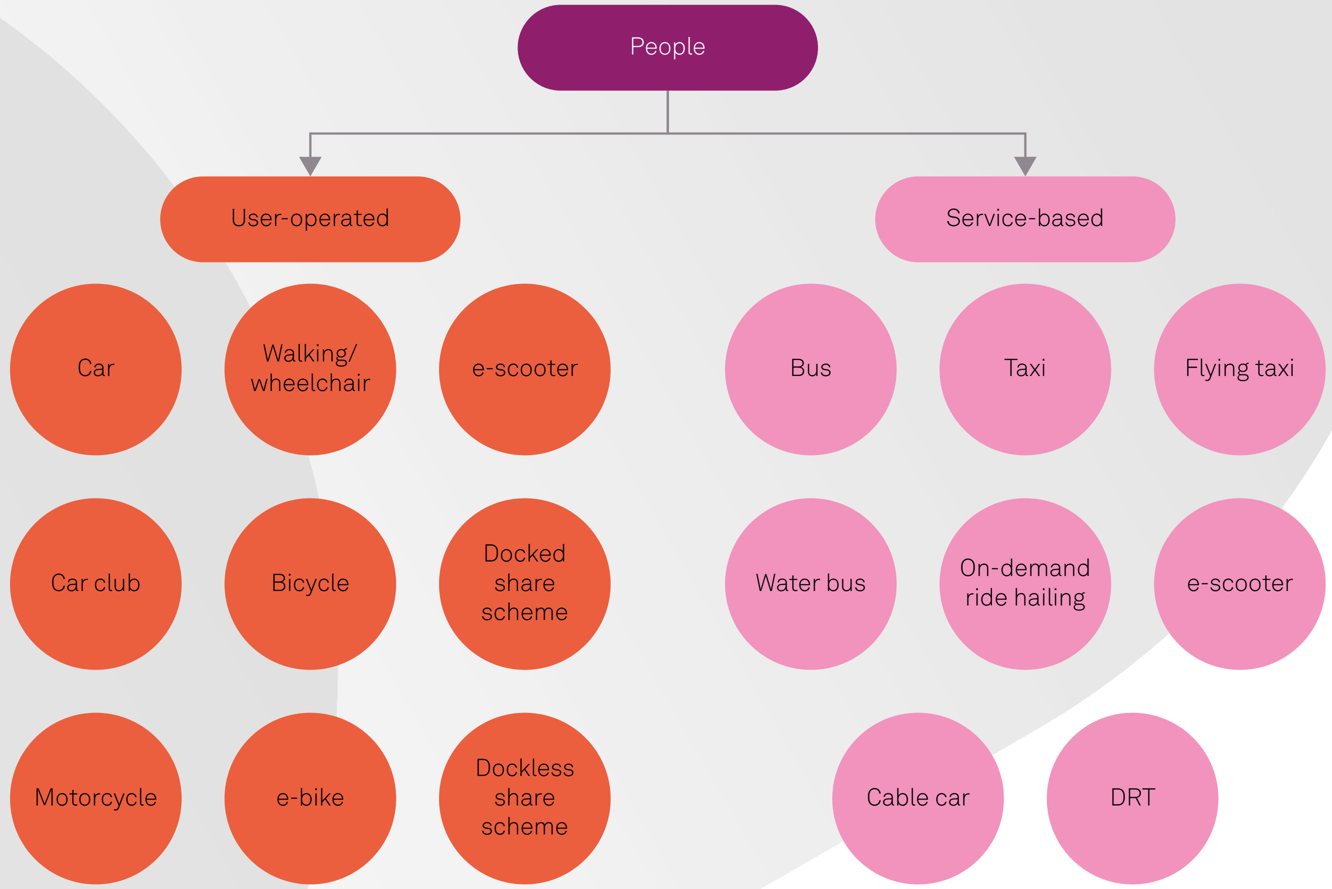
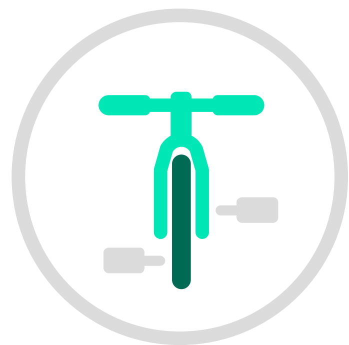


Figure 5: Overview of people-based last mile solutions

An introduction to each of the modes displayed in **Figure 5** is given below, while more detail on user-operated and service-based modes can be found in **Table 2** and **Table 3** respectively both of which are located in **Appendix A.**



3.2.1 User-operated

Cars are four-wheeled motor vehicles which are owned or leased by an individual or household and operate on the road network. They are an extremely popular modal choice for last mile travel making up 60% of journeys between 1 and 2 miles in 2017 and over 80% of journeys between 2-5 miles in addition to fulfilling longer journeys by road[11]. Cars offer users convenience and flexibility on travel times and routes, and as such can be the best modal choice for certain journeys but an overreliance on private cars causes problems for local authorities, especially in meeting their sustainability targets. Most cars and vans are powered by internal combustion engines which emit carbon emissions, but there is a push from the UK government to transition to electric powertrains which will significantly reduce the carbon impact from passenger transport, however this will not combat congestion issues and associated loss of productivity. A comprehensive charging network on a local and national level is required to facilitate the electrification of the passenger car fleet.

Example: Scotland has a national electric vehicle charging network to facilitate the transition from internal combustion engines (ICE) to electric vehicles (EVs). They have rapidly built up the network from 55 public chargers in 2013, to over 1000 in 2020. The charging status, technical details and location can be found on their online map which is updated in real time. In 2019, the registration of new battery electric and plug-in hybrid vehicles grew by 46% compared with 33% across the rest of the UK. In 2018, 1.6% of all new car sales qualified as Ultra Low Emission Vehicles which grew from 1.1% the year prior[12].

Car clubs offer a fleet of vehicles which can be rented for short periods of time, typically by the hour. The vehicles have restrictions on where they must be picked up and dropped off from, often with dedicated parking spaces but they can also be permitted to park within geofenced areas if the operator permits it. In London, ZipCar have a Flex option where cars can be picked up and dropped off at different locations, thus users do not have to pay for usage while they are not in the vehicle and can complete one-way journeys via car club vehicles[13].

Example: Surrey County Council operate a car club which is currently operated by Enterprise Car Club. They have a fleet of 30 cars based in seven towns with plans to expand to three more. They report that for every car club car provided, 10 private vehicles are removed from the road and that the average car club vehicle emits 33% fewer carbon emissions than the average car in the UK passenger fleet[14].

11 Department for Transport, NTS0308: Average number of trips by trip length and main mode: England, July 2018, accessed from: [https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/1487/148705.htm]
12 Scottish Government, Statistics on the number of electric vehicles in Scotland: FOI release, February 2019, accessed from: [https://www.gov.scot/publications/foi-19-00181/]
13 Zipcar, Flex your next A to B with one way car sharing, accessed October 2020, accessed from: [https://www.zipcar.com/en-gb/flex]
14 Surrey County Council, Car clubs, accessed October 2020, accessed from: [https://www.surreycc.gov.uk/roads-and-transport/sustainable-driving/car-clubs]

Motorcycles are two-wheeled vehicles powered solely by a motor and operate on the road network to conduct last mile journeys. Most models have an internal combustion engine (ICE), however there are electric versions on the market. Motorcycles are popular only within certain demographics with riders tending to be male and young.

Example: Motorbikes are mainly used for recreational purposes and viewed as a luxury good in developed countries such as the UK. However, in developing countries they dominate road transport due to the relatively low cost of travel and can more easily be manoeuvred through congested cities. 58% of the world's motorcycles are located within the Asia Pacific and other regions of Asia such as the Southern and Eastern Asia. In Thailand 87% of households own at least one motorcycle[15].

Walking/wheelchair usage is the most basic form of active travel and involves self-propulsion usually for short journeys. Walking/wheelchair use is a fundamental mode of transport which makes up an important part of daily life. Most complete end-to-end journeys require some element of walking or wheelchair use such as to move from a carpark to the entrance of a workplace. It is the most common modal choice for journeys under 1 mile and is often required to make other modal connections; for example, the average walk to a bus stop is 580m in the UK (outside of London)[16]. There is a push across the UK to increase walking as a last mile mode due to its health benefits to the user and zero carbon emissions during travel.

Example: London's Borough of Waltham Forest was a recipient of the Mini Holland programme which aimed to improve conditions for pedestrians and cyclists through redirecting non-local traffic and re-allocating roadspace towards active travellers. The interventions included wider footways and raised junction tables, new street furniture, tree planting, zebra crossings, improved street lighting, seating, and cycling infrastructure. In addition, land previously dedicated to traffic was repurposed for public spaces, street art and pocket parks. The scheme resulted in 10,000 fewer cars on the road each day[17].

Bicycle usage is another form of active travel, where the user propels a two-wheeled vehicle through the pedals. Bikes can be used in privately owned or have docked or dockless operating models. The length of journey completed via this mode varies greatly with user's fitness levels, the terrain and cycling infrastructure. One of the biggest barriers to cycling in the UK is the perceived safety of travelling by bike on a mixed-use road, and this is a particular deterrent for women.

Example: The Netherlands is known for its high utilisation of bicycles. Today it has over 22,000 miles of cycle paths to accommodate safe travel and over 25% of all trips are made by bicycle, compared with only 2% in the UK. This percentage rises in urban centres such as a significant 38% in Amsterdam and 59% in the university city of Groningen. "Bicycle civil servants" are a feature of major Dutch cities and their role is to maintain and improve the cycle path network.

15 J. Misachi, WorldAtlas, Countries with the highest motorbike usage, August 2019, accessed from: [https://www.worldatlas.com/articles/countries-that-ride-motorbikes.html]
16 G. Wakenshaw and N. Bunn, How far do people walk?, July 2015, accessed from: [https://www.wyg.com/uploads/files/news/WYG_how-far-do-people-walk.pdf]
17 Just Economics, The Pedestrian Pound: the business case for better streets and places, updated 2018, accessed from: [https://www.livingstreets.org.uk/media/3890/pedestrian-pound-2018.pdf]

e-bikes can be used in privately owned, docked or dockless operating models. They are two-wheeled vehicles which can be powered by electricity in addition to being propelled by pedals. It is possible to retrofit mechanical bicycles with electric motors to create e-bikes. The electric motors are powered by rechargeable batteries which must be plugged into an electricity supply and can be topped up through regenerative braking. The electric assistance opens up cycling to new demographics as it enables easier travel and also increases the distance and widens the types of terrain that people are prepared to travel by bike.

Example: A study of e-bike riders in the city of Oxford determined that new, hillier routes are being travelled by e-cyclists which were not made previously with conventional bikes. 24% of e-bike trips originated from the city centre and travelled to a destination in the hilly east side of the city, whereas only 2% of conventional bike trips made journeys along these routes[18]. There was also an increase in distance travelled by e-bikes with 49% of hires being under two miles compared with 91% on conventional bikes and the longest distance travelled in a day was 20.5 miles on an e-bike compared to eight miles on a standard bike.

e-scooters are an emerging mode of transport in the UK, with legislation which previously prevented their use on public roads being eased in 2020. This process has been sped up in response to the Covid-19 pandemic. Privately owned e-scooters are still not currently legal on roads or pavements but hired schemes are being introduced across the UK. Given their electric powertrains, they emit no tailpipe emissions, they take up little space when not in use and are an accessible mode to a wider range of physical abilities than bikes. As such they have received a lot of attention from the transport sector but there are still concerns over the safety of riders and other road users.

Example: 500 Lime scooters and 100 spin scooters (to be scaled up to 300) were deployed in Milton Keynes as a reaction to covid-19 social distancing measures in 2020. Spin reported over 10000 miles ridden in just over one month of operation from 3500 users and claim that approximately 41% of e-scooter trips taken in Milton Keynes are direct replacements of car journeys[19].

Docked share schemes consist of shared micro-mobility modes such as bikes, e-bikes or e-scooters which can be rented from fixed docking stations. The docking stations are deployed in strategic locations within the geographic operating area. Users must begin and end their journey at a docking station, ensuring that their modal choice is securely docked on return to avoid extra charges.

Example: Águeda, Portugal introduced an electric bike sharing scheme 'BeAgueda' in 2011 to encourage people to cycle in the hilly city. A total of 10 electric bikes were used to travel around 40,000 kilometres over the first four years of operation. In response to demand from residents, the city plans to grow the scheme up to 20 bikes in four locations.

18 Department for Transport and Bikeplus Carplus, Shared Electric Bike Programme Report 2016, 2016, accessed from: [https://como.org.uk/wp-content/uploads/2018/05/Shared-Electric-Bike-Programme-Final-Report.pdf]
19 Get Smarter Travel MK, E-scooter trials, accessed October 2020, accessed from: [getsmartertravelmk.org/smart/e-scooter-trials]

Dockless share schemes were developed to overcome user challenges in accessing docking stations. They do not require the user to end their journeys at specific locations, instead the bike or e-scooter can be 'parked' anywhere within a geofenced operational area. Once the ride is over, the micro-mobility mode can securely lock itself without the need for a fixed attachment (docking stations). The dockless micro-mobility mode can be located through GPS tracking and can be hired via a smartphone application. There are guidelines as to how and where to leave the vehicles so that they can be easily found by the next user and are not obstructing pavements or roads. The downside of dockless over docked share schemes, is that the chosen mode is more susceptible to vandalism and if users do not follow the parking guidance then they can cause obstructions to other road and pavement users.

Example: Dockless bike schemes gained popularity in China. In 2017 service operator Mobike reported that more than 2.5 billion miles had been travelled by their users across China. In Beijing, Mobike reported that 81% of trips start at a bus station and 44% start at a subway location. They also analysed that for last mile trips less than 5km, 92.9% could be completed in less time by shared bike and public transport combinations compared with cars.[20]

3.2.2 Service-based

Buses are a traditional mode of transport which have a high capacity for passengers and travel along a fixed route for a fare. The fares can vary with journey length and operational area. Typically, there are discounts for weekly or monthly travel passes or a carnet system where users can bulk buy journeys in advance for use within a set periods of time. In general, UK bus usage has been in decline - the number of local bus passenger journeys in England fell by 29 million or 0.7% to 4.32 billion in the year ending March 2019.[21]

Example: Helsinki, Finland operate a 1400 strong bus fleet making up over 120 lines inside the city. The authorities aim to electrify 30% of bus fleet by 2025[22]. In 2016, 367 million journeys were made by public transport modes in Helsinki with over half of journeys made by bus. They reported an average of 23.3% occupancy rate across the bus fleet[23]. Users can pay as they go or buy a travel card which offers unlimited journeys for a period of 14 to 365 days depending on preference. Across the whole public transport network, Helsinki ran a surplus of 18.9 million euros showing the effectiveness of the system. While it is important to note that the scale of this offering is not applicable to rural UK counties, this example demonstrates the art of the possible for public transport systems.

20 Mobike, Bike-sharing and the City, April 2017, accessed from: [https://mobike.com/global/public/Mobike%20-%20White%20Paper%202017_EN.pdf]
21 Department for Transport, Annual bus statistics: England 2018/19, December 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/852652/annual-bus-statistics-2019.pdf]
22 C. Morris, Charged EVs, IEA case study: electric buses in Helsinki, Finland, July 2020, accessed from: {https://chargedevs.com/newswire/iea-case-study-electric-buses-in-helsinki-finland/]
23 Kaupunkipyorat, Annual Reprt 2016, 2016, accessed from: [https://kaupunkipyorat.hsl.fi/en/node/9047]

Water buses are waterborne vessels which transport people over bodies of water with fixed routes, timetables and stops. Water taxis are similar to waterbuses but operate on an on-demand basis and are less common.

Example: The London Thames Clipper service operates along 23 piers on the river Thames. In 2017, two new 179-seater catamarans were added to the Thames Clipper fleet costing £6.3million in total. Services run from early in the morning until late at night seven days a week. Contactless payments can be made through oyster card or contactless credit/debit card[24]. The vessels include an on-board café for an enhanced user experience over other service-based modes. Leeds offers a daily water taxi service between Leeds Dock and Granary Wharf. Journeys cost £1 per person and the location of the boats can be tracked live via TaxiTrak.

Cable cars are a transport system in which cabins are suspended on a continuous moving cable driven by a motor at one end of the route. It is a solution often used to transport people over difficult terrain, such as sleep slopes on a mountain or in the case of urban areas over rivers.

Example: TfL Emirates Air has been ranked as one of Transport for London's (TfL) best transport lines. The £36 million project opened to the public in 2012 after an accelerated design and construction period of just 15 months. It comprises of 34 gondolas or cabins and can achieve a throughput of 2500 passengers per hour in each direction. It continues to operate without a subsidy attracting a steady flow of riders and operates with a level of reliability at 99.4%[25].

Taxis are motorised vehicles where a dedicated driver takes passengers from origin to destination for a fare. Classes of taxi include Hackney Cabs which can be hailed from the street or procured from dedicated taxi ranks and Private Hire services which must be pre-booked and cannot be procured through other means. In 2018, there were 5.1 licensed taxi and private hire vehicles per 1,000 people in England.[26] The use of this mode is relatively infrequent due to relatively high cost per mile - the average person in England makes 9 taxi or private hire trips per year and covers a distance of 55 miles with 47% of journeys conducted for leisure purposes, according to 2017 DfT data[27].

Example: London is famous for its taxi fleet known as black cabs. It is unique in requiring the passing of an examination by any prospective drivers which tests a driver's understanding of London's road geographies known as 'The Knowledge'. In 2018 there were 21,000 registered London taxis, all with wheelchair accessibility.

24 London Reconnections, London's First Highway: Part 2 - the surprising success of river buses, January 2017, accessed from: [https://www.londonreconnections.com/2017/londons-first-highway-part-2-surprising-success-river-buses/#:~:text=TfL%20River%20Bus%20Subsidy%20Policy&text=Thames%20Clippers%20are%20the%20only,operates%20during%20peak%20commuter%20hours.&text=Indeed%20this%20subsidy%20situation%20is,subsidised%20and%20charging%20premium%20fares]
25 Gondola Project, What does the future hold for London's first and only urban cable car?, January 2018, accessed from: [http://gondolaproject.com/2018/01/11/what-does-the-future-hold-for-londons-first-and-only-urban-cable-car/#more-18940]
26 Department for Transport, Taxi and Private Hire Vehicle Statistics, England: 2018, October 2018, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/751202/taxi-and-phv-england-2018.pdf]
27 Department for Transport, Taxi and Private Hire Vehicle Statistics, England: 2018, October 2018, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/751202/taxi-and-phv-england-2018.pdf]

On demand ride-hailing is an example of where technology has been applied to a traditional mode (in this case private hire taxis) to improve the user experience. On-demand ride hailing services can be booked via a smartphone application at the time in which the journey is required. The service is enabled through fleet management which helps to provide minimal wait times. Algorithms work out the closest driver and the vehicles use routing systems to locate passengers.

Example: Uber is an on-demand ride hailing service which operates in cities all over the world and has become a market disruptor displacing usage of traditional taxi services. Uber does not own vehicles, instead it employs drivers who use their own vehicles to complete journeys. They encourage shared occupancy journeys by helping customers with similar origins and destinations to 'pool' for a reduced fare.

Demand responsive transport (DRT) services seek to consolidate single occupancy car journeys by facilitating shared minibus travel for multiple passengers heading in the same direction. The services operate from 'corner to corner', so there are no fixed routes or bus stops. Instead, the app shows people a clear map of where their virtual bus stop is. Users are picked up and dropped off within approximately 200m of their requested destinations with the aim that even with multiple pick-ups, there are no lengthy detours. **Integrated DRT (iDRT)** looks at using DRT to connect disconnected areas to main train and bus routes (or other modes) which are high frequency and high capacity (and commercially viable).

Example: ArrivaClick DRT services are operational in Leicester with connections to a business park, the city centre, the university and main railway stations. The service consists of luxury 15-seater minibuses which can accommodate wheelchairs and pushchairs. The operating hours are between 6am and 11pm Monday to Saturday to cater for commuters and leisure travellers. ArrivaClick services in Liverpool had to be withdrawn as they could not be made commercially viable[28]. Oxford's PickMeUp service completed its two-year pilot in June 2020 and is expected to restart operations if a funding application to the DfT's Rural Mobility Fund is successful. PickMeUp's pricing system encouraged the use of public transport services where possible, charging an additional surcharge for journeys which could have been taken by existing oxford bus company services[29]. Plans for the renewed PickMeUp service would connect passengers to park-and-ride mobility hubs for onward connections on larger vehicles complementing existing services further and demonstrating an iDRT service[30].

28 Arriva, FAQs: Liverpool and Leicester, accessed October 2020 from: [https://www.arrivabus.co.uk/arrivaclick/arrivaclick-liverpool-and-leicester-faqs]
29 Experience Oxfordshire, Oxford Bus Company's PickMeUp Service Expands Due to Popular Demand Creating New Jobs, accessed from: [https://www.experienceoxfordshire.org/oxford-bus-companys-pickmeup-service-expands-due-to-popular-demand-creating-new-jobs/]
30 Route One, Oxford PickMeUp DRT to return in revised form?, June 23 2020, accessed from: [https://www.route-one.net/news/oxford-pickmeup-drt-to-return-in-revised-form/]

Flying Taxis or air taxis are aircraft which are designed to carry a small number of passengers over short distances by occupying low air space. Electric vertical take-off and landing (VTOL) aircraft are expected to be used as flying taxis which after testing phases will eventually operate autonomously, flying without a pilot. To be commercially viable and affordable to a wider consumer base they will likely operate a shared service.

Example: Dubai is expected to be the launch pad for commercial air taxis, with services projected to begin in 2022. They have carried out advanced tests with autonomous aerial vehicle companies such as Volocopter and EHang.

Connected automated vehicles (CAVs) is a term which refers to a set of vehicles with a range of automated technological features. In this review we are considering The Society of Automotive Engineering's Level 4 and 5 vehicles which can operate without a driver present in some or all environments. These are sometimes known as self-driving or driverless cars. The removal of the driver transitions cars from user-operated to service-based modes opening up car travel to new demographics such as those without a driving licence. Autonomous vehicles promise improved safety, reduced emissions and cheaper travel compared with ride hailing, given the absence of labour costs. It is unclear yet whether CAVs will be available for private ownership or be predominantly or exclusively adopted by fleet operators.

Example: Waymo is one of the companies currently developing the technology to enable CAV deployment, an initiative they began in 2009. They have been testing the technology on users in Phoenix, Arizona as part of their beta tests and reported 1500 monthly active users in 2019. Those who participate must sign a non-disclosure agreement and agree not to report any malfunctions to the press but benefit from driverless journeys in a 100 square mile operating area. The company aims, ultimately, to achieve 100% of trips taking place in driverless cars[31].

31 A. J. Hawkins, The Verge, Waymo will allow more people to ride in its fully driverless vehicles in Phoenix, October 2020, accessed from: [https://www.theverge.com/2020/10/8/21507814/waymo-driverless-cars-allow-more-customers-phoenix]

3.3 Goods-based Solutions

The efficient movement of goods over the last mile is essential to ensure a reliable and sustainable supply chain. Some goods deliveries follow predictable scheduled delivery times, while others must react to the changing demand of consumers, such as fast food delivery services. **Figure 6** shows an overview of the goods-based solutions considered within the literature review split into direct and indirect categories.

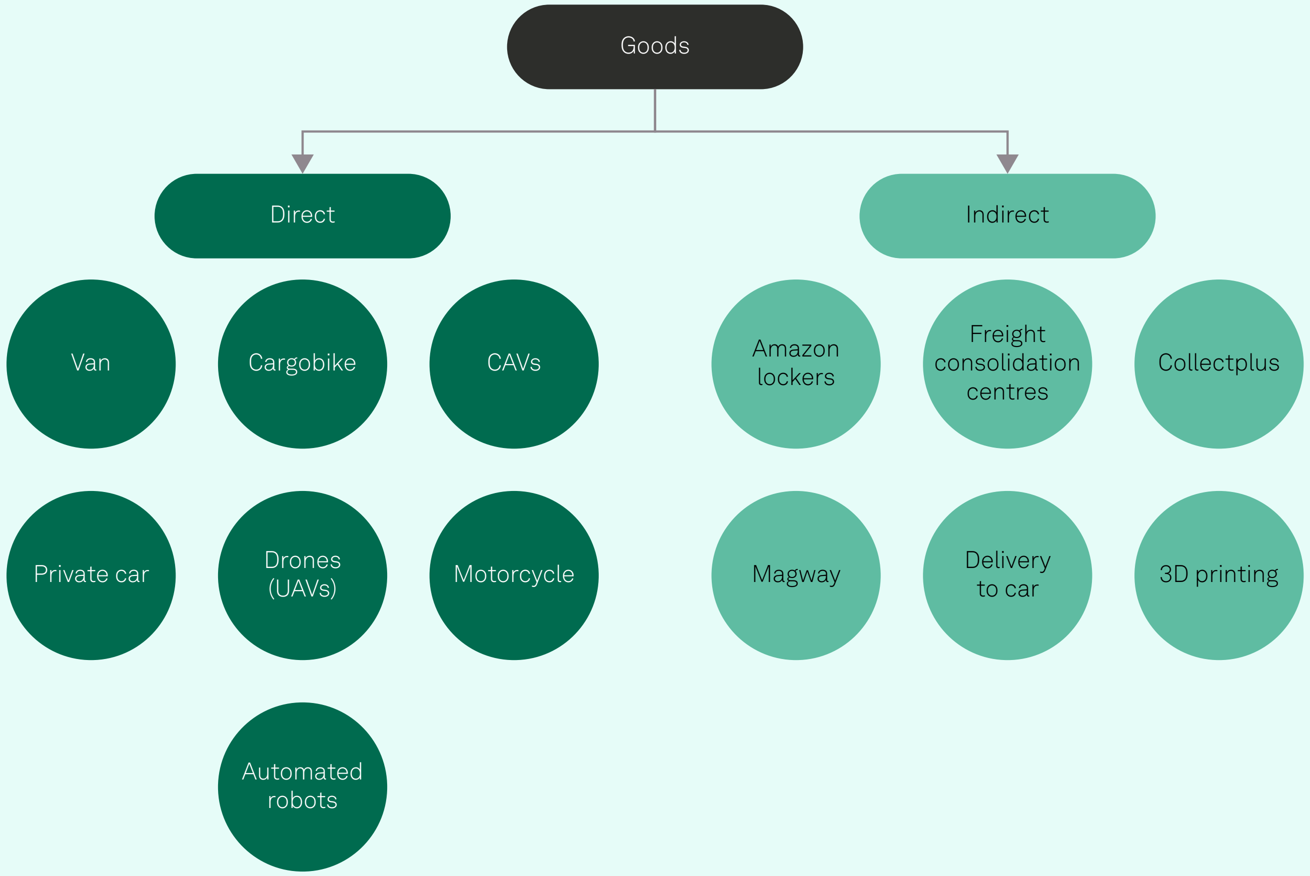


Figure 6: Overview of goods-based last mile solutions

An introduction to each of the modes displayed in **Figure** 6 is provided below, while more detail on direct and indirect modes can be found in **Table 5** and **Table 6** respectively both of which are located in **Appendix B.**

3.3.1 Direct

Vans are an extremely common mode of last mile delivery due to their relatively high payload yet compact size (compared with an HGV) which allow them to deliver a high quantity of parcels in urban and rural areas. Vans are traditionally powered through internal combustion engines but there are electric models available and operational throughout the UK. Due to the dominance of van travel for last mile delivery of goods, electrification of vans is vital to reducing carbon emissions from the transport sector.

Example: Logistics company, DPD set a target to electrify 10% of its van fleet across all of its 68 depots in the UK by the end of 2020. They have begun the transition with a mixture of Nissan and MAN vehicles. The MAN vans have a range of between 65-70 miles from their 36kW batteries and can be charged from 0-80% in 45 minutes using rapid charging technologies[32].

Private cars are four-wheeled motor vehicles which are owned by an individual rather than a company or service provider and can be used to deliver items on an ad-hoc basis. Drivers typically have zero contracted hours, and many will work for multiple employers to allow the flexibility to choose the journeys they want to make. This reduces the investment and maintenance costs for logistics companies and allows them more fleet agility, responding to changing demands.

Example: Amazon employs drivers to deliver packages through the Amazon Flex program. This allows the drivers to use their own vehicles so long as they meet the minimum size requirements for the type of deliveries they sign up to (Amazon Logistics or Amazon Prime Now). Drivers must also have a compatible smartphone and motor insurance for business travel.

Motorcycles are two-wheeled vehicles powered solely by a motor and operate on the road network to conduct last mile journeys. When used to make deliveries they are often fitted with a box to the rear for carrying cargo. Their ability to move through traffic more quickly than cars or vans makes them ideal for delivering quickly in congested areas however their use brings increased safety risks for the driver compared with car or van use.

Example: Motorcycles play a key role in the delivery of hot takeaway meals due to their speed and relatively low operational costs compared with cars. Deliveroo offers a food delivery service and allow their riders to use motorised scooters and provide thermal backpacks to transport the food in, removing the requirement of fitted cargo boxes.[33]

32 DPD, DPD boosts electric fleet to 600 with UK's first MAN Truck & Bus 3.5t right-hand drive electric vans, accessed October 2020, accessed from: [https://www.dpd.co.uk/content/about_dpd/press_centre/dpd-uk-boosts-electric-fleet-to-600-with-uks-first-MAN-electric-vans.jsp#:~:text=The%20parcel%20industry%20EV%20leader,to%20600%20vehicles%20in%20total]

32 Deliveroo, What are the requirements for being a rider?, accessed October 2020, accessed from: [https://riders.deliveroo.com/en-gb/support/new-riders/rider-requirements]

Cargobikes are bicycles specially designed for carrying large or heavy loads predominantly pedal powered and can be assisted by an electric motor.

Example: The cargobike operator Pedal & Post delivers about 10-25% of Yodel's parcels, which corresponds to approximately 200 a day, into Oxford by two-wheeled cargobikes. They are now looking to upgrade their fleets to larger e-assist cargo trikes to deliver the larger items and expand with the aim of delivering 100% of parcels over the last mile via cargobike[34].

Drones are also known as unmanned aerial vehicles (UAVS) which are aircraft piloted by remote control or onboard computers. Vertical Take-off and Landing (VTOL) UAVs tend to be battery powered and are used to deliver small payloads over relatively short distances while winged UAVs require a runway and can carry larger payloads under more challenging conditions.

Example: Solent Transport began trialling the use of UAVs for delivering medical supplies between hospitals on the mainland and the Isle of Wight in 2020 as part of the DfT's Future Transport Zone trials. They are using large, fixed wing UAVs with twin engines which currently carry up to 40kg of cargo between hospitals[35].

Automated robots are small, battery powered robots which deliver last mile items without the need for a driver and travel at low speeds along pavements.

Example: Starship delivery robots operate in Milton Keynes and can deliver food to residents of the area. Each robot can operate over a 4-mile radius and has a battery life of two hours which constitutes to up to 6 km of driving. Given their electric powertrain they emit no tailpipe emissions and therefore have the potential to improve local air quality by removing demand for van and car travel. They travel along the pavements at walking pace and have not been reported to be the subject of vandalism. They saw a surge in demand during the Covid-19 pandemic due to their autonomous nature requiring no human contact at point of delivery.

Connected Automated Vehicles (CAVs) can be used for last mile deliveries of goods in addition to transporting people. The automated driving technology can, in theory, be applied to vehicles of all sizes. CAVs have the potential to increase safety and dramatically reduce the cost of transport by removing the labour costs of drivers.

Example: Ford Motor Co are in collaboration with Walmart's delivery service Postmates designing an autonomous goods delivery service. The pilot is due to take place in Miami, USA with initially human-driven vehicles simulating the behaviour of autonomous vehicles before rolling out a commercial offering in 2021. The aim of the innovation is to decrease delivery costs to be able to compete with Amazon and other large online retailers.

34 Department for Transport, Government Response to Call for Evidence: The Last Mile - Delivering goods more sustainably, March 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/786879/last-mile-call-for-evidence-government-response.pdf]

35 Solent Transport, Drones will be used to transport medical supplies across the Solent to support the response to COVID-19, April 2020, accessed from: [https://www.solent-transport.com/news/item/drones-will-be-used-to-transport-medical-supplies-across-the-solent-to-support-the-response-to-covid-19

3.3.2 Indirect

Amazon lockers are self-serviced kiosks where amazon customers can access their purchases instead of ordering the parcels directly to their home or workplace and can be used as a drop-off location for returned packages too. This gives customers who may not be home during normal delivery hours, greater flexibility in collecting and returning packages. The lockers are located at participating partner businesses such as shopping centres and train stations, universities and corporate offices and can be accessed using a unique customer barcode generated after purchase.

Example: Warwick University in Coventry has 375 lockers across five locations on their campus. They are accessible for 365 days of the year and as they are located outdoors can be accessed at any time of the day offering maximum flexibility of pick up and drop off times. It is the largest installation of amazon lockers in the UK[36].

CollectPlus allows customers to send and collect parcels via a network made up of thousands of newsagents, convenience stores, supermarkets and petrol stations rather than relying on dedicated post offices. Similar to amazon lockers, this gives greater flexibility for customers and facilitates an easy returns process. QR codes are used to track the deliveries.

Example: Londis, McColl's, Nisa, Spar and Costcutter all have collectplus branches.

Delivery to car is a service which allows customers to add their vehicle as a delivery destination if they are fitted with a 'smartbox'. A courier receives a GPS location of the car along with the registration number and a one-time code that permits them access to the boot space. The customer is sent real-time updates on their mobile, including order confirmation through to a final photo confirming successful delivery and the secure locking of their car thereafter.

Example: Delivery to car operations were trialled in the UK in 2016 with a small-scale feasibility study that saw John Lewis packages delivered to Jaguar Land Rover staff[37]. Learnings from the trials included the need for extremely accurate GPS tracking to enable couriers to quickly locate a specific Jaguar or Land Rover in a carpark full of similar models.

36 Warwick University, Amazon Lockers, accessed October 2020, accessed from: [https://warwick.ac.uk/services/retail/shops/amazon]
36 R. Arthur, Forbes, John Lewis And Jaguar Land Rover Are Trialing Shopping Deliveries Straight To Your Car, February 2017, accessed from: [https://www.forbes.com/sites/rachelarthur/2017/02/03/john-lewis-and-jaguar-land-rover-are-trialing-shopping-deliveries-straight-to-your-car/#63dd52b27f82]

Freight consolidation centres can reduce the distance travelled by highly emitting HGVs and improve the efficiency of last mile logistics. Deliveries destined for the same target area are combined into one high-load vehicle which travels to an urban consolidation centre where the goods can be split into smaller, less emitting vehicles for last mile delivery.[38]

Example: The London Boroughs Consolidation Centre introduced a solution to consolidate suppliers to the council and improve efficiency of their own supply chain for goods. As part of the scheme they mandated use of the off-site consolidation centre for all council premises deliveries and banned personal deliveries to the workplace as well as reducing delivery schedule to buildings to 2-3 times per week. The centre collates and consolidates the range of goods across suppliers and sorts them for onward last mile delivery to the council's sites via two low emission (Euro V) trucks which are to be replaced with ULEVs. This project was successful in reducing the number of vehicle trips to council sites by 46% and total distance travelled by delivery vehicles by 45% meanwhile increasing vehicle capacity utilisation by over 70%[39].

Magway is a concept which uses linear motors to propel parcels in sealed pipes along underground or over ground tracks thus reducing the need for heavy delivery vehicles on the road. While not always directly a last mile solution, Magway can help reduce the distances required for last mile travel, opening up more alternatives to van deliveries. The pipes can be used to connect major hubs to freight consolidation centres and therefore serve as last mile delivery too.

Example: Magway is set to alleviate the stress on local freight networks into and out of major UK airports by constructing pipes which will transport goods. After this deployment, they plan to build a longer, 100km route beginning construction in 2023 which will be the first of many planned to build up a comprehensive network along key freight routes in the UK[40].

3D printing is a technology which has the potential to provide an alternative last mile delivery. It is an additive manufacturing process whereby layers of material are built up to create a 3D part and can be conducted wherever the printer is located. This enables consumers to download designs remotely and print objects at home instead of ordering the product readymade. Local storage of 3D printing materials would take up much less space than occupied by conventionally manufactured products and could be delivered in large quantities and at lower frequencies from out-of-town warehouses directly to the homes of consumers thus reducing demand for last mile deliveries.

Currently, domestic 3D printing is not highly utilised due in part to high unit costs and material and size limitations, reducing the number of applications of 3D printing technology for desirable products[41].

38 D. Paddeu, The Bristol-Bath Urban freight Consolidation Centre from the perspective of its users, Case Studies on Transport Policy, Volume 5, September 2017, Pages 483-491, accessed from: [https://www.sciencedirect.com/science/article/abs/pii/S2213624X17301682]
39 Transport for London, The London Boroughs Consolidation Centre – a freight consolidation success story, accessed from: [http://content.tfl.gov.uk/lbcc-case-study.pdf]
40 J. Bates, Airport World, Going underground, September 2020, accessed from: [https://airport-world.com/going-underground/]
41 A. Mckinnon, The Possible Impact of 3D Printing and Drones on Last-Mile Logistics: An Exploratory Study, Built Environment, December 2016, Volume 42, Pages 617-629, DOI: 10.2148/benv.42.4.617

3.4 Enabling Technologies

The introduction or continuous development of enabling technologies is required to realise the benefits of last mile solutions fully or partially. Descriptions of a range of enabling technologies are provided below:

- **Connectivity** is a collective term for a set of digital infrastructure technologies including telecoms services such wi-fi, 3G, 4G, and 5G. While we have telecom coverage in much of the UK today, the introduction of 5G technology will offer higher access speeds, lower latency and allow a higher number of devices to be connected, permitting the development of different technologies, business models and products[42]. A comprehensive and sophisticated connectivity coverage will be required to enable vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications which in turn will enable the introduction of cooperative drone flight, flying taxis and connected autonomous vehicles.[43] Increased digital connectivity can also enable a reduction of journeys altogether as virtual meetings can in some instances provide an equivalent or better solution than in-person interactions.
- **Automation** considers the application of control systems which can carry out operations independently of human input. The automation of cars has had the most public attention, but it also applies to the automation of tasks such as packaging and sorting in warehouses. The transition from tasks completed by humans to machines introduces greater reliability and improved safety.
- **Electrification** refers to the transition from internal combustion engines to electric powertrains in traditionally motorised vehicles such as cars and vans. The transition is being accelerated through UK government policy which is legislating the ban of new conventional vehicle sales by 2030. The powertrain transition needs to be met with a comprehensive electric vehicle charging infrastructure including home, work and public networks.
- **Dynamic routing technology** develops logistics routes in reaction to real-time demand, adapting as required. This has the potential to increase the efficiency of fleet utilisation and optimise journey length which can contribute to substantial cost and environmental savings compared with static routing[44]. Dynamic routing technology is an enabler for demand responsive services and ride hailing applications.
- **Intelligent kerbside management** allows logistics companies to book space on otherwise restricted kerbsides through the creation of 'virtual loading bays'. This can aid the efficiency of deliveries by allowing vehicles to park near the delivery point without causing congestion or receiving a fine. The virtual nature allows for agile pricing and parking restrictions depending on time and day[45].

42 E. Barratt and E. De Clerk, Intelligent Transport, What does next-generation connectivity mean for transport and mobility?, June 2019, accessed from: [https://www.intelligenttransport.com/transport-articles/81491/what-does-next-generation-connectivity-mean-for-transport-and-mobility/]
43 C. Cottrill, Government Office for Science, Data and digital systems for UK transport: change and its implications, December 2018, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766718/Dataanddigital.pdf]
44 ORTEC, Dynamic Routing, accessed October 2020, accessed from: [https://ortec.com/en-gb/dictionary/dynamic-routing#:~:text=Dynamic%20routing%20in%20logistics%20means,adjustments%20to%20achieve%20best%20fit]
45 UK research and Innovation, Kerb - Intelligent Kerbside Management, accessed October 2020, accessed from: [https://gtr.ukri.org/projects?ref=971471]
46 MaaS Alliance, What is MaaS?, accessed October 2020, accessed from: [https://maas-alliance.eu/homepage/what-is-maas/]

The concept of **mobility as a service (MaaS)** introduces flexibility of travel choices by replacing the private ownership model with access to a range of on-demand modal choices. According to the MaaS alliance,

> "MaaS is the integration of various forms of transport services into a single mobility service accessible on demand".

To add most value, the various transport services should be accessible through a single platform or application and payment should be taken through that channel[46].

3.5 Enabling Interventions

Enabling interventions are policy-based solutions which are designed to realise desired modal shift and drive certain behaviours. Examples of enabling interventions include:

- **Clean Air Zones/Ultra Low Emission Zones** are intended to improve air quality in urban areas by deterring drivers from entering the zone with a vehicle which does not meet the minimum standards by enforcing a charge.
- **Road user charging** covers any charges enforced on road vehicles for entering a certain geographical area or road. This is designed to limit the number of vehicles entering the zone/road and thus reduce congestion. Flexible pricing can be used to spread the peak of travel demand. This differs from road tolling which is exclusively used to recover the costs of building, operating and maintaining infrastructure.
- **Parking charges and fines** are a key source of income for many local authorities and can be used to redistribute parking behaviour away from urban centres and towards suburban areas where there is more land available by varying prices. Fining drivers whose parking is not compliant with local laws discourages the blocking of carriageways and footways which can be disruptive to other road users.
- **Road user restrictions** only permit certain modes to travel through an area of road. Pedestrianisation reclaims road space for use of pedestrians exclusively while some road restrictions also only permit access to buses, taxis and bikes. Road user restrictions are used to improve the experience and safety of pedestrians, encouraging active travel while also deterring private car usage by enforcing a detour. There can be unintended consequences of road user restrictions if traffic is simply displaced to adjourning roads.

46 MaaS Alliance, What is MaaS?, accessed October 2020, accessed from: [https://maas-alliance.eu/homepage/what-is-maas/]

4 Next Steps

This literature review provides an overview of last mile solutions for the movement of people and goods which are currently available or in development.

The success of implementing and/or growing the uptake of more sustainable last mile transport solutions depends on some technological, commercial, regulatory and social factors which will be explored further in the context of local transport authorities. User acceptance of last mile mobility solutions is subjective and varies widely across different demographics. It will therefore be important in the next steps to consider localised levels of acceptance and sensitivities to interventions when proposing any new solutions.

The next step is to define the Problem Definition for transport authorities like Buckinghamshire council who are trying to overcome the challenges of improving last mile connections. The problem definition will cover elements such as process inefficiencies, propensity for change and budget constraints which need to be overcome. This will be aided by extensive stakeholder engagement across many departments within Buckinghamshire council. Part of this process will entail developing a more specific definition of last mile mobility, considering the scope of distances and use cases which apply.

To evaluate how effectively each of the last mile solutions in this review will address the defined Problem Definition we will develop a multicriteria decision analysis (MCDA) framework. The MCDA will be used to systematically evaluate the last mile solutions and generate a short list for further consideration. The MCDA will be reviewed during a workshop with key stakeholders from Buckinghamshire council to ensure it is comprehensive and relevant. We will also consider the enabling technologies and solutions which would aid the introduction of new modes or facilitating modal shift to existing modes when creating the MCDA framework.

5 Appendix A

5.1 Overview of People-based Solutions

Table 1 explains the column headings in **Table 2** and **Table 3** and how to interpret the information within them.

Table 1: Explanation of column headings for people-based last mile solution review

Column heading	Description
Name of mode	Name of the mode or solution
Maturity	**Established** – Currently in operation in towns such as Aylesbury **Emerging** – In the early stages of introduction to towns such as Aylesbury **Future** – Currently in development or pilot phase and not commercially available
Cost to implement	This considers the cost of implementing the required infrastructure, building from the current offering **Low** – Limited new infrastructure required **Medium** – New infrastructure or high maintenance costs required but can be shared with other modes **High** – High cost of dedicated infrastructure
Required infrastructure	A description of the infrastructure requirements for this mode/solution **Essential** – Mode cannot operate without this infrastructure **Preferred** – The success of the mode and level of uptake depends on this infrastructure **Enabling** – Technologies which could vastly improve the offering of this mode but that the success of the mode is not contingent on
Benefits	Wider benefits of the introduction of this mode (user, environmental, health, urban planning, cost)
Limitations/ Barriers	Examples of the limiting factors of the solution e.g. accessibility, distance, capacity
Cost to user	**User-operated:** The approximate cost per mile or hour, where appropriate, for a typical journey using this mode **Service-based:** Low, medium or high relative to each other
Maximum capacity	The maximum number of occupants which can be accommodated at any one time

Table 2 provides information on each of the user-operated people-based last mile solutions and **Table 3** provides information on each of the service-based people-based last miles solutions.

Table 2: Overview of user-operated people-based last mile solutions

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Cost to user	Maximum occupancy
Car	Established	Medium	**Essential** • Road network • Traffic signals • Road signage • Parking infrastructure (on-street and offstreet) and payment methods • Petrol re-filling stations or electric charging network **Preferred** • Traffic management systems • Traffic calming measures • Automatic Number Place Recognition (ANPR) and CCTV systems for monitoring behaviour **Enabling** • Electrification will eliminate tailpipe emissions and reduce overall carbon emissions • Connectivity will enable V2V and V2I communications • Autonomy will turn this solution into a service-based mode and improve safety	• Revenue generator for councils from parking fees and fines • Users can customise their vehicle based on their preferences (make/model/interior design) • Highly convenient on-demand transport • Versatile mode - can be used to transport luggage or goods (e.g. groceries) and passengers (e.g. children) • Electric vehicles can be used in place of combustion engine vehicles to reduce environmental impacts of tailpipe emissions	• Requires a driving licence and minimum age 17 years old • No maximum age, but many elderly people are not able to drive due to medical conditions • The majority of journeys are single occupancy which is highly inefficient and increases impact of cars on congestion • Requires parking space when not in use which creates a high demand for land use which can be a challenge in dense urban areas • No flexibility in return journey mode • High initial sunk costs of investment and significant asset depreciation over time. • Road network capacity limitations at peak travel times cause congestion on the road network • Perceived and actual safety of driving • Limited charging infrastructure network for EV transition especially for those without access to off-street parking facilities which leads to inclusivity issues • High cost of new roads and building new roads on greenfield sites is controversial and politically unpopular	23.8p to 89.1p per mile (excluding fuel), 37.7p to £1.03 (Including fuel) RAC estimates that cost of car usage for a vehicle from new over 3 years with average mileage 10,000 per year are between 23.8p and 89.1p depending on initial value. Fuel costs are additional approximately 13.9p per mile if petrol is £1.20 per litre[47] Parking and road charger fees plus any fines are additional[48]	Car: 4-6 Van: 2-3
Car club	Established	Low	**Essential** The same requirements as car/van plus: • Parking facilities • Application/website for booking and setting up an account with licence details **Preferred** • Dedicated car club spaces • Dedicated EV chargers	• Reduces need for car ownership • Spreads out cost of car ownership charging users on a per trip basis as opposed to high upfront and maintenance costs of private car ownership • Car club fleets can be replaced more frequently and have better fuel efficiency than the average car on the road • One vehicle can service many users, reducing the number of vehicles required, therefore freeing up land • Encourages a mobility as a service model with users matching modal choice to trip purpose rather than using car as the default to justify sunk costs	• Requires driving licence • Minimum age requirements (e.g. 19 for Enterprise car club) plus restrictions on minimum length of driving experience (e.g. hold a licence for at least 1 year) • Potential that vehicles are not available at the time you require them • Most operating models do not allow one-way trips and must be returned to the same location that they are picked up	From approx. £2.70 per hour depending on provider, location and membership plan Pay hourly/daily rate plus mileage charge. Membership fees unlock better hourly rates	4-6
Motorcycle	Established	Medium	**Essential** • Road network. • Parking infrastructure (on-street and off-street) but less space required per vehicle compared with a car • Petrol re-filling stations or electric charging network **Preferred** • In some cases, mopeds/motorbikes are permitted within bus lanes	• Motorcycles have relatively cheap operating and maintenance costs compared with a car • They are an on-demand, convenient means of transportation • They can access certain places that cannot be accessed by cars and buses • Better fuel efficiency than large vehicles such as cars, limiting their environmental impact from tailpipe emissions	• Requires a motorcycle licence • Minimum age between 16 and 24 depending on size of engine • No protection from weather • Requires specialist clothing and personal protection equipment • Reduced passive safety features compared with a car • Perceived and actual safety of riders is a barrier • Restricted demographics, mainly young and male	20p to 34p per mile (including fuel but not inc. initial cost of the motorcycle) based on 4800 miles travelled per year[49]	1-2

47 RAC, Typical vehicle running costs - for a petrol engine car, January 2016, accessed from: [https://media.rac.co.uk/blog_posts/typical-vehicle-running-costs-for-petrol-engine-cars-42585]
48 Enterprise Car Club, Rental That's Right Up Your Street, accessed October 2020, accessed from: [https://www.enterprisecarclub.co.uk/gb/en/home.html?mcid=paidsearch:31525770&mcid=paidsearch:1738&gclid=EAIaIQobChMIx_iyqODZ7AIVpoBQBh2rOw8VEAAYASAAEgLeTPD_BwE&gclsrc=aw.ds]
49 E. Hersh, NimbleFins, What's the Total Cost of Owning a Motorcycle?, May 2020, accessed from: [https://www.nimblefins.co.uk/how-much-does-it-cost-own-motorcycle]

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Cost to user	Maximum occupancy
Walking/ wheelchair	Established	Low	**Essential** • Safe pavements alongside roads or dedicated footpaths • Stairs, escalators or ramps for inclines and decline • Footbridges or modal connections for crossing bodies of water • Drop kerbs for wheelchair access • Pedestrian crossings such as zebra or pelican for safe crossing of roads **Preferred** • Clear wayfinding (signposting in addition to digital maps on portable devices) • Covered walkways for shelter from adverse weather • Street lighting for visibility and safety at night	• Active travel has personal health benefits (both physical and mental) for the user. • Does not contribute to carbon or other air polluting emissions • Does not contribute to road congestion • Free mode of travel for the user • Reliable and on-demand travel times • Arup estimate the benefit: cost ratio of walking infrastructure to be 13:1[50]	• Fitness and mobility levels limit the distance people are prepared to travel • Slow travel times • Journey distance is limited to under 3km for most users • Demanding physical terrain such as hilly topography or uneven ground limits the demographics able to travel by walking or using a wheelchair • Perceived and actual safety can deter users • Perceived and actual personal security (particularly at night and for more vulnerable populations) can deter users • Pedestrians are vulnerable to the negative health implications of poor air quality • Availability of continuous walking infrastructure especially in rural and semi-rural areas Is often limited • Poor weather conditions are a deterrent • Reallocating road space from drivers to pedestrians can be a very unpopular political decision	Free	1
Bicycle	Established	Low	**Essential** • Bikes require roads, bridleways or dedicated cycle paths. **Preferred** • Clear wayfinding (signposting in addition to digital maps on portable devices). • Secure bicycle parking and storage facilities. • Traffic separation measures such as bollards can be put in place to improve the safety and uptake of cycling.	• Active travel has personal health benefits (both physical and mental) for the user • Does not contribute to carbon or other pollutant emissions • Require much less land use for parking than cars - up to 10 bikes can fit into one car parking space[51] • Bikes take up less road space then cars reducing impact on congestion • Bikes can bypass congestion where there is sufficient road width or dedicated cycle paths which make journey times preferable to car usage • Parking process easier and faster than locating public car parking spaces and free • Free at point of use (however upfront and maintenance costs apply) • Reliable travel times and faster journey times than walking	• Fitness and mobility levels limit the distance people are prepared to travel • Demanding physical terrain such as hilly topography or uneven ground limits the demographics choosing to cycle • Most people only willing to cycle up to 3 miles • While the majority of the population have the physical capacity and ability to cycle, many are deterred from cycling due to safety concerns • There is a large gender bias in the demographics, with far more men taking up cycling than women • Bike theft is prevalent especially in urban areas and makes bike ownership unappealing to many • Cyclists are more exposed to the negative effects of poor air quality • Showering facilities often preferred for commuters	16p per mile. Cycle scheme estimates that bike ownership costs approximately 16p per mile including cost of purchase, insurance, equipment, breakdown cover and maintenance costs over a 5-year period and assuming 2500 miles per year	1
e-bike	Emerging	Low	**See 'Bicycle'** e-bikes can be plugged into mains electricity removing the need for public charging infrastructure.	• Makes cycling more accessible to a wider range of demographics including people with reduced fitness • Faster journey times compared with mechanical bikes • Enables longer distances by bike, and/or travel in more challenging terrains such as hilly areas • Very affordable compared with a car and many work-place schemes can spread the initial cost • Still requires some self-propulsion and therefore gives the user some active travel and fitness benefits	• Safety concerns remain • Threat of theft still prevalent • No protection from weather • Greater purchase price than mechanical bicycles	8p to 12p per mile[52] A full charge of an e-bike battery is approximate 7p	1

50 Arup, The economic case for investment in walking, November 2018, accessed from: [https://www.victoriawalks.org.au/Assets/Files/Arup-economic-case-for-walking_Final.pdf]
51 Cyclehoop, Car Bike Port, accessed October 2020, accessed from: [http://www.cyclehoop.com/product/bike-racks-and-cycle-stands/car-bike-port/]
52 M. Brown, e-bikeshop.co.uk blog, Electric Bike Running Costs, October 2013, accessed from: [https://www.e-bikeshop.co.uk/blog/post/electric-bike-running-costs/#:~:text=But%20on%20average%20an%20electric,average%2030%2D150pence%20per%20mile]

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Cost to user	Maximum occupancy
e-scooter	Emerging	Low	**Essential** • Depending on the legislation, e-scooters do not require specialised infrastructure but can be used on public roads or on dedicated cycle lanes • Phone application for locating, reserving, and paying for trips **Preferred** • Some separation from motor vehicles is preferable for safety purposes, this includes shared lanes with bicycles, use on pedestrianised streets or on pavements **Enabling technologies** • Automation can be used for e-scooters to independently redistribute themselves and return to popular pickup destinations	• Requires much less land use than parking car. • Faster mode than walking and most cyclists, reaching speeds of up to 14.8mph • More accessible than walking or cycling due to lesser baseline fitness and physical mobility requirements	• No protection from weather • Legislation only permits the use of hired e-scooters in certain unrestricted areas of the UK • Age restrictions (16 or 18 depending on the area) • Some providers require proof of a driving licence. • Use of technology to access the shared modes can be a barrier to demographics less familiar or with no access to smartphones • Safety concerns for e-scooter users and other road users. They can also pose a risk to pavement users if used improperly	Approx. £1 per mile Typically unlock fee + price per minute For Lime users in Milton Keynes that equates to £1 + 20p per minute. Top speed approximately 14 miles per hour, at £14 per hour gives minimum cost of £1 per mile	1
Docked shared scheme	Emerging	Medium	**Essential** • Docking stations • Bikes/e-bikes/e-scooters • Phone application for locating nearest docking station and for unlocking mode of choice • Payment station **Preferred** • Dedicated paths • Access to helmet hire **Enabling technologies** • GPS tracking could help to safeguard micro mobility modes from theft	• Cheap for user, no initial investment costs or personal consequences of theft • Good for cities where storage space for users may be limited • Fits well into a MaaS solution as no sunk cost for user and can come back via a different mode • Reliable system - bikes will be in the same docking stations with fixed locations • See above for bicycle and/or e-scooter usage benefits	• One-way flow of journeys during rush hour requires redistribution of assets • Bad weather affects usage/seasonal trends	Varies with mode and operator	1
Dockless shared scheme	Emerging	Low	**Essential** • Bikes/e-bikes/e-scooters • Smooth surface such as road network/pavement/ cycle lanes • Phone application for locating nearest docking station and for unlocking mode of choice • Payment station • GPS tracking and digital infrastructure for locating, unlocking and paying for the mode **Preferred** • Dedicated paths • Access to helmet hire	• No need for user to locate a docking station at the beginning/end of journey • Good for cities where storage space for users may be limited • Fits well into a MaaS solution as no sunk cost for user and can come back via a different mode • Cheap for user, no initial investment costs or risk of theft • See above for bicycle, e-bike and/or e-scooter usage benefits	• Higher chance of vandalism than docked schemes • Assets have to be redistributed • Geofencing of operational areas to stop people travelling too far out of the city limit the distance people can travel • Bad weather affects usage/seasonal trends of micro-mobility solutions	Varies with mode and operator	1

Table 3: Overview of service-based people-based last mile solutions

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Cost to user	Maximum occupancy
Bus	Established	Medium	**Essential** • Road network • Bus stops • Bus depot/overnight storage • Method of purchasing tickets (app, machines, on bus etc.) **Preferred** • Bus lanes and priority at junctions • Bus only streets • Bus shelters	• Shared travel reduces congestion • The emissions of fleet vehicles can be controlled more easily by LAs as it does not rely on consumer choice	• Declining patronage numbers across the UK • Disparity of cost across the UK (£1.50 per bus journey in London, and as high as £5.65 for a 5-mile journey in Hampshire in 2019) • Require high occupancy to be commercially viable • Low frequency in many areas	Low to medium (free to £5.65 per 5-mile journey)	Approx. 70 (single decker), 100 (double decker) and 150 (bendy bus), including seated and standing passengers[53]
Water bus	Established	High	**Essential** • An appropriate body of water is required • Docks are required for boats to moor against for safe embarking and disembarking, particularly important to ensure wheelchair access is safe and secure • Water management **Preferred** • Digital platforms can be used to track boats for better user experience and track wait times	• Removes traffic from the road, alleviating congestion • Café/bar can be on board for better user experience • Wheelchair accessible • Can be a fast alternative to road travel	• Requires smooth bodies of water to operate • The size of the boat is limited by the width of the body of water (due to turning circling and passing other vessels) and any obstacles such as bridges which it has to navigate • There are fewer powertrain options for vessels as opposed to road vehicles and therefore tend to run on diesel engines which emit significant levels of pollutant gases	Medium to High	Max 222 (Thames clipper)[54]
Cable car	Established	High	**Essential** • Dedicated towers to be constructed • Cable car cabins • Electricity supply • Cables	• Cheaper alternative for steep hill climbs than bridges or tunnels • Removes traffic from the road, alleviating congestion • Fast and reliable travel times • Zero on-site emissions • Solar panels can be attached to the cabins for even more sustainable travel	• Substantial and dedicated Infrastructure required • Typical operating capacity of 1,000-2,000 passengers per hour per direction[55]	Medium	Up to 30[56]
Taxi	Established	Low	**Essential** • Same infrastructure as private cars **Preferred** • Taxi base • Dedicated taxi lanes (usually joint with bus lanes) • Taxi ranks • Rapid EV charging infrastructure • Smart phone application	• Convenient, on-demand form of transport which offers a point to point service up to 24 hours a day • Can accommodate luggage • Price is per vehicle not per person so can be cheaper than other modes when at full occupancy • Drivers are licensed • Many taxis (inc. black cabs) are designed to be wheelchair accessible • Taxi drivers often have a specialised knowledge of their local roads (in London, drivers must take the Knowledge test) • Fleets of vehicles make good use cases for transitioning to EVs due to Consolidation OF charging infrastructure at a base location	• High price makes this mode less accessible than most • Unreliable waiting times during peak usage hours • Door coverage in rural areas • Contributes to poor air quality and carbon emissions as most vehicles are ICE, idling increases the impacts	High	3-5

63 UK Government, Specs - bus length, assets.publishing.service.gov.uk › file › buslength
64 Uber Boat by Thames Clippers, River Thames hits milestone of 40 million passengers, October 2018. accessed from: [https://www.thamesclippers.com/news/river-thames-hits-milestone-of-40-million-passengers#:~:text=The%20new%20222%20capacity%20boat,capacity%20by%20eight%20per%20cent]
65 L. Rubiano, W. Jia & G. Darido, World Bank Blogs, Innovation in the air: using cable cars for urban transport, accessed from: [https://blogs.worldbank.org/transport/innovation-air-using-cable-cars-urban-transport]
66 S. Tezak, M Lep, Solutions for increasing the capacities of cable cars. Journal of Sustainable Development of Transport and Logistics, 2019, 4(1), 31-37. doi:10.14254/jsdtl.2019.4-1.4.

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Cost to user	Maximum occupancy
On-demand ride hailing	Emerging	Low	**Essential** • Digital platform • Same road infrastructure as private cars **Preferred** • Rapid charging stations (if electric vehicles are used)	• Convenient, on-demand form of transport which offers a point to point service up to 24 hours a day • Can accommodate luggage • One app can be used in any location where services are available • Typically, much quicker pick-up than taxis which are booked over the phone (longer wait than a rank) • Shared journeys can be facilitated and encouraged through cost savings • Flexible model which responds to demand allows for more drivers to be active at peak times • Perceived and actual costs lower than traditional taxis	• Not all vehicles are wheelchair accessible • Perceived safety and security concerns • Some legal battles over driver rights • Surge pricing leads to unreliable travel costs	Medium	3-5
DRT	Emerging	Low	**Essential** • Same road infrastructure as private cars • Digital platform • Minibuses with approximately 7-15 seats **Preferred** • In very congested areas, the use of bus lanes can support operation	• DRT works as a low infrastructure alternative to other public transport modes • Consolidation of single passenger journeys into one vehicle to reduce congestion and emissions	• Lack of financial sustainability has caused may DRT system in the UK to cease operations • Limited by users' willingness to share	Low to Medium	Variable but many services offer 7-15 seats
Flying Taxis	Future	High	**Essential** • Take-off and landing pads • Extensive charging infrastructure • New air traffic control monitoring	• Removes traffic from the road, alleviating congestion • Electric powertrain does not emit pollutants into the air • Their flight path is not restricted by bodies of water	• High technology Investment costs • currently payload, capacity and range are limited by battery technology but that is set to advance in the near future • Adverse weather can affect the operation, performance and safety • User acceptance may be a barrier • New air space management required	Unknown but expected to be high	Expected 2-4
CAVs	Future	Medium	**Essential** • Same road infrastructure as private cars • Connectivity **Preferred** • More advanced connectivity e.g. 5G **Enabling technologies** • Connectivity to enable V2V and V2I communications for improved safety and efficiency of the network • Electrification to reduce environmental impact of motorised travel	• Increased safety features designed to reduce road traffic accidents and accident-caused congestion • Improves accessibility for mobility-impaired, elderly, visually impaired and under-aged drivers • Removal of labour costs from service-based solutions • More productive journeys, as removal of driving responsibilities allows passengers to engage in activities such as sleep, reading or replying to emails • Self-parking and electric vehicle charging • Enables more journey sharing • May facilitate rightsizing of vehicles which will increase efficiency of single and dual occupancy journeys	• Vehicle size and user's willingness to share a small unattended vehicle with strangers • Policy regulations are not currently in place to support L4 vehicles • Private ownership vs. a service-based model could have large impacts on the realised benefits of CAVs	Unknown but expected to be much cheaper than taxis	Expected 2-6 seats but technology can be applied to larger vehicles

6 Appendix B

6.1 Overview of Goods-based Solutions

Table 4 explains the column headings in **Table 5** and **Table 6** and how to interpret the information within them.

Table 4: Explanation of column headings for people-based last mile solution review

Column heading	Description
Name of mode	Name of the mode or solution
Maturity	**Established** – Currently in operation in towns such as Aylesbury **Emerging** – In the early stages of introduction to towns such as Aylesbury **Future** – Currently in development or pilot phase and not commercially available
Cost to implement	From a transport authority's perspective, an indication of the costs of the infrastructure or maintenance required to facilitate the solutions (assuming the assets are privately funded) **Low** - Limited new infrastructure required **Medium** - New infrastructure or high maintenance costs of existing infrastructure **High** - High cost of dedicated infrastructure
Required infrastructure	A description of the infrastructure requirements for this mode/solution **Essential** – Mode cannot operate without this infrastructure **Preferred** – The success of the mode and level of uptake depends on this infrastructure **Enabling** – Technologies which could vastly improve the offering of this mode but that the success of the mode is not contingent on
Benefits	Wider benefits of the introduction of this mode (environmental, health, urban planning, cost)
Limitations/ Barriers	Examples of the limiting factors of the solution e.g. accessibility, distance, capacity
Load Capacity	The approximate maximum load capacity in kilograms

Table 5: Overview of direct goods-based last mile solutions

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Load Capacity
Motorcycle	Established	Medium	**Essential** • Road network • Parking infrastructure • Petrol re-filling stations or electric charging network **Preferred** • In some cases, mopeds/motorbikes are permitted within bus lanes	• Can negotiate traffic quicker than vans leading to more reliable and faster journey times • Take up much less parking space and road capacity than cars • Cheaper to operate and fewer emissions per mile travelled than vans • Many models of moped are electric which eliminates tailpipe emissions • Lower purchase price than a van	• Smaller load capacity than vans therefore likely need to reload from base throughout the day or cater to an on-demand service • Perceived and actual safety of riders	130-230kg (inc. driver)[57]
Cargobike	Emerging	Low	**Essential** • Cargobikes require roads, bridleways or dedicated cycle paths • Batteries for e-Cargobikes can be removed for recharging using a three-pin plug, so no additional charging infrastructure is required • Local depot for reloading • Secure parking and storage **Preferred** • Wider cycle lanes so as not to obstruct other cycles • Increase in the number of micro distribution hubs.	• Reduced noise pollution, congestion and carbon emissions compared with motorised transport • Can contribute to improved air quality as zero tailpipe emissions • Good journey time reliability as less affected by road congestion than vans • Reduced running costs (zero fuel costs per mechanical cargobikes and very cheap electricity costs for e-Cargobikes) • Can help businesses and councils achieve sustainability goals • Delivers active travel benefits to riders • Cycle freight riders can cover total distances of up to 80-100 kilometres per day	• Lack of knowledge of this mode • Perception that it is slower mode than motorised travel even though it can be faster over short distances • Limited number of companies which offer cycle services for subcontracting • Given payload limitations, cycle couriers typically need to reload to match the 10-15 deliveries per hour that a van can achieve (in mail and parcel industry), which limits the service radius to between two and eight kilometres[58] • Requires base fitness levels from riders • Investment in cargobikes can be significant especially for small businesses, despite being less than vans/cars • Average cost of cargobike is £1900 and e-Cargobike is £4,100 exc. VAT	100kg[59]
Private car	Established	Medium	**Essential** • Road network. • Traffic signals • Road signage • Parking infrastructure • Petrol re-filling stations or electric charging network **Preferred** • Traffic management systems • Traffic calming measures • ANPR and CCTV system **Enabling technologies** • Electrification to reduce environmental impact of motorised travel • Connectivity to enable V2V and V2I communications Autonomy will turn this solution into a service-based mode and improve safety	• Reduces capital costs for delivery companies • Flexible working for employees • Agile model for staff based on demand	• Limited by car capacity • Companies have less control on emissions of each vehicle and therefore may find it harder to comply with fleet averages • Concerns around employee rights and levels of safety and training	Approximately 385kg (inc. driver)[60]

57 New Touring Rider, How Much Weight Can My Motorcycle Carry?, accessed October 2020, accessed from: [https://newtouringrider.com/how-much-weight-can-my-motorcycle-carry/]
58 Transport for London, Cycle Freight Study, March 2018, accessed from: [http://content.tfl.gov.uk/cycle-freight-study.pdf]
59 Department for Transport, Government Response to Call for Evidence: The Last Mile - Delivering goods more sustainably, March 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/786879/last-mile-call-for-evidence-government-response.pdf]
60 Honda, Maximum Load for Your Vehicle, accessed October 2020, accessed from: [http://techinfo.honda.com/rjanisis/pubs/QS/AH/A1919T5AWG/enu/GUID-DFE42D95-882B-4E62-9C8B-41D7311949FD.html]

Name of mode	Maturity	Cost to implement	Required Infrastructure	Benefits	Limitations/Barriers	Load Capacity
Vans	Established	Medium	**See 'Private car'**	• Vans have a lower rate of accidents per mile than other road vehicles • Vans have a higher payload than most other last mile delivery solutions • Traditional mode which is well understood and has many trained drivers • Uses existing road networks • Can reduce environmental impacts through electrification of van fleets	• Van usage contributes to air pollution and carbon dioxide emissions, harming the environment and public health • Vans can exacerbate congestion problems, especially when operating at peak travel times or obstructing road traffic when parked at pick-up and drop-off locations • Higher initial cost of investment than modes such as cargobikes • Poor journey time reliability as dependent on reliable road networks • Requires drivers which increase labour costs	600kg[61]
Drones	Future	High	**Essential** • Verti-ports and verti-stops to facilitate UAV landings and take-offs • Runways for winged UAVs • Receiving vessels, such as lockers or other storage facilities, for package deliveries • Charging stations • Unmanned Traffic Management for low air space. • Communication network. **Enabling technologies** • Connectivity to improve efficiency of cooperate drone logistics	• Does not contribute to road congestion • Reduced labour costs as one employee can oversee the operation of many drones • Fast and reliable journey times • Reduced emissions compared with motorised road transport and can be zero emissions if electric • Cheaper delivery costs due increased fuel efficiency and reduced labour costs • No human operator therefore reduced risk of fatal accidents • Increase in accuracy of deliveries to the correct recipient by removing human error • Positive reaction from business leaders - a survey revealed that 56% of business leaders were positive about drones and their benefits which rose to 83% when asking those who already use drones in their business	• Range of batteries limits journey length and utilisation time • Higher skilled workers required to oversee drone operations and carry out maintenance • Limited loading capacity, especially VTOL • Relies on the introduction of an Unmanned Traffic Management (UTM) system and new legislation for safe operation which is currently not set up in the UK • Likely to have restricted use around major airports or military installations which could disrupt flight paths • New research (2019) from the PwC has found public perception remains a barrier to drone uptake in the UK with just 31% of people feeling positive towards drones and more than two thirds are concerned about the use of drones for crime	VTOL: 5kg
Automated robot deliveries	Emerging	Low	**Essential** • Robots travel along pavements, so good walking infrastructure with accessible drop kerbs are necessary	• Automated robot delivery vehicles are battery powered, removing tailpipe emissions • Robots can travel on pavements and therefore do not contribute to and are not adversely affected by road congestion • Reduced labour cost (one employee can operate a fleet remotely) • Charge lasts a full day and they can be charged at night • During Covid-19, delivery robots increased in popularity due to the 'contactless' delivery aspect • Starship reports that they are not subject to vandalism	• Payload limited by volume (approximately 2 bags of grocery shopping) • Slow maximum speed (walking pace) limits delivery opportunities for hot or perishable items • Risk of being subject to theft or vandalism • 4-mile delivery radius (star ship) • Battery life: 2 hours (6 km of driving), Charging time: 45min • Take up space on pavements which are shared with pedestrians	Winged: 100kg
CAVs	Future	Medium	**Essential** • Same road infrastructure as private cars/vans • Communications network **Preferred** • More advanced connectivity e.g. 5G. **Enabling technologies** • Connectivity to enable V2V and V2I communications for improved safety and efficiency of the network • Electrification to reduce environmental impact of motorised travel	• Reduced labour costs as driver can be removed • Improved safety and reduced profit loss from collisions and congestion • Improved fuel efficiency from smoother diving style, reducing carbon emissions per mile travelled • Better road network efficiency from CAV deployment	• Last meter delivery would need a different system or human intervention • Requires reallocation of labour from driving professions • High investment costs in developing the technology • Concerns over insurance and legal challenges are barriers to implementation • Public perception of safety remains a barrier	10kg[62]

61 Department for Transport, Government Response to Call for Evidence: The Last Mile - Delivering goods more sustainably, March 2019, accessed from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/786879/last-mile-call-for-evidence-government-response.pdf]
62 Swiss Post, Factsheet Starship Delivery Robot, accessed October 2020

Table 6: Overview of indirect goods-based last mile solutions

Name of mode	Maturity	Required Infrastructure	Benefits	Limitations/Barriers	Load Capacity
Amazon lockers	Established	**Essential** • A set of lockers • No additional physical infrastructure required as located at existing businesses	• Greater flexibility and convenience for customers to receive parcels around their schedule (e.g. evening and weekend pickups) • Consolidation of deliveries to a 'hub' rather than individual residences is much more efficient for the logistics provider • Items can also be returned via the amazon lockers • Lockers are located near other businesses which the customer may be frequenting anyway (such as petrol stations) which consolidates last mile journeys of goods and people. • Lockers may lead to greater revenue and footfall for businesses where lockers are located	• All items in an order have to fit within a volume of 16 x 12 x 14 inches • Deliveries must be collected within 3 days before the items are collected and returned (customer is refunded in this instance) • Some lockers are located within buildings such as Whole Food stores, therefore access times are limited to store opening hours • There are a limited number of lockers in each location, which cannot be shared between users. The largest locker hub in the UK is at Warwick university where there are 115 • Parcels can be delivered to the lockers by any mode but likely to be vans • Only available for amazon customers	4.5kg
Collectplus	Emerging	**Essential** • No additional infrastructure required since it uses the existing network of convenience stores, newsagents, supermarkets and petrol stations	• Greater flexibility and convenience for customers to receive parcels around their schedule (e.g. evening and weekend pickups) • The Collectplus network is made up of locations with much longer operating hours than post offices making sending, receiving and returning of parcels more convenient • 90% of people who live in the UK's towns and cities are within one mile of a Collectplus Store • Consolidation of deliveries to a Collectplus 'hub' rather than individual residences is much more efficient for the logistics provider	• The goods take up space in small stores which may have limited capacity • Packages are limited by size and weight of 60cm x 50cm x 50cm and 10kg	10kg
Delivery to car	Established	**Essential** • Compatible vehicle fitted with a 'smartbox' • Accurate GPS tracking	• Convenient for consumers who do not have to be present to receive a delivery • Consolidation of journeys, if delivering to many cars within the same carpark e.g. workplace	• Can only delivery items which fit in boot space and this varies from vehicle to vehicle • Requires installing a smartbox into the customer's vehicle to allow for unlocking and locking by a third party • Some users are not comfortable with a stranger accessing the boot of their car • Relies upon vehicles not constantly moving throughout the day for efficient delivery	Information not available
Freight con-solidation centres	Established	**Essential** • Warehouses and sorting centre • Proximity to strategic road network	• Cost savings for customers by negotiating bulk buy discounts with suppliers passed down from reduced delivery costs • Greater buying power through collective or collaborative procurement • Helps control the quantity and flow of goods being delivered • Reduces negative environmental impacts and helps to achieve sustainability objectives • Better control of enabling vehicles to run full when completing journeys in both directions	• High initial cost of investment • Requires a high throughput from the same direction to benefit from the efficiencies of scale • Requires low emission lorries and last mile delivery vehicles to realise the environmental benefits • Requires the input and cooperation of many companies for maximum profit benefits • A strong business case is required to convince private companies to participate	N/A

Name of mode	Maturity	Required Infrastructure	Benefits	Limitations/Barriers	Load Capacity
Magway	Future	**Essential** • Distribution pipes with 1 metre diameter • Autonomous pods • Tracks	• Capable of fulfilling 90% of parcels distributed by Customer Fulfilment Centres • Save up to 70% of costs compared to using the road network • Not limited by driver requirements and no risk of injury to humans during operation • Design enables tracking of parcels along route and a highly configurable throughput • Secure delivery method which works in all weathers • Uses dedicated infrastructure which can go alongside existing highway systems and therefore has minimal impact on other modes • Does not contribute to and is not adversely affected by road congestion • A single system has a capacity equivalent to 40,000 40-foot articulated lorry journeys a week[63]	• Requires dedicated infrastructure with high initial investment costs • Small load capacity per pod	Pod capacity unknown Maximum system throughput is two lorry loads per minute[64]
3D printing	Emerging	**Essential** • No built infrastructure required but requires a 3D printer at end location • Connectivity network to send designs remotely	• Enables locally produced goods or components which reduces overall travel demand • Less waste produced than other manufacturing techniques • Reduces land required for storage of goods as can be produced with shorter lead times	• Limited by speed of printing • Limited by the size and materials which are supported by 3D printing technologies • Relies on consumer investment in printer at home • Perceived and actual technological barriers depending on consumer competence • Still requires distribution of raw materials to point of manufacture	Winged: 100kg

63 Magway, A HIGH-CAPACITY DELIVERY SYSTEM, accessed October 2020, accessed from: [https://www.magway.com/#:~:text=A%20single%20system%20has%20a,and%20outside%20of%20our%20cities]
64 C. Krieger, Jewish News, February 2020, accessed from: [https://jewishnews.timesofisrael.com/the-groundbreaking-start-up-behind-the-future-of-parcel-delivery/]

May 2021

Appendix D2

Problem Definition

ADEPT LIVELABS Transforming Local Places

Buckinghamshire Council

CATAPULT Connected Places

Setting the Scene

> "There has never been a time of greater change for the 'last mile'."
>
> World Economic Forum, January 2020[1]

The movement of goods and people over the first and last mile is a vital component of end-to-end journeys - which are essential to daily life. The speed, efficiency and cost of last mile travel all have an impact on productivity and local economic growth.

Currently, there is an overreliance on vehicles powered by internal combustion engines to fulfil short journeys which has caused overcrowding on the road network, in many parts of the UK, leading to high congestion levels in urban areas and at peak travel times. Heavier congestion levels result in longer and less reliable travel times by road and can lead to more road traffic collisions.

The issues of overdependence on cars to fulfil last mile passenger journeys and the significant rise of registered diesel vans to fulfil increased demand for e-commerce home deliveries are widespread and permeate much of the UK. However, overcoming these issues cannot be done through a 'one size fits all' solution but instead requires a great deal of nuance in approach especially between urban, sub-urban and rural environments.

The Connected Places Catapult is conducting an in-depth feasibility study to scope the last mile needs of local authorities such as Buckinghamshire with the intention of trialling relevant solutions in Aylesbury - the results of which will be disseminated across similar authorities.

This document, as part of the study, identifies the challenges that first and last mile mobility solutions can address as well as the challenges to their successful adoption in the context of Buckinghamshire and similar UK local authorities.

1 http://www3.weforum.org/docs/WEF_Future_of_the_last_mile_ecosystem.pdf

Scoping the Challenge

The Connected Places Catapult conducted interviews with fourteen members of Buckinghamshire Council representing eleven topic areas and departments: public transport, parking, active travel, traffic management, road infrastructure, contractors, sustainability, future mobility strategy, taxi licencing , master planning and electric vehicle charging.

To scope the challenge, the CPC's approach was to collect, collate and report on the views and experiences of Buckinghamshire council's officers. Therefore, the language used in this document reflects that of the interviewees and the subsequent problem definitions have been validated in a workshop after this document was drafted.

The interviews were designed to uncover the main challenges experienced by local authorities which prevent a more environmentally sustainable last mile mobility system. The interviews covered the current pain points around movement of goods and people, both generic and last mile specific. Interviewees were asked to consider whether future demand is manageable given the current solutions and whether there are any expected changes to these pain points over the next 5/10/15 years. We also captured the biggest barriers to implementing change from the perspective of each team.

Considering Covid-19

The short-term impacts of Covid-19 have been significant and widespread. The effects on the movement of goods and people have been numerous; some examples include:

- Increase in remote working reducing the need to commute
- Increase in home deliveries from e-commerce replacing trips to supermarkets and highstreets
- Higher uptake of active travel for transport and leisure activities
- Reduction in public transport patronage
- Acceleration of regulatory changes such as legalisation of e-scooter trials
- Introduction of emergency funding for active travel infrastructure

While the longevity of each reported trend is unclear, it is widely expected that transport demand will be altered indefinitely, with the enactment of a national lockdown acting as a watershed. The change in transport demands brings about new opportunities and challenges for a sustainable future. The impacts of Covid-19 will be thoroughly considered in a standalone work package, but the findings will be disseminated across the other deliverables.

Using this Document

This problem definition is designed to be used in parallel with the Connected Places Catapult's 'Last Mile Mobility Literature Review' report which outlines the state of last mile mobility across the UK and discusses potential transport solutions in addition to enabling technologies and policies. The literature review is not exhaustive of all potential solutions and is a working document with new ideas welcomed throughout the process. A list of acronyms used in this document and their meanings are given below.

Acronyms

DfT	Department for Transport	LA	Local Authority
EV	Electric Vehicle	LGV	Light Goods Vehicle
HGV	Heavy Goods Vehicle	UK	United Kingdom
ICE	Internal Combustion Engine		

Developing Problem Statements

Broad themes permeated through the interviews, with the same pain points revealed to be consequential to different departments and teams. The following eight problem statements outline the key relevant challenges experienced in Buckinghamshire which we believe will also be applicable to other similar authorities. Under each problem statement is an explanation of why this is an issue for last mile mobility along with a selection of root causes mentioned by interviewees or common knowledge in the industry. The importance of understanding the cause and effects of each problem statement is paramount to the success of overcoming them.

The problem statements are written from the view of a local authority; defining the current barriers to promoting and achieving sustainable last mile mobility.

Problem statements

1. Investment in active travel is restricted by public and political perception.
2. Heavy Goods Vehicles are routed through towns and villages.
3. Reliance on diesel vans to fulfil low density last mile deliveries.
4. On-demand delivery vehicles cause traffic disruption.
5. Powerful lobbying from car users perpetuates driving dominance.
6. New housing developments are not setting best practice.
7. Public transport is inefficient over the last mile.
8. Long-term change is difficult to plan and implement.

Exploring the Problem Statements

1. Investment in active travel is restricted by public and political perception

Barriers to active travel are as much cultural as they are based on any physical requirements. The perception that **cycling is less desirable than driving** leads to a vicious cycle where it is politically controversial to invest in new cycling infrastructure yet cycling is unlikely to increase in popularity until there is investment in safe and robust infrastructure. Active travel is at the top of the transport sustainability hierarchy and has personal health benefits to the user and is therefore a desirable modal choice for local authorities (LAs). Modal shift towards active travel will improve air quality, reduce congestion, reduce land use required from parking, improve public health and reduce carbon emissions.

The root causes of this problem statement include:

- **Perceived and actual safety concerns** - roads are not designed with safety or convenience of cyclists in mind. On some routes, cyclists must give way to access roads or are forced on the edge of the road with puddles, potholes and debris causing hazards.
- **Poorly maintained infrastructure** - limited footway maintenance has led to uneven pavements and large puddles which make walking undesirable and cycling measures are not consistent enough; cycle paths appear and disappear throughout a journey. Bike racks at final destinations and transport exchange hubs are not all sufficiently sturdy and therefore do not give residents confidence that their unattended bikes are secure and protected from theft.
- **Cycling infrastructure is controversial** - it is difficult to get members to vote in support of investment in cycling infrastructure due to low public acceptance and personal preferences to use a car. Carriageway widths are limited and taking space away from motor vehicles is not readily accepted by residents and can receive lots of political backlash.
- **Limited dedicated funding** - funding streams for cycling and walking infrastructure are included in general highway budgets. This figure must cover footways, cycle paths, roads and there is no increased budget to maintain any new infrastructure which creates a barrier to new construction initiatives. Major road developments and maintenance budgets prioritise their main modal use case - motorised traffic which leaves little budget left for other road users such as implementing a pedestrian crossing on these roads.
- **Behaviour change** - cycling is not a culturally common last mile mobility solution and is seen as more of a leisure activity than commuting mode especially in more rural areas. Behaviour change and a shift in mindset is required to alter this which is difficult to achieve quickly and without investment. There is a lack of promotion/marketing to accompany any new initiatives and residents need to see significant visible and sustained improvements to infrastructure to be convinced it is safe to make changes to their longstanding routine.

2. Heavy Goods Vehicles are routed through towns and villages

Road logistics rely on existing road infrastructure, which in counties with no motorway networks means relying primarily on old road networks which run directly through towns and villages. HGVs passing through the county therefore have no choice but to travel through urban centres contributing to **air and noise pollution** as well as **congesting streets** and creating an **undesirable environment for active travellers.** Often these journeys through the urban centres have no direct benefit to residents as the goods are destined elsewhere.

The root causes of this problem statement include:

- **Lack of alternative routes** - link roads can offer alternative routes away from urban centres, but they risk simply moving the problem to new housing developments and any additional capacity being counteracted by increased demand from population growth.
- **Through traffic** - a large proportion of HGV traffic through urban centres is destined elsewhere and is not making last mile deliveries in the urban centre itself, contributing to congestion and noise and air pollution but no local economic advantage. In addition, HGVs making multi-drop deliveries which include urban centres as a drop-off have no choice but to route through potentially congested areas.
- **Unit cost sensitivity** - logistics companies are commercial enterprises which run on very tight margins. Any new initiative to improve sustainability must also have a strong business case and provide a return on investment. Decarbonisation of large freight vehicles is expensive and there is a limited availability of alternative fuel vehicles on the market. Many greener fuels require dedicated infrastructure such as biofuel filling stations, hydrogen stations or electric vehicle charging making it hard for local authorities to mandate maximum vehicle emission levels without first co-investing in enabling infrastructures.

3. Reliance on diesel vans to fulfil low density last mile deliveries

Consolidating last mile journeys is a balance between maximising payload and minimising distance/time taken to deliver each package. In low-density drop-off routes where stops may be some distance apart, **diesel vans are currently deemed to be the cheapest and fastest solution.** Diesel vans contribute to noise and air pollution and congestion and are the fastest growing vehicle type in the UK. It is therefore in a local authority's best interest to diversify last mile deliveries and reduce reliance on diesel vans.

The root causes of this problem statement include:

- **Increase in e-commerce deliveries** - the increased demand for goods delivered directly to the home rather than to shops or businesses has changed the nature of last mile destinations. There is a balance to be struck between allowing residents the benefits of online retail, fast and low-cost delivery and returns and yet also managing the detrimental effects of their delivery methods.
- **Payload** - there are limited alternative solutions to vans to fulfil current payload delivery demand given the existing set up of logistic systems and infrastructure.
- **Consumer behaviour** - consumers expect fast and often free delivery even when items are not required urgently. Encouraging consumers to act responsibly and value the sustainably impacts of delivery methods is key to enabling change.
- **Limited consolidation opportunities** - obtaining a high enough throughput in any one direction to justify consolidation is a challenge in low density areas. Inefficiencies in company logistics and the expectation of faster delivery has resulted in multiple vans from the same company travelling to the same neighbourhood at different times of the day to fulfil orders. The inefficient coordination of LGV deliveries causes unnecessary duplication of journeys and vehicles travelling at less than full capacity reduce efficiency further.
- **Parking obstructions** - vans can be the cause of increased congestion when illegally parked to be closer to the pick-up/drop-off point which causes obstruction to the road.
- **Cost of electrification** - while the running costs of electric vans are considerably lower than their diesel counterparts, the distance travelled on one charge is lower and the initial investment in both the vehicles and charging infrastructure is a barrier to change, especially for smaller businesses.
- **Regulations** - goods vehicles less than 3.5 tonnes are less regulated than heavier vehicles and hence more popular, this has resulted in many small logistics firms which don't have depots using light goods vehicles to fulfil last mile journeys.
- **Limited last mile freight strategy** - it is difficult to influence and control private logistics companies and especially to encourage any collaborations to improve efficiency. As such many authorities do not have a specific last mile freight strategy, making it difficult to measure or actuate change.

4. On-demand delivery vehicles cause traffic disruption

A rise in on-demand delivery services from providers such as Deliveroo and Just Eat has caused an increase in single-occupant vehicles such a mopeds and motorbikes to facilitate food deliveries. In addition, Amazon and logistics companies such as Hermes now operate a model where drivers can sign up to deliver parcels on an ad-hoc basis using their private vehicle. In both cases, this results in more deliveries being conducted by non-professional drivers who do not always fully adhere to parking or driving regulations. These breaches in regulations can pose a safety threat to other road users and contribute to congestion by disrupting traffic flow. Allowing drivers to use their own vehicles also makes the delivery fleet more likely to be made up of older, and more polluting vehicles,

The root causes of this problem statement include:

- **Pay per drop** - the fee structure of associated delivery systems encourages the driver to deliver as many orders as possible in the shortest time which leads to a disregard for parking regulations and can lead to unsafe driving decisions for themselves and other road users.
- **Gig economy** - the business models of the gig economy mean that drivers use their own vehicles and do not require any formal training in addition to basic legal requirements. The personal vehicles are likely to be older models than those which are fleet operated which are more damaging to the environment.
- **Parking obstructions** - on-demand delivery vehicles are often found parking illegally so that they can be closer to pick-up/drop-off points and this causes obstruction on the road.

5. Powerful lobbying from car users perpetuates driving dominance

Powerful lobbying from car drivers ensures that private cars are the prime focus of road infrastructure, which takes away from public and active transport requirements and prevents trials of more innovative solutions. Given the political sensitivity of the issue, politicians are reluctant to introduce any measures which appear to restrict or punish private car usage. Cars contribute to noise and air pollution in addition to congestion levels and demand significant land use for parking. While a transition to electric powertrains will address air quality and global warming effects, congestion and land use demand will remain significant issues if car usage and ownership does not reduce.

The root causes of this problem statement include:

- **Strength in numbers** - residents have a sense of entitlement for car ownership and are highly dependent on car usage as a mode of transport. There is little accountability by individuals in the role they play in contributing to congestion by using their cars for short journeys. A sense of entitlement or feeling of insignificance as an individual to make a difference is stopping people making more sustainable transport decisions. As the majority, car owners have a powerful case for maintaining the status quo.
- **Car culture** - residents view cars as a hobby in addition to a mode of transport and take pride in their vehicles. Suggestions to change powertrain or deter usage will garner resistance.
- **Reluctance to transition to EVs** - ICE powertrains dominate the car market and emit greenhouse gas emissions and air pollutants with every mile travelled. The reluctance or inability to transition to electric vehicles due to high cost and lack of charging infrastructure means there is slow progress to reduce tailpipe emissions. Electric vehicles are not accessible to everyone and commuting by EV is not supported by current charging infrastructure.
- **Political sensitivities** - deterring car usage is politically sensitive and as such is not a viable option especially around local elections. The 'carrot' approach of encouraging transitions to electric powertrains is seen as a less controversial route to reduced emissions but does nothing to relieve congestion.
- **Parking** - there needs to be a balance between the conflicting needs of stimulating the local economy by encouraging visitors to the Highstreet and reducing traffic in urban centres. Businesses often encourage on street parking close to shops to increase footfall but channelling drivers into carparks further out can reduce congestion in the very centre of towns making them more pedestrian friendly.
- **Rural setting** - for many residents in villages there are no other viable modal options available which can offer the same flexible on-demand, door-to-door service at the perceived affordability of a private car.

6. New housing developments are not setting best practice

Retrofitting existing infrastructure is notoriously difficult and expensive, yet the opportunity to set examples of best practice in new developments is often left unrealised. New housing developments are continuing to be built without strong public transport networks, active travel, car clubs or electric vehicle charging infrastructure. These developments risk repeating the mistakes which have led to a car dependent society, exacerbating the problem rather than addressing it.

The root causes of this problem statement include:

- **Lack of freight consideration** - housing developments are more focussed on residential needs and the movement of people and are less focussed on the movement of goods into and out of the development. This leads to missed opportunities in the planning stages for consolidation and sustainable last mile solutions and can lead to high volumes of motorised freight traffic travelling through new developments.
- **Conflicts within urban planning** - local authorities often have to play catch up with housing developers when it comes to urban planning. LAs generally lack the resources and urban design skills which are required to create a sense of place to help influence specific desired behaviours and are limited in their power against developers who are funding the projects. First/last mile considerations need to be incorporated earlier into development planning stages to encourage sustainable travel choices.
- **Resistance from developers** - infrastructure which incurs high costs for developers such as mandatory electric vehicle charging with every new property is highly contested by contractors which can delay projects and increase project costs and house prices. Developers are also primarily interested in initiatives which will sell houses quickly and an abundance of off-street parking facilitating multi-car households is one of them.
- **Reliance on existing services** - new developments expect residents to use existing services and facilities which may be located miles from their homes rather than building new facilities alongside the new housing. This leads to longer journey lengths to access amenities and does not facilitate local initiatives.

7. Public transport is inefficient over the last mile

The public transport network is limited in the geographies it covers and therefore the communities it serves effectively. For those who cannot drive and rely on public transport services this can be a problem of accessibility and convenience, deterring residents from making trips at all leading to unproductivity and disconnection from wider society. For car owners who do not rely on public transport, there is little advantage or incentive to taking it as parking is provided in town centres and buses get stuck in the same congestion. Given the sunk costs of car ownership, residents are likely to perceive that public transport incurs an additional cost to car usage.

The root causes of this problem statement include:

- **Limited bus services** - there is a good level of service for those living in the right areas, but buses are not a feasible option for those who don't live near the main bus routes (which are often along A roads), cutting off more rural communities.
- **Road public transport is affected by congestion** - roads have a limited carriageway width and the road space must be shared between buses, HGVs, LGVs, cars, taxis, motorbikes, bikes and pedestrians. At peak times, heavy congestion builds at key junctions and along major roads and a lack of dedicated infrastructure for more sustainable modes (bus lanes, bus priority junctions etc.) results in all modes getting stuck in the same traffic. This means there is little incentive to use a bus over a private vehicle as total journey times are likely to be longer.
- **Inefficient modal connections** - the current public transport system does not accommodate easy or convenient modal connections, making it difficult to use public transport as a last mile solution to another transport hub.
- **Lack of funding** - the required investment to make services viable is considerable and since small towns do not qualify for significant DfT funding it is unclear where money should come from to improve or extend services. As patronage levels have been on the decline for many years there is a conflict as to whether bus services should continue to be subsidised.
- **Lack of data** - the use of buses for last mile journeys and patronage levels are unknown due to lack of data. This makes it difficult to create a service which meets the needs of the user or to measure the success of any new initiatives.
- **Strict procurement rules** - bus procurement rules make it difficult to actuate changes such as frequency, operating times and routes to meet the evolving needs of residents.
- **Public resistance to new infrastructure** - while commuting long distances by train is popular, especially into London, proposing new railways through countryside which could accommodate more local and regional movements is very controversial and unpopular.

8. Long-term change is difficult to plan and implement

Political alliances change relatively frequently, and funding pots are drip fed and highly contested between authorities. Most funding requires shovel ready proposals for successful bid attempts, yet this is costly, and objectives can be overhauled with a change in leadership causing inefficiencies and frustration. Without a strategic view of intended social, environmental and economic impacts and a clear roadmap and business case to achieve that, getting the relevant stakeholders onboard is a challenge and can hamper innovation.

The root causes of this problem statement include:

- **Resistance to change** - many processes have been operating in the same way for years. Initiating change to the way money is spent, or how systems operate attracts resistance from both residents and council members. Testing new technologies without concrete data is difficult and tight regulations make trials of new modes and technologies challenging to put into effect. On limited budgets there is little margin for error if new technologies do not have favourable outcomes which leads to a conservative approach from LAs with many wanting to follow the trends rather than set them.
- **Lack of preventative measures** - most highway spending is exhausted by reactive measures to reported problems (e.g. pothole), with only approximately a quarter spent on prevention measures. The limited resources to introduce preventative measures can lead to higher expenditure and more intrusive roadworks in the long run.
- **Lack of data** - gaps in qualitative and quantitative data gathering means that the need or desire for new solutions cannot be captured effectively to build up a convincing business case for change. It also makes it difficult to assess the success of a new scheme. Local transport plans are supported by census data which is updated too infrequently to remain relevant and many assumptions must be drawn which impedes the authority's ability to react promptly to shifts in public acceptance, wants and needs.
- **Limited revenue funding** - funding for highways is mainly used up on maintaining current infrastructure, making it difficult to implement new projects and try innovative solutions. The government focuses on capital funding but does not increase revenue funding to allow for maintenance or operation of new initiatives making them very difficult to sustain.
- **Policy and legislation** - there is a lack of policy to enable and encourage a long term approach which means the longevity of schemes is not always captured in the success criteria of a new project.

Addressing the Problems

Existing Initiatives

Buckinghamshire Council has many active initiatives designed to tackle the problem statements discussed within this document and to create a more sustainable last mile system. These include **parking sensor trials** to increase data collection of parking behaviour and enable real time monitoring of parking regulation conformance. The **Aylesbury Garden Town** project is using urban planning to create a sense of place and increase the green credentials of the town. **Charging infrastructure** networks are being developed across the county to aid and encourage the transition to electric vehicles. The construction of **new link roads** has been planned to connect new housing developments to longstanding urban centres which will act as alternative access routes for HGVs passing through the county. **Demand Responsive Transport** funding proposals have been submitted to the DfT to trial more effective public transport offerings to those not currently served well by bus networks.

Developing New Initiatives

The Connected Places Catapult will build on the existing initiatives and consider new solutions which complement them. Following the distribution of the draft Problem Definition document, a workshop attended by the interviews plus other key members of Buckinghamshire council was conducted. The purpose of the workshop was to test the robustness of the problem statements and to allow contributions to the weighting of the multi-criteria decision analysis. This document has since been revised to include additional thoughts from workshop attendees.

A multi-criteria decision analysis (MCDA) framework will be developed to evaluate how effectively the last mile solutions in the Literature Review address the challenges laid out in the Problem Definition. The analysis framework will be used to generate a short list of solutions for further consideration with the intention of trialling some of these solutions in Aylesbury.

May 2021

Appendix D3

Multi-criteria Decision Analysis

ADEPT LIVELABS Transforming Local Places

Buckinghamshire Council

CATAPULT Connected Places

Executive Summary

We conducted multi-criteria decision analysis on the state-of-the-art last mile mobility solutions. Our top five results for the movement of goods and people make up the short-lists which will be considered for a pilot in Aylesbury.

We evaluated the state-of-the art last mile mobility solutions through a multi-criteria decision analysis (MCDA) framework to determine the most suitable solutions for local authorities such as Buckinghamshire Council based on a bespoke set of criteria. The criteria were derived from stakeholder consultations with Buckinghamshire Council and while applicable to similar authorities, the framework should be reviewed to address local priorities. The framework analysis was performed against the solution's characteristics, potential benefits, and associated deployment and operational challenges.

MCDA results can be interpreted in many ways since the numerical outcomes have many underlying assumptions which have to be carefully considered. The two main ways to use these results are to firstly consider the deployment of the top scoring solutions and/or enabling technology interventions of such solutions. The second is to use the results table to identify better equivalent options to existing poorly scoring solutions. For example, the van and the car are both low scoring yet highly utilised existing modes so it can be worth considering a middle-ranked solution that can directly replace such lowest scoring solutions.

For the movement of people, the top five solutions are:

1. Walking
2. Bicycle
3. e-scooter
4. e-bicycle
5. Dockless share scheme (bicycle)

Category	Mode	Solution (5 to 18)	Benefit (0 to 60)	Challenges (-39 to 0)	Total (-34 to 78)	Rank (Total)
User-operated	Walking	18	58	-12	64	1
User-operated	e-bicycle	13	53	-18	48	2
User-operated	Bicycle	13	51	-18	46	3
User-operated	e-scooter	12	49	-17	44	4
User-operated	Docked shared bike scheme	12	52	-21	43	5
User-operated	Dockless shared bike scheme	13	50	-21	42	6
Service-based	Segregated CAV	9	46	-18	37	7
Service-based	Taxi	12	24	0	36	8
Service-based	Cable car	10	48	-25	33	9
Service-based	Green bus	10	38	-15	33	9
Service-based	Bus	10	31	-9	32	11
User-operated	Electric car club	10	32	-11	31	12
Service-based	On-demand ride hailing	11	25	-7	29	13
User-operated	Electric car	10	27	-8	29	13
Service-based	Connected Autonomous Vehicle	10	40	-23	27	15
User-operated	Car club	10	22	-5	27	15
Service-based	Water bus	9	31	-14	26	17
Service-based	Demand Responsive Transport	11	24	-9	26	17
Service-based	Flying Taxi	7	45	-29	23	19
User-operated	Motorcycle	12	18	-8	22	20
User-operated	Car	12	10	0	22	fail

It is important to note that all of the top five solutions are active travel or micro mobility modes and while these have huge advantages to the environment, public health and congestion are not accessible to all demographics or suitable for all last mile journey purposes. As such these modes should be enabled and encouraged as much as possible but complemented by more versatile modes which offer accessibility, weather protection, load/passenger capacity when required.

For the movement of goods the top five solutions are:

1. Cargobikes
2. Automated robots
3. Collectplus
4. 3D Printing
5. Drones

Category	Mode	Solution (7 to 14)	Benefit (0 to 39)	Challenges (-33 to 0)	Total (-26 to 63)	Rank (Total)
Direct	Cargobike	17	33	-12	38	1
Direct	Automated robots	20	36	-20	36	2
Indirect	Collectplus	23	13	-3	33	3
Indirect	3D printing	18	27	-15	30	4
Direct	Drones	16	35	-22	29	5
Direct	Electric moped	14	21	-9	26	6
Indirect	Freight consolidation centre	13	22	-10	25	7
Indirect	Magway	14	30	-21	23	8
Direct	Electric van	13	17	-9	21	9
Indirect	Amazon lockers	20	13	-12	21	9
Indirect	Delivery to car	18	13	-10	21	9
Direct	Motorcycle	14	12	-7	19	12
Direct	Connected Autonomous Vehicle	8	23	-14	17	13
Direct	Van	16	0	-2	14	fail
Direct	Private car	16	0	-4	12	fail

Unlike the top results for the movement of people, the top five solutions here are more diverse. There are a mix of direct and indirect solutions as well as a range of technology maturity levels.

The sensitivity analysis showed that both MCDA frameworks are biased towards options which are high scoring in the Benefits and Solution categories. Therefore, the framework could be adapted by scaling the Challenges category to increase its relative impact on the overall score if the interest of the council is to implement fast change rather than focus on long-term benefits. If the focus was on limiting the challenges, then the results would suggest that vans could be replaced with electric vans for quick wins on reducing tailpipe emissions with much fewer challenges than introducing Cargobikes but this would continue to have negative effects on congestion and safety of other road users.

The top five results from each table will be considered for a pilot demonstration in Aylesbury. More information will be gathered regarding infrastructure requirements and a mapping exercise will be conducted to look for suitable locations within Aylesbury to host the pilot. We will also consult members of Buckinghamshire Council for contextual insights onto their suitability in Aylesbury. A high-level pilot specification and business case will be delivered for the chosen solution(s) making best use of shared infrastructure where possible.

Contents

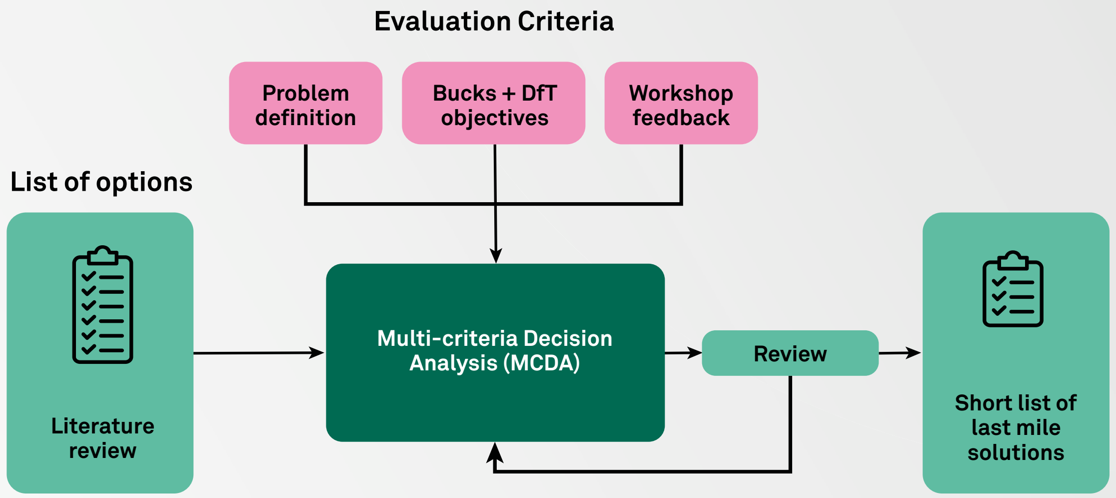
1 Overview

Multi-criteria decision analysis was used to evaluate each last mile solution in CPC's Literature Review for their potential deployment. A short-list of options has been generated for more detailed research on infrastructure requirements.

1.1 Introduction

This report is the third output in a series of deliverables by the Connected Places Catapult (CPC) for the last mile mobility in-depth feasibility study as part of Buckinghamshire's ADEPT Live Lab programme. The first two deliverables; the Literature Review and Problem Definition form the foundations of this report and have informed the list of potential last mile mobility options and their evaluation criteria respectively; these are required inputs to the multi-criteria decision analysis (MCDA) framework. The inputs and outputs of the MCDA framework are shown in ***Figure 1.***

Figure 1: Inputs and outputs of multi-criteria decision analysis



The long-list of last mile solutions needed to be evaluated for their suitability of deployment in local authorities with a mix of urban, semi-rural and rural communities and as such do not have the same characteristics of large cities where many solutions are currently established or emerging. We found from the developing the Problem Definition that there are challenges which must be overcome to deliver a successful last mile system for the movement of goods and people. While decarbonisation of the transport system is an imperative for local authorities and the UK to achieve Net Zero targets, there are also other important criteria which modal solutions must fulfil, in order for the movement of people and goods over the last mile to be efficient, affordable and have capacity to meet growing demands. The criteria are broad and the challenges complex and are therefore unlikely to be fully met or solved respectively by a single solution. As such, we required a way of ranking the options and we chose multi-criteria decision analysis.

1.2 Methodology

MCDA is an approach to ordering a large selection of options from the most preferred to least preferred based on how well they meet the contextual objectives[1]. The process enables decisions to be made on the best way to proceed when approaching a multifaceted problem. For complex problems, whereby one solution is unlikely to meet all the objectives, the approach allows for the relative impacts of meeting one objective in full to be compared with meeting many objectives to a lesser extent. This is achieved by applying a weighting to each criterion so that the importance of meeting some objectives over others can be compared. The MCDA framework is the table in which; the scoring and weightings are assigned, the scoring system is applied to each option being considered and where the numerical outputs can be compared.

Figure 2 describes the steps taken to deliver multi-criteria decision analysis on a list of potential last mile solutions.

Figure 2: Conducting multi-criteria decision analysis

Conducting multi-criteria decision analysis

1. Establish the decision context
2. Identify the long list of options
3. Identify the evaluation criteria and a scoring range that reflect the value associated with the consequences of each option
4. Scoring - apply a score to each, i.e. assess the value associated with the consequences of each option
5. Weighting - assign weights for each of the criteria to reflect their relative importance to the decision
6. Multiply the weights and scores for each of the options to derive an overall score.
7. Examine the results
8. Conduct a sensitivity analysis of the results to changes in scores or weights

1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191506/Mult-crisis_analysis_a_manual.pdf

The **decision context** for evaluating the potential effectiveness of each model decision is the current last mile mobility landscape in Buckinghamshire with the challenge context of reducing detrimental environmental impacts while stimulating the local economy and alleviating congestion.

Connected Places Catapult's **Last Mile Mobility - Literature Review** describes the state-of-the art modal solutions for the movement of people and goods over the last mile categorised by established, emerging and future modes. The solutions explored in the literature review make up the **'longlist' of options** which were inputted into the multi-criteria decision analysis framework. The intended output is a short-list of solutions which best fulfil the transport objectives of Buckinghamshire council and similar authorities.

The evaluation criteria were developed from the problem statements explored in **the Last Mile Feasibility - Problem Definition** document which covers the main challenges and barriers to implementing change in the last mile system from a local authority perspective. Additional evaluation criteria were added to include the perspective of the user or service provider so that likely uptake could be considered. The categories of the evaluation criteria are:

- **Solution**: Basic properties of the solution including maturity, capital and revenue costs
- **Benefits**: Societal, economic or environmental benefits which could be achieved by modal shift to this mode using the car or van as the baseline
- **Challenges:** Cultural, legislative or technology challenges which may act as barriers to implementation.

To reflect the importance that any new mobility solution must contribute to decarbonisation, a pass/fail statement was included in the criteria, whereby instead of a relative scoring systems - solutions which do not lead to a reduction of carbon emissions can be ruled out of further consideration.

The **scoring system** aims to apply a numerical value to often subjective and qualitative characteristics and therefore the overall scores differ based on the perspective of the person completing it. To balance the bias and to reach mutual agreement on the scoring, an iterative approach was taken.

- Firstly, an example mode was chosen and marked by three adjudicators independently. Where the scores differed, changes to the description of the criterion or scoring ranges were made to aid a more aligned approach. Where scores still differed, a discussion led to the ultimate score rating
- Secondly, all modes were marked independently by two adjudicators and a similar evaluation of different scores took place
- Finally, a review of both scores was conducted by two independent reviewers followed by a discussion to finalise the final scorings.

Scoring was applied for each solution (column by column) and then the relative scores between solutions for a criterion were assessed (row by row).

The **weightings** of each criteria were developed by CPC based on Buckinghamshire council's stated objectives and validated during a workshop with members of Buckinghamshire council. We had previously engaged with these members through individual interviews when we were developing the Problem Definition.

An **overall score** was derived by multiplying the reviewed scores by the weightings for each criteria and summing them together.

Examining the results entailed a closer inspection of the top five solutions in addition to identifying key 'quick wins' whereby highly utilised low scoring modes could be replaced with higher scoring modes (even if they are not ranked in the top percentiles) especially where the challenges to overcome are minimal.

Sensitivity analysis was applied by varying the weighting of each category (solution, benefits and challenges) to determine their significance in the overall rankings and reveal any bias in the framework.

2 MCDA Framework

The framework criteria, descriptions and weightings differ slightly between the frameworks for assessing solutions for the movement and people and goods. They are presented separately in the sections below.

2.1 Movement of People

Table 1 lists the categories of criteria, the title of the evaluation criteria and descriptions on how each was scored for the last mile solutions for the movement of people.

Appendix D3 – Multi-criteria decision analysis

Table 1: Evaluation criteria for the movement of people

Category		Evaluation criterion	Criterion description
Solution		Maturity	Maturity level considers whether there is precedent of successful deployment/trials in similar locations. The highest score is awarded to the most established mode in similar LAs.
Solution		Capital Cost	Initial capital cost required from local authority or service provider to enable rollout of the solution compared with an existing private car. The highest score is awarded to the solution with the lowest capital costs.
Solution		Revenue cost	The value of revenue costs including labour, insurance, infrastructure maintenance and modal repairs/ replacement which is incurred by the LA or service provider. Maintenance of private vehicles is not considered here but is covered by accessibility (cost). The highest score is awarded to the cheapest (lowest) revenue cost for the LA/service provider.
Benefits	Societal	Accessibility (physical)	A rating linked to the proportion of local demographics who could be reasonable expected to physically use the mode for last mile journeys. The highest score is awarded to those which are accessible to wheelchair users, elderly populations and young children.
Benefits	Societal	Accessibility (cost)	Considers the relative cost per mile/minute (depending on which is more appropriate) which is incurred by the user including payback time of assets if privately owned. The highest score is awarded to the mode with cheapest (lowest) cost for the user.
Benefits	Societal	User convenience	Considers the reliability, availability, speed and flexibility (of destination) that the mode provides. This includes wait times, distance to access mode and whether it offers a flexible/door to door service and considers parking responsibilities. The highest score is awarded to solutions the perceived most convenient for the user.
Benefits	Societal	Safety of other users	Considers the impact of using this mode on other users of the shared infrastructure (e.g. impact on all other road users in shared use lanes). The modes are scored on best infrastructure scenario such as segregated bike lanes where available. The highest score is awarded to solutions which cause the least risk to other road users.
Benefits	Societal	Active travel health benefits	Considers the health benefits that are achieved through using this mode. This can include mental and physical health benefits. For modes which are not door-to-door services such as a bus it is assumed there are some active travel benefits from the last mile connection. The highest score is awarded to solutions with the greatest active health benefits for the user.
Benefits	Economic	Improvements to road congestion	Considers the potential of the solution to reduce current congestion levels in the local last mile area. The highest score is awarded to solutions with the highest potential for a reduction in congestion.
Benefits	Environmental	Does this solution lead to positive environmental impacts?	**Dealbreaker question to ensure new solutions aid sustainable transport targets.** **(PASS/FAIL)**
Benefits	Environmental	Reduction in CO_2 tailpipe emissions	Considers the potential to reduce environmental impacts on global warming. This includes reducing tailpipe emissions directly through modal choice and reducing the number of km travelled by consolidating journeys. The highest score is awarded to the lowest emitters of carbon emissions or modes which enable the greatest reduction in the km travelled by higher emitters.
Benefits	Environmental	Improvement in air quality (NOx and particulates)	Considers the potential to reduce the negative impacts of travel on air quality. This includes reducing emissions directly through modal choice and reducing the number of km travelled. The highest score is awarded to the solutions which are the lowest emitters of NOx and PM emissions per km travelled or enablers of the greatest reduction in km travelled by higher emitters.
Benefits	Environmental	Reduction in noise pollution	Considers the potential to reduce the negative impacts of travel on noise pollution. Potential for noise reduction in residential areas or during antisocial hours scores most highly. The highest score is awarded to solutions which emit the least noise pollution or reduce the need for noisier modes.
Challenges	Enabling tech and infrastructure	New infrastructure requirements	Considers the cost and scale of any new infrastructure that is required or preferred for a successful deployment. The highest score is awarded to the solutions which require no new infrastructure.
Challenges	Enabling tech and infrastructure	Reliance on enabling technology	Considers whether the solution requires the implementation of enabling technologies for successful deployment. If the enabling technology is required and not yet available this would be included in the maturity score. The highest score is awarded to solutions with no reliance on new enabling technologies.
Challenges	Enabling Interventions	New legislative requirements	Considers the challenge of introducing new legislation to accompany the deployment or growth of the solution. The highest score is awarded solutions with precedence legislation in similar LAs or where there are insignificant infrastructure requirements to sign off.
Challenges	Culture	Use case versatility	Considers the limitations regarding reasonable length of journeys and whether baggage/passengers can be taken via this mode. The highest score is awarded to the mode which offers greatest use case versatility including longer journeys.
Challenges	Culture	Perceived user safety	Considers any challenges to the level of protection given to the user when used as intended (e.g. bikes on cycle lanes). The highest score is awarded to the greatest perceived protection for the user.
Challenges	Culture	Political perception/ public acceptance	Considers whether the implementation (or growth) of this solution is likely to gain resistance from the public. The highest score is given to solutions which will be supported/obtain no political resistance.

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Table 2 lists the scoring options and weightings assigned to each evaluation criterion based on their relative importance.

Table 2: Criteria weightings for the movement of people

Category	Evaluation criterion	Sporting options	Weighting
Solution	Maturity	0 to 3	1
Solution	Capital Cost	0 to 3	2
Solution	Revenue cost	0 to 3	3
Solution	Weighted scoring range		5 to 18
Benefits	Accessibility (physical)	0 to 3	2
Benefits	Accessibility (cost)	0 to 3	1
Benefits	User convenience	0 to 3	2
Benefits	Safety of other users	0 to 3	3
Benefits	Active travel health benefits	0 to 3	2
Benefits	Improvements to road congestion	0 to 3	3
Benefits	Does this solution lead to positive environmental impacts?	**PASS / FAIL**	
Benefits	Reduction in CO_2 tailpipe emissions	0 to 3	3
Benefits	Improvement in air quality (NOx and particulates)	0 to 3	3
Benefits	Reduction in noise pollution	0 to 3	1
Benefits	Weighted scoring range		0 to 60
Challenges	New infrastructure requirements	-3 to 0	2
Challenges	Reliance on enabling technology	-3 to 0	2
Challenges	New legislative requirements	-3 to 0	3
Challenges	Use case versatility	-3 to 0	2
Challenges	Perceived user safety	-3 to 0	2
Challenges	Political challenges	-3 to 0	2
Challenges	Weighted scoring range		-39 to 0
Total weighted range			-34 to 78

2.2 Movement of Goods

Table 3 lists the categories of criteria, the title of the evaluation criteria and descriptions on how each was score for the last mile solutions for the movement of goods. It is largely the same as the movement of people with the changes from user safety to driver safety, and unit cost implications and user acceptance to public acceptance.

Table 3: Evaluation criteria for the movement of goods

Category		Evaluation criterion	Criterion description
Solution		Maturity	Maturity level considers technical maturity (TRL) in addition to whether there is precedent of successful deployment/trials in similar locations. The highest score is awarded to the most established mode.
Solution		Capital Cost	Initial capital cost required from local authority or service provider to enable rollout of the solution compared with an existing van. The highest score is awarded to the solution with the lowest capital costs.
Solution		Revenue cost	Level of continued revenue cost including labour, insurance, infrastructure maintenance and modal repairs/ replacement which is incurred by the LA or logistics company. The highest score is awarded to the lowest revenue cost.
Solution		Operational cost	Considers the impact on the revenue cost of delivery for logistics companies including labour/fuel costs. The highest score is given to solutions which offer the lowest operational costs once the mode is established.
	Societal	Safety of other users	Considers the impact of using this mode on other users of the shared infrastructure (e.g. impact on all other road users in shared use lanes). The modes are scored on best infrastructure scenario such as segregated bike lanes where available. The highest score is awarded to solutions which cause the least risk to other road users.
	Economic	Improvements to road congestion	Considers the potential of the solution to reduce current congestion levels in the local last mile area. The highest score is awarded to solutions with the highest potential for a reduction in congestion.
	Environmental	Does this solution lead to positive environmental impacts?	**Dealbreaker question to ensure new solutions aid sustainable transport targets. (PASS/FAIL)**
	Environmental	Reduction in CO_2 tailpipe emissions	Considers the potential to reduce environmental impacts on global warming. This includes reducing tailpipe emissions directly through modal choice and reducing the number of km travelled by consolidating journeys. The highest score is awarded to the lowest emitters of carbon emissions or modes which enable the greatest reduction in the km travelled by higher emitters.

Challenges (continued from Environmental)	Environmental	Improvement in air quality (NOx and particulates)	Considers the potential to reduce the negative impacts of travel on air quality. This includes reducing emissions directly through modal choice and reducing the number of km travelled. The highest score is awarded to the solutions which are the lowest emitters of NOx and PM emissions per km travelled or enablers of the greatest reduction in km travelled by higher emitters.
	Environmental	Reduction in noise pollution	Considers the potential to reduce the negative impacts of travel on noise pollution. Potential for noise reduction in residential areas or during antisocial hours scores most highly. The highest score is awarded to solutions which emit the least noise pollution or reduce the need for noisier modes.
Challenges	Enabling tech and infrastructure	New infrastructure requirements	Considers the cost and scale of any new infrastructure that is required or preferred for a successful deployment. The highest score is awarded to the solutions which require no new infrastructure.
Challenges	Enabling tech and infrastructure	Reliance on enabling technology	Considers whether the solution requires the implementation of enabling technologies for successful deployment. If the enabling technology is required and not yet available this would be included in the maturity score. The highest score is awarded to solutions with no reliance on new enabling technologies.
Challenges	Enabling Interventions	New legislative requirements	Considers the challenge of introducing new legislation to accompany the deployment or growth of the solution. The highest score is awarded solutions with precedence legislation in similar LAs or where there are insignificant infrastructure requirements to sign off.
Challenges	Culture	Use case versatility	Considers the limitations regarding reasonable length of journeys and whether baggage/passengers can be taken via this mode. The highest score is awarded to the mode which offers greatest use case versatility including longer journeys.
Challenges	Culture	Public acceptance	Considers whether the solution is likely to be supported politically and by members. The highest score is given to solutions which will be supported/obtain no political resistance.

Table 4 lists the scoring options and weightings assigned to each evaluation criterion based on their relative importance.

Table 4: Criteria weightings for the movement of goods

Category	Evaluation criterion	Sporting options	Weighting
Solution	Maturity	0 to 3	1
Solution	Capital Cost	1 to 3	3
Solution	Revenue Cost	1 to 3	3
Solution	Operational cost	1 to 3	1
Solution	Weighted scoring range		7 to 24
Benefits	Safety for other users	0 to 3	3
Benefits	Improvements to road congestion	0 to 3	3
Benefits	Does this solution lead to positive environmental impacts?	**PASS / FAIL**	
Benefits	Reduction in CO_2 tailpipe emissions	0 to 3	3
Benefits	Improvement in air quality (NOx and particulates)	0 to 3	3
Benefits	Reduction in noise pollution	0 to 3	1
Benefits	Weighted scoring range		0 to 39
Challenges	New infrastructure requirements	-3 to 0	3
Challenges	Reliance on enabling technology	-3 to 0	2
Challenges	New legislative requirements	-3 to 0	1
Challenges	Use case versatility	-3 to 0	3
Challenges	Public acceptance	-3 to 0	2
Challenges	Weighted scoring range		-33 to 0
Total weighted range			-26 to 63

2.3 Long List of Options

The long list of solutions taken from CPC's Live Lab: Last Mile Mobility Literature Review. A brief modal/solution description is provided along with the key assumptions for the movement of goods and people in ***Table 5*** and ***Table 6*** respectively with the key for the categorisation of solutions shown below:

Movement of people	User-operated
	Service-based
Movement of goods	Direct
	Indirect

Table 5: Modal description and key assumptions for the movement of people

Modal description	Key assumptions
Private ICE cars are four-wheeled motor vehicles which are owned or leased by an individual or household and operate on the road network.	• Powered by internal combustion engines (ICE) • Privately owned • Operate on existing road network which is maintained by LA
Electric cars are a subset of cars which are powered by batteries and emit no tailpipe emissions.	• Zero tailpipe emissions • Privately owned • Require some public charging infrastructure for widescale adoption but can currently be used by residents with private charging facilities • Operate on existing road network which is maintained by LA • More expensive purchase price than ICE • Lower running costs than ICE equivalent
Walking/wheelchair usage is the most basic form of active travel and involves self-propulsion usually for short journeys.	• Can operate on existing pavements but better walking infrastructure required for widespread adoption for last mile journeys • Viable for shorter journeys only
Bicycle (bike) usage is a form of active travel, where the user propels a two-wheeled vehicle through the pedals.	• Privately owned • Can operate on existing road network but require dedicated segregated lanes for safe widespread adoption which can be shared with e-bikes and e-scooters • Limited demographic reach due to limited use cases, perceived safety challenges and physical limitations
e-bicycles (e-bikes) are two-wheeled vehicles which can be powered by electricity in addition to being propelled by pedals.	• More physically accessible than mechanical bicycles • Privately owned • Can operate on existing road network but require segregated lanes for safe widespread adoption which can be shared with bikes and e-scooters
e-scooters are motorised stand up scooters classified as a form of micro-mobility.	• Privately owned (with legislation in place to allow this) • Powered by electric motors and zero tailpipe emissions • Must operate in segregated lanes which can be shared with bikes and e-bikes
Docked share schemes consist of shared micro-mobility modes such as bikes, e-bikes or e-scooters which can be rented from fixed docking stations.	• Scored with assumption of mechanical bicycles for demonstration purposes • Can operate on existing road network but require dedicated segregated lanes for safe widespread adoption which can be shared with e-bikes and e-scooters • Require motorised vehicles to redistribute bikes
Dockless share schemes were developed to overcome user challenges in accessing docking stations. They do not require the user to end their journeys at specific locations, instead the bike or e-scooter can be 'parked' anywhere within a geofenced operational area.	• Scored with assumption of mechanical bicycles for demonstration purposes • Can operate on existing road network but require dedicated segregated lanes for safe widespread adoption which can be shared with e-bikes and e-scooters • Require motorised vehicles to redistribute bikes
Car clubs offer a fleet of vehicles which can be rented for short periods of time, typically by the hour.	• ICE vehicles which are newer and more energy efficient than average private ICE vehicle • Sufficient coverage in area to allow for good convenience to users
e-car clubs offer the same service as car clubs but with solely battery electric vehicles.	• Battery electric powertrains across the fleet • Sufficient coverage in area to allow for good convenience to users • Some capital investment from LA or carclub provider for dedicated car club EV charger installations
Motorcycles are two-wheeled vehicles powered solely by a motor and operate on the road network to conduct last mile journeys	• ICE vehicles • Very limited demographics due to perceived safety
Buses are a traditional mode of transport which have a high capacity for passengers and travel along a fixed route for a fare.	• Facilitate consolidation of journeys • Require some prioritisation mechanisms such as bus lanes for effective deployment • Some walking required to get to and from bus stops
Green buses are a subset of buses which emit zero tailpipe emissions and are propelled through battery or hydrogen power.	• Same baseline assumptions as buses • Powered solely by hydrogen or electric powertrains (no hybrid models) • Assumed limited market availability of vehicles compared with ICE buses • Assume new dedicated charging/fuelling infrastructure required
Water buses are waterborne vessels which transport people over bodies of water with fixed routes, timetables and stops.	• Suitable body of water available

Cable cars are a transport system in which cabins are suspended on a continuous moving cable driven by a motor at one end of the route.	• Zero emissions
Taxis are motorised vehicles where a dedicated driver takes passengers from origin to destination for a fare. Depending on the license taxis can be hailed or pre-booked.	• ICE vehicles
On demand ride-hailing are similar to taxi services but instead of being hailed must be booked via a smartphone application at the time in which the journey is required. The service is enabled through fleet management which helps to provide minimal wait times.	• ICE vehicles • Cheaper than taxis
Flying Taxis or air taxis are aircraft which are designed to carry a small number of passengers over short distances by occupying low air space.	• Accessible to wheelchairs • Not deployed until a high safety clearance is achieved • High cost of use
Connected Autonomous Vehicles (CAVs) are motorised vehicles which fulfil last mile journeys without the need for a driver onboard.	• Not deployed until a high safety clearance is achieved • Battery electric vehicles • Requires a management system and manned cleaning regime
Segregated CAVs are low speed autonomous pods which do not interact with other road traffic and instead follow a designated route segregated from other traffic.	• Not deployed until a high safety clearance is achieved • Travel at low speed and no mixing with other road traffic • Battery electric vehicles
Demand Responsive Transport (DRT) facilitate shared minibus travel for multiple passengers heading in the same direction. The services operate from 'corner to corner', so there are no fixed routes or bus stops and are booked via an app.	• Facilitate consolidation of journeys • ICE vehicles • Assume can use bus lanes where available but no new dedicated infrastructure required

Table 6: Solution description and key assumptions for the movement of goods

Solution description	Key assumptions
Vans are an extremely common mode of last mile delivery due to their relatively high payload yet compact size (compared with an HGV) which allow them to deliver a high quantity of parcels in urban and rural areas.	• Operate on existing road network which is maintained by LA
Electric vans are a subset of vans which are powered by a battery and motor and emit zero tailpipe emissions.	• Operate on existing road network which is maintained by LA • Similar payload to diesel vans • Limited market availability of vehicles
Private cars are four-wheeled motor vehicles which are owned by an individual rather than a company or service provider and can be used to deliver items on an ad-hoc basis.	• Older vehicles which are more polluting • Operate on existing road network which is maintained by LA
Motorcycles are two-wheeled vehicles powered solely by a motor and operate on the road network to conduct last mile journeys with a cargobox attached to carry goods.	• Low payload • Operate on existing road network which is maintained by LA
Cargobikes are bicycles specially designed for carrying large or heavy loads predominantly pedal powered and can be assisted by an electric motor.	• New dedicated infrastructure required for safe and effective deployment
Drones are also known as unmanned aerial vehicles (UAVS) which are aircraft piloted by remote control or onboard computers.	• Requires a manned fleet management system
Automated robots are small, battery powered robots which deliver last mile items without the need for a driver and travel at low speeds along pavements.	• Pavements will need to be adapted for safe and effective deployment • Requires a manned fleet management system
Connected Automated Vehicles (CAVs) are motorised vehicles which fulfil last mile journeys without the need for a driver onboard.	• Battery electric vehicle fleets • Standard car size • Require a manned fleet management system and human interaction for loading and unloading • Operate on existing road network which is maintained by LA

Amazon lockers are self-serviced kiosks where amazon customers can access their purchases instead of ordering the parcels directly to their home or workplace and can be used as a drop-off location for returned packages too.	• Diesel vans deliver to amazon locker locations • Consolidation of last mile journeys and reduced stopping leads to safer travel, reduced congestion and reduced tailpipe emissions
CollectPlus allows customers to send and collect parcels via a network made up of thousands of newsagents, convenience stores, supermarkets and petrol stations rather than relying on dedicated post offices.	• Diesel vans deliver to CollectPlus locations • Assume consolidation of last mile journeys and reduced stopping leads to safer travel, reduced congestion and reduced tailpipe emissions
Delivery to car is a service which allows customers to add their vehicle as a delivery destination if they are fitted with a 'smartbox'.	• Diesel vans deliver to car locations • Consolidation of last mile journeys and reduced stopping l eads to safer travel, reduced congestion and reduced tailpipe emissions
Freight consolidation centres allow for deliveries in HGVs to be sorted at a centre outside of urban centres and for goods to be split into smaller, less emitting vehicles for last mile delivery.	• Enable less polluting and smaller vehicles are used for last mile delivery
Magway is a concept which uses linear motors to propel parcels in sealed pipes along underground or over ground tracks thus reducing the need for heavy delivery vehicles on the road.	• Assume not a last mile solution but allows for more sustainable modes to fulfil last mile
3D printing is a technology which has the potential to provide an alternative last mile delivery.	• Assume very limited use cases • Assume privately owned 3D printers • Assume some delivery of raw materials still required

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3 Results

The results, score breakdown by category and final rank for each solution are shown in ***Table 7*** and ***Table 8*** for the movement of people and the movement of goods respectively. The fully populated MCDA framework can be found in ***Appendix A.***

3.1 Movement of People

Walking achieves the highest score of 64 (out of a possible 78) and is a standout winner overall with the next highest scoring solution being e-bicycle at 48. The high score of walking reflects the benefits of zero cost to the user, high levels of physical accessibility over short distances, active travel benefits for the user and convenience of having no responsibility for parking or maintaining an asset.

There is only a 6-point difference between the next five solutions scoring between 48 and 42 and therefore local context including road gradients and cultural preferences should be considered when deciding if and when to pilot the solutions. The docked and dockless share schemes have been evaluated as bicycle rentals but since e-bicycles score higher than mechanical bicycles as a private mode it is worth considering these instead for a share scheme.

The top five solutions for the movement of people are all classed as active travel solutions and while these have huge advantages to the environment, public health and congestion they are not accessible to all demographics or suitable for all last mile journey purposes. As such these solutions should be enabled and encouraged as much as possible but must be complemented by access to more versatile solutions which offer accessibility, weather protection, load/passenger capacity when required.

When considering direct replacements for car trips, it can be seen that car clubs offer some advantage (+4 point uplift), better still would be transition to electric cars (+7) and higher ranking is electric car clubs (+9 points) therefore considering the implementation of an electric car club in addition to supporting new active travel modes could be highly beneficial.

As discussed in the Last Mile Mobility: Literature Review document there are certain advantages that service-based passenger transport has over user-operated solutions, mainly that that the user can engage in other activities during the former making travel time more productive. The highest scoring service-based solution is the segregated CAV which are low speed autonomous pods that do not interact with other road traffic and instead follow a designated route segregated from other traffic. Given that active travel modes cannot be expected to replace all car journeys, introducing a service-based solution alongside the facilitation of more active travel would allow for a more versatile passenger transport network while still discouraging private car usage.

Table 7: MCDA results overview for the movement of people

Category	Mode	PASS/ FAIL	Solution (5 to 18)	Benefit (0 to 60)	Challenges (-39 to 0)	Total (-34 to 78)	Rank (Total)
User-operated	Walking	pass	18	58	-12	64	1
User-operated	e-bicycle	pass	13	53	-18	48	2
User-operated	Bicycle	pass	13	51	-18	46	3
User-operated	e-scooter	pass	12	49	-17	44	4
User-operated	Docked shared bike scheme	pass	12	52	-21	43	5
User-operated	Dockless shared bike scheme	pass	13	50	-21	42	6
Service-based	Segregated CAV	pass	9	46	-18	37	7
Service-based	Taxi	pass	12	24	0	36	8
Service-based	Cable car	pass	10	48	-25	33	9
Service-based	Green bus	pass	10	38	-15	33	9
Service-based	Bus	pass	10	31	-9	32	11
User-operated	Electric car club	pass	10	32	-11	31	12
Service-based	On-demand ride hailing	pass	11	25	-7	29	13
User-operated	Electric car	pass	10	27	-8	29	13
Service-based	Connected Autonomous Vehicle	pass	10	40	-23	27	15
User-operated	Car club	pass	10	22	-5	27	15
Service-based	Water bus	pass	9	31	-14	26	17
Service-based	Demand Responsive Transport	pass	11	24	-9	26	17
Service-based	Flying Taxi	pass	7	45	-29	23	19
User-operated	Motorcycle	pass	12	18	-8	22	20
User-operated	Car	fail	12	10	0	22	fail

3.2 Movement of Goods

Table 8: MCDA results overview for the movement of goods

Category	Mode	PASS/ FAIL	Solution (7 to 14)	Benefit (0 to 39)	Challenges (-33 to 0)	Total (-26 to 63)	Rank (Total)
Direct	Cargobike	pass	17	33	-12	38	1
Direct	Automated robots	pass	20	36	-20	36	2
Indirect	Collectplus	pass	23	13	-3	33	3
Indirect	3D printing	pass	18	27	-15	30	4
Direct	Drones	pass	16	35	-22	29	5
Direct	Electric moped	pass	14	21	-9	26	6
Indirect	Freight consolidation centre	pass	13	22	-10	25	7
Indirect	Magway	pass	14	30	-21	23	8
Direct	Electric van	pass	13	17	-9	21	9
Indirect	Amazon lockers	pass	20	13	-12	21	9
Indirect	Delivery to car	pass	18	13	-10	21	9
Direct	Motorcycle	pass	14	12	-7	19	12
Direct	Connected Autonomous Vehicle	pass	8	23	-14	17	13
Direct	Van	**fail**	16	0	-2	14	**fail**
Direct	Private car	**fail**	16	0	-4	12	**fail**

Unlike the top results for the movement of people, the top five solutions here are more diverse. There are a mix of direct and indirect solutions as well as a range in technology maturity. Cargobikes come out as the top choice for the movement of goods closely followed by automated robots. Both solutions offer zero tailpipe emission replacement journeys of van deliveries. The pay off with Cargobikes is that physical labour is required and there is a reduced payload compared with vans. Automated robots have a further limited payload but can offer reduced operational costs due to the lack of driver and low fuel costs given their electric powertrain.

Working down the list, Collectplus services are already in operation in Buckinghamshire but this concept can be expanded and more actively encouraged to enable greater consolidation of last mile trip destinations. The goods would still need to be collected by the customer creating the need for more people-based last mile journeys but given the short distance nature of these trips they are likely to be done by active travel modes or as part of another errand.

In fourth place, 3D printing of goods directly in a house or business mitigates the need for multiple delivery journeys but the current cost of 3D printing and the limited materials which can be used are large barriers to implementation.

The last spot in the top five is taken by drones which offer the chance to release road space for other modes (such as passenger modes) by delivering goods through the air. This has large advantages to road safety, carbon emissions and congestion but of the top five, drones have the greatest challenges to overcome including new legislation and their reliance on enabling technologies which are not currently widespread.

While not particularly high ranking, the electric van scores considerably higher than a diesel van against the MCDA framework criteria. This shows that while a transition to electric vans will not solve all the problems created by diesel vans such as congestion and safety issues, they do offer significant immediate advantages to the environment and therefore could be considered for use cases whereby vans offer the most economical solution.

Considering both top five short-lists side by side advantages could be derived from shared infrastructure savings. For example, better walking infrastructure would benefit automated robot deployment and segregated Cargobike lanes could also be suitable for e-bicycles, bicycles and or e-scooters if designed with the intent of safe, shared spaces. Given the larger size of Cargobikes compared with passenger bicycles, the same cannot necessarily be said for bike lanes being automatically suitable for Cargobikes.

3.3 Sensitivity Analysis

The MCDA framework uses the weighting of scores for an individual criterion to differentiate the relative importance of characteristics. For the sensitivity analysis, we chose to look at how altering the relative weightings of categories would impact our rankings of the long list in general and our top five solutions in particular. Firstly, we considered rankings the solutions by the total score for each category: Solution, Benefits and Challenges independently. This is useful to see where solutions which have the greatest potential benefits but may also currently have the most significant challenges can be part of a future roadmap once some of the barriers have been overcome. Secondly, by using six combinations of the scale factor, x where **A= Solution, B = Benefits and c = Challenges further sensitivity analysis** was conducted.

The nine scenarios for the sensitivity analysis testing are outlined below:

1. Solution only: A
2. Benefits only: B
3. Solutions only: C
4. Weighted Solution: xA + B + C
5. Weighted Benefits: A + xB + C
6. Weighted Challenges: A + B + xC
7. Diminished Challenges xA + xB +C
8. Diminished Benefits: xA + B + xC
9. Diminished Solution: A + xB + xC

The results and change in rank position for scenarios 1-3 are shown in ***Table 9*** for the movement of people and ***Table 10*** for the movement of goods. The remaining six scenarios where the scale factor, x is set to 1.5 are shown in ***Appendix B.***

3.3.1 Movement of people

Table 9 demonstrates that the top five solutions are relatively unchanged when the Solution score and Benefits categories are considered independently, however they have significant challenges to overcome compared with some more traditional road based solutions such as taxis, cars and car clubs.

Table 9: Example sensitivity analysis of the movement of people

	MCDA Overview			Solution		Benefits		Challenges	
Category	Mode	Total (-34 to 78)	Rank (Total)	Rank (solution)	Change in rank	Rank (benefit)	Change in rank	Rank (challenge)	Change in Rank
User-operated	Walking	64	1	1	0	1	0	10	-9
User-operated	e-bicycle	48	1	2	0	2	0	14	-12
User-operated	Bicycle	46	3	2	1	4	-1	14	-11
User-operated	e-scooter	44	4	5	-1	6	-2	13	-9
User-operated	Docked shared bike scheme	43	5	5	0	3	2	17	-12
User-operated	Dockless shared bike scheme	42	6	2	4	5	1	17	-11
Service-based	Segregated CAV	37	7	19	-12	8	-1	14	-7
Service-based	Taxi	36	8	5	3	17	-9	1	7
Service-based	Cable car	33	9	12	-3	7	2	20	-11
Service-based	Green bus	33	10	12	-3	11	-2	12	-3
Service-based	Bus	32	11	12	-1	13	-2	7	4
User-operated	Electric car club	31	12	12	0	12	0	9	3
Service-based	On-demand ride hailing	29	13	10	3	16	-3	4	9
User-operated	Electric car	27	14	12	1	15	-2	5	8
Service-based	Connected Autonomous Vehicle	27	15	12	3	10	5	19	-4
User-operated	Car club	26	16	12	3	19	-4	3	12
Service-based	Water bus	26	17	0	-2	13	4	11	6
Service-based	Demand Responsive Transport	23	18	10	7	17	0	7	10
Service-based	Flying Taxi	22	19	21	-2	9	10	21	-2
User-operated	Motorcycle	22	20	5	15	20	0	5	15
User-operated	Car	22	fail	fail	fail	fail	fail	fail	fail

The top five ranked solutions if we considered the categories of Solution, Benefits and Challenges separately are listed below with the overall top five for comparison. Solutions which appear in top five ranked overall score are highlighted in **bold.**

Overall	Solution	Benefits	Challenges
1. Walking **2. e-bicycle** **3. Bicycle** **4. e-scooter** **5. Docked shared bike scheme**	**1. Walking** **2. E-bicycle** **3. Bicycle** 4. Dockless shared bike scheme **5. e-scooter** **6. Docked shared bike scheme** 7. Taxi	**1. Walking** **2. e-bicycle** 3. Dockless shared bike scheme **4. Bicycle** **5. Dockless shared bike scheme**	1. Taxi 2. Car club 3. On-demand ride hailing 4. Electric car 5. Motorcycle

Walking remains the highest ranked solution when the Solution and Benefits categories are considered independently reflecting the maturity of the solution and the relatively low capital and revenue costs and the undeniable benefits of a free, zero emission mode. However, walking doesn't appear at all in the top five solutions with the fewest challenges showing that the limited use case versatility and infrastructure requirements do act as barriers to widespread adoption and need to be mitigated. Interestingly four of the top five solutions overall appear in the top five solutions by Benefits only and none appear in the top five solutions by Challenges only. This shows that the MCDA framework for people may be biased towards the benefits that a solution can bring and is reflected in the higher maximum score of 60 for the Benefits category compared to the lowest negative score for Challenges being -39. Examining scenario SIX where the challenges are weighted by a 50% uplift (scale factor = 1.5) to bring the equivalent range of scores to -58.5 to 0, to be more in line with the Benefits range of 0 to 60 brings about minimal change in the top five ranked solutions.

3.3.2 Movement of goods

Table 10 demonstrates that the ranking system is more sensitive to each of the solutions, benefits and challenge categories with significant changes to the rank when each are considered independently.

Table 10 Example sensitivity analysis of the movement of goods

MCDA Overview					Solution (A)		Benefits (B)		Challenges	
Category	**Mode**	**PASS/ FAIL**	**Total (-26 to 63)**	**Rank (Total)**	**Rank**	**Change in rank**	**Rank**	**Change in rank**	**Rank**	**Change in Rank**
Direct	Cargobike	pass	38	1	6	▼ -5	3	– -2	9	▼ -8
Direct	Automated robots	pass	36	2	2	– 0	1	– 1	13	▼ -11
Indirect	Collectplus	pass	33	3	1	▲ 2	10	▼ -7	2	– 1
Indirect	3D printing	pass	30	4	4	– 0	5	– -1	12	▼ -8
Direct	Drones	pass	29	5	7	– -2	2	▲ 3	15	▼ -10
Direct	Electric moped	pass	26	6	10	– -4	8	– -2	5	– 1
Indirect	Freight consolidation centre	pass	25	7	13	▼ -6	7	– 0	7	– 0
Indirect	Magway	pass	23	8	10	– -2	4	▲ 4	14	▼ -6
Direct	Electric van	pass	21	9	13	– -4	9	– 0	5	– 4
Indirect	Amazon lockers	pass	21	9	2	▲ 7	10	– -1	9	– 0
Indirect	Delivery to car	pass	21	9	4	▲ 5	10	– -1	7	▲ 2
Direct	Motorcycle	pass	19	12	10	▲ 2	13	– -1	4	▲ 8
Direct	Connected Autonomous Vehicle	pass	17	13	15	– -2	6	▲ 7	11	▲ 2
Direct	Van	**fail**	14	**fail**	**fail**	**fail**	**fail**	**fail**	**fail**	**fail**
Direct	Private car	**fail**	12	**fail**	**fail**	**fail**	**fail**	**fail**	**fail**	**fail**

The top five ranked solutions if we considered the categories of Solution, Benefits and Challenges separately are listed below with the overall top five for comparison. Solutions which appear in top five ranked overall score are highlighted in **bold.**

Overall	Solution	Benefits	Challenges
1. Cargobike **2. Automated robots** **3. Collectplus** **4. 3D printing** **5. Drones**	**1. Collectplus** 2. Amazon lockers **3. Automated robots** **4. 3D printing** 5. Delivery to car	**1. Automated robots** **2. Drones** **3. Cargobike** 4. Magway **5. 3D printing**	**1. Collectplus** 2. Motorcycle 3. Electric moped 4. Electric van 5. Freight consolidation centre 6. Delivery to car

4 Next Steps

Working in consultation with Buckinghamshire council for each of the shortlisted solutions, we will identify key challenges for implementation in Aylesbury.

For the challenges, we will propose any mitigating actions such as the accompaniment of enabling technologies or policy interventions. We will also evaluate the current state of infrastructure and compare with the defined requirements to aid the location selection for pilot implementation. Decisions will subsequently be made on which solution(s) would be most suitable for a pilot in Aylesbury and for this solution a high-level pilot specification and outline business case will be developed.

In the case where existing solutions have scored highly e.g. walking we will consider any technology or policy interventions which can encourage more users of the solution and will ensure that any pilot of other modes does not negatively impact on the high-scoring existing solution.

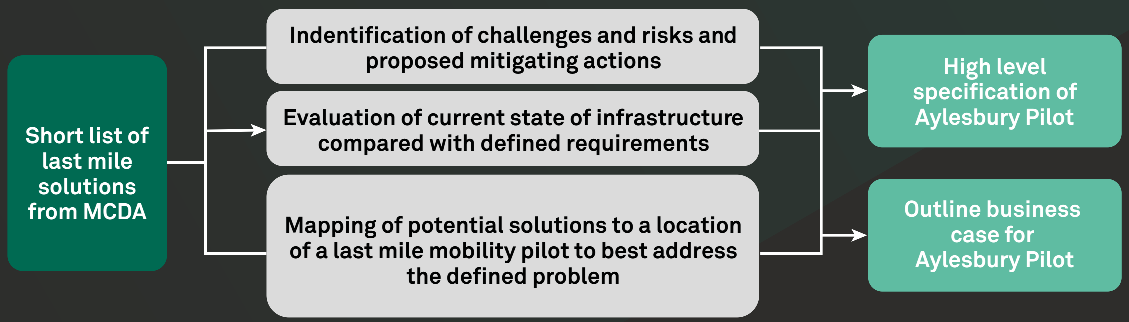
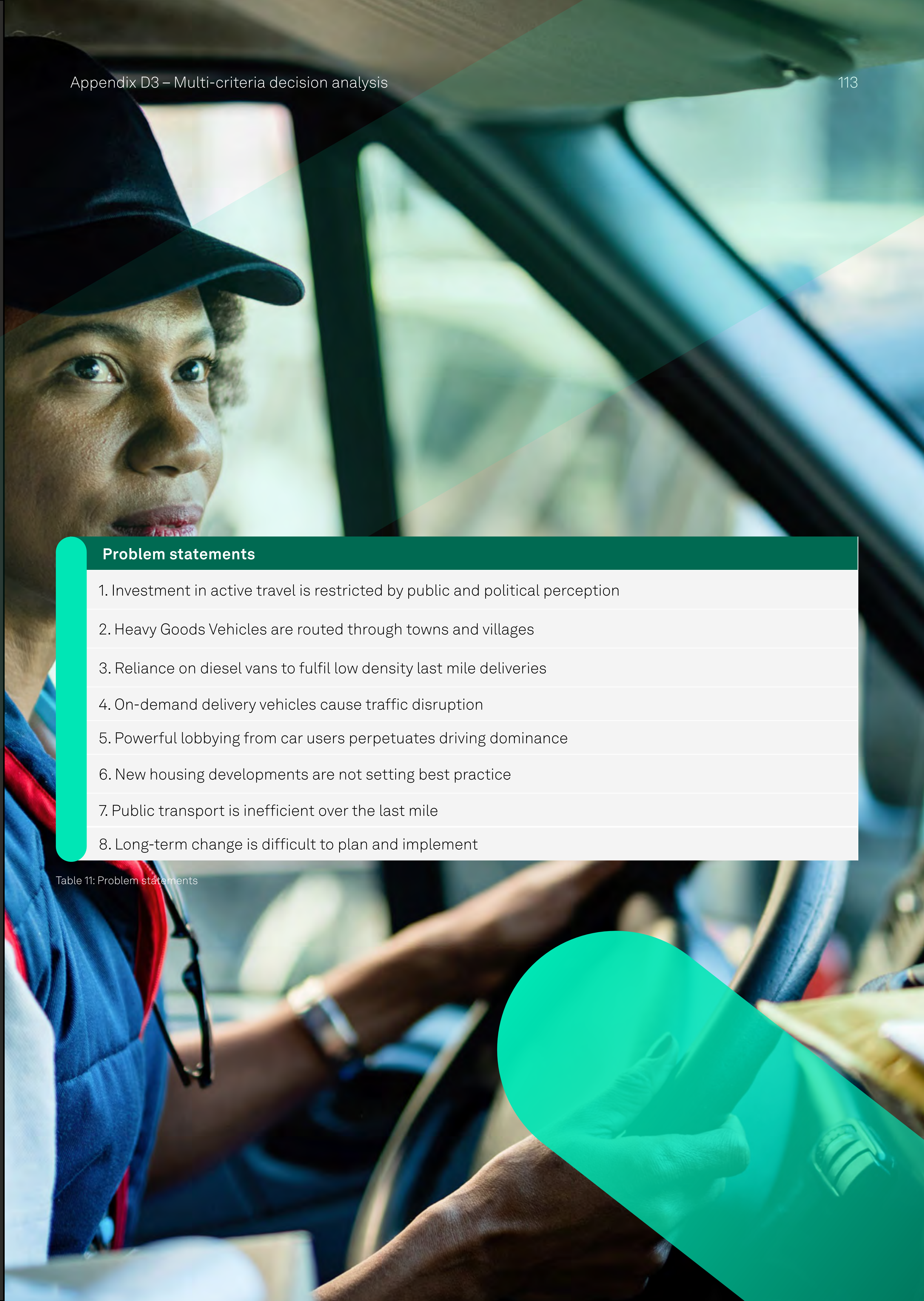


Figure 3: Next steps for modal selection

When considering a combination of solutions to trial we will look back to the problem statements outlined in CPC's Problem Definition document and displayed in Table 11 to ensure good coverage across the main challenges.



Problem statements
1. Investment in active travel is restricted by public and political perception
2. Heavy Goods Vehicles are routed through towns and villages
3. Reliance on diesel vans to fulfil low density last mile deliveries
4. On-demand delivery vehicles cause traffic disruption
5. Powerful lobbying from car users perpetuates driving dominance
6. New housing developments are not setting best practice
7. Public transport is inefficient over the last mile
8. Long-term change is difficult to plan and implement

Table 11: Problem statements

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Appendix A

Table 12: Completed MCDA framework for the movement of people

Category		Evaluation Criteria	Explanation	Scoring Options	Weighting	eighted score ran
Solution		Maturity	Maturity level considers whether there is precedent of successful deployment/trials in similar locations. The highest score is awarded to the most established mode in similar LAs.	established in similar LAs = 3pt established elsewhere in UK= 2pt proof of concept in UK = 1 pt not yet available in UK = 0pt	1	1 to 3
Solution		Capital Cost	Initial capital cost required from local authority or service provider to enable rollout of the solution compared with an existing private car. The highest score is awarded to the solution with the lowest capital costs.	low = 3pt medium = 2pt high = 1pt	2	2 to 6
Solution		Revenue cost	The value of revenue costs including labour, insurance, infrastructure maintenance and modal repairs/replacement which is incurred by the LA or service provider. Maintenance of private vehicles is not considered here but is covered by accessibility (cost). The highest score is awarded to the cheapest (lowest) revenue cost for the LA/service provider.	low = 3pt medium = 2pt high = 1pt	3	3 to 9
		Solution subtotal				7 to 21
[illegible]	Societal	Accessibility (physical)	A rating linked to the proportion of local demographics who could be reasonable expected to physically use the mode for last mile journeys. The highest score is awarded to those which are accessible to wheelchair users, elderly populations and young children.	high = 3pt medium = 2pt low = 1pt very limited demographics= 0pt	2	0 to 6
[illegible]	Societal	Accessibility (cost)	Considers the relative cost per mile/minute (depending on which is more appropriate) which is incurred by the user including payback time of assets if privately owned. The highest score is awarded to the mode with cheapest (lowest) cost for the user.	high = 3pt medium = 2pt low = 1pt not regularly affordable= 0pt	1	0 to 3
[illegible]	Societal	User convenience	Considers the reliability, availability, speed and flexibility (of destination) that the mode provides. This includes wait times, distance to access mode and whether it offers a flexible/door to door service and considers parking responsibilities. The highest score is awarded to solutions the perceived most convenient for the user.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	2	0 to 6
[illegible]	Societal	Safety of other users	Considers the impact of using this mode on other users of the shared infrastructure (e.g. impact on all other road users in shared use lanes). The modes are scored on best infrastructure scenario such as segregated bike lanes where available. The highest score is awarded to solutions which cause the least risk to other road users.	high = 3pt medium = 2pt low = 1ptx no benefit = 0pt	3	0 to 9
[illegible]	Societal	Active travel health benefits	Considers the health benefits that are achieved through using this mode. This can include mental and physical health benefits. For modes which are not door-to-door services such as a bus it is assumed there are some active travel benefits from the last mile connection. The highest score is awarded to solutions with the greatest active health benefits for the user.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	2	0 to 6
[illegible]	Economic	Improvements to road congestion	Considers the potential of the solution to reduce current congestion levels in the local last mile area. The highest score is awarded to solutions with the highest potential for a reduction in congestion.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
[illegible]	Environmental	Does this solution lead to positive environmental impacts?	**Dealbreaker question to ensure new solutions aid sustainable transport targets.**	**PASS/FAIL**	**NA**	**PASS/FAIL**
[illegible]	Environmental	Reduction in CO2 tailpipe emissions	Considers the potential to reduce environmental impacts on global warming. This includes reducing tailpipe emissions directly through modal choice and reducing the number of km travelled by consolidating journeys. The highest score is awarded to the lowest emitters of carbon emissions or modes which enable the greatest reduction in the km travelled by higher emitters.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
[illegible]	Environmental	Improvement in air quality (NOx and particulates)	Considers the potential to reduce the negative impacts of travel on air quality. This includes reducing emissions directly through modal choice and reducing the number of km travelled. The highest score is awarded to the solutions which are the lowest emitters of NOx and PM emissions per km travelled or enablers of the greatest reduction in km travelled by higher emitters.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
[illegible]	Environmental	Reduction in noise pollution	Considers the potential to reduce the negative impacts of travel on noise pollution. Potential for noise reduction in residential areas or during antisocial hours scores most highly. The highest score is awarded to solutions which emit the least noise pollution or reduce the need for noisier modes.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	1	0 to 3
		Benefits subtotal				0 to 54
Challenges	Enabling tech & infrastrcuture	New infrastructure requirements	Considers the cost and scale of any new infrastructure that is required or preferred for a successful deployment. The highest score is awarded to the solutions which require no new infrastructure.	no new infrastructure = 0pt low = -1pt medium = -2pt high = -3pt	2	-6 to 0
Challenges	Enabling tech & infrastrcuture	Reliance on enabling tech	Considers whether the solution requires the implementation of enabling technologies for successful deployment. The highest score is awarded to solutions with no reliance on enabling technologies (e.g. GPS, connectivity, electrification).	no reliance = 0pt some reliance = -1pt medium reliance = -2pt significant reliance = -3pt	2	-6 to 0
Challenges	Enabling interventions	New legislative requirements	Considers the challenge of introducing new legislation to accompany the deployment or growth of the solution. The highest score is awarded solutions with precedence legislation in similar LAs or where there are insignificant infrastructure requirements to sign off.	no new legislation = 0pt small changes = -1pt medium changes = -2pt significant changes = -3pt	3	-9 to 0
Challenges	Culture	Use case versatility	Considers the limitations regarding reasonable length of journeys and whether baggage/passengers can be taken via this mode. The highest score is awarded to the mode which offers greatest use case versatility including longer journeys.	no challenge = 0pt good versatility = -1pt poor vesatility = -2pt very limited use case = -3pt	2	-6 to 0
Challenges	Culture	Perceived User safety	Considers any challenges to the level of protection given to the user when used as intended (e.g. bikes on cycle lanes). The highest score is awarded to the greatest perceived protection for the user.	no challenge = 0pt low risk = -1pt medium risk = -2pt high risk = -3pt	2	-6 to 0
Challenges	Culture	Political perception/public acceptance	Considers whether the implementation (or growth) of this solution is likely to gain resistance from the public. The highest score is given to solutions which will be supported/obtain no political resistance.	no challenge = 0pt some resistance = -1pt negative -2pt very negative = -3pt	2	-6 to 0
		Challenges subtotal				-39 to 0
Total						-32 to 75

Evaluation Criteria	e-scooter Score (reviewed)	ICE Car Score (reviewed)	Electric car Score (reviewed)	Walking/wheelchair Score (reviewed)	Car club Score (reviewed)	Electric car club score (reviewed)	Bicycle Score (reviewed)	Docked shared bike scheme Score (reviewed)	Dockless shared bike scheme Score (reviewed)	Motorcycle Score (reviewed)	e-bicycle Score (reviewed)	[illegible] Score (reviewed)	[illegible] score	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] Score (reviewed)	[illegible] score (reviewed)
Maturity	2	3	3	3	3	3	3	3	2	3	3	3	2	3	0	2	2	0	2	2	1
Capital Cost	2	3	2	3	2	2	2	2	2	3	2	2	1	3	2	2	3	2	1	3	1
Revenue cost	2	1	1	3	1	1	2	2	2	1	2	1	2	1	1	1	1	2	2	1	2
Solution subtotal	6	7	6	9	6	6	7	7	6	7	7	6	5	7	3	5	6	4	5	6	4
Accessibility (physical)	2	2	2	3	2	2	1	1	1	0	2	3	3	3	3	3	3	3	3	3	3
Accessibility (cost)	2	2	2	3	2	2	3	2	2	2	3	2	2	0	0	2	1	2	2	2	2
User convenience	3	2	2	2	2	2	2	2	3	3	3	1	1	3	2	0	3	3	0	2	2
Safety of other users	1	0	0	3	0	0	2	2	2	0	2	1	1	1	2	2	1	2	3	1	3
Active travel health benefits	2	0	0	3	1	1	3	3	3	0	2	1	1	0	1	1	0	0	1	0	1
Improvements to road congestion	3	0	0	3	1	1	3	3	3	1	3	2	2	1	3	3	1	1	3	2	2
Does this solution lead to positive environmental impacts?	pass	fail	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass
Reduction in CO2 tailpipe emissions	3	0	3	3	1	3	3	3	3	1	3	2	3	1	3	1	1	3	3	1	3
Improvement in air quality (NOx and particulates)	3	0	2	3	1	2	3	3	3	1	3	1	2	1	3	1	1	2	3	1	2
Reduction in noise pollution	3	0	2	3	1	2	3	3	3	1	3	1	2	0	0	0	0	2	2	1	2
Benefits subtotal	22	6	13	26	11	15	23	22	23	9	24	14	17	10	17	13	11	18	20	13	20
New infrastructure requirements	-2	0	-1	-2	0	-2	-2	-2	-2	0	-2	-1	-2	0	-2	-2	0	-1	-3	-1	-2
Reliance on enabling tech	0	0	-2	0	-1	-2	0	-1	-1	0	0	0	-2	0	-3	0	-2	-3	0	-2	-2
New legislative requirements	-1	0	0	0	-1	-1	0	-1	-1	0	0	-1	-1	0	-3	-2	-1	-3	-3	-1	-2
Use case versatility	-2	0	0	-3	0	0	-2	-2	-2	-1	-2	-1	-1	0	-2	-1	0	0	-1	0	0
Perceived User safety	-2	0	0	-1	0	0	-2	-2	-2	-3	-2	0	0	0	-1	0	0	-1	-1	0	-1
Political perception/public acceptance	-1	0	-1	0	0	0	-3	-2	-2	0	-3	-1	-1	0	-2	-1	0	-2	-3	0	-1
Challenges subtotal	-8	0	-4	-6	-2	-5	-9	-10	-10	-4	-9	-4	-7	0	-13	-6	-3	-10	-11	-4	-8
Total	20	13	15	29	15	16	21	19	19	12	22	16	15	17	7	12	14	12	14	15	16

Table 13: Completed MCDA framework for the movement of goods

Category		Evaluation Criteria	Description	Scoring Options	Weighting	Weighted Score Range
Solution		Technology Maturity	Maturity level considers technical maturity (TRL) in addition to whether there is precedent of successful deployment/trials in similar locations. The highest score is awarded to the most established mode.	competitive market= 3pt limited market availability = 2pt proof of concept = 1pt not yet available = 0pt	1	0 to 3
		Capital cost	Initial capital cost required from local authority or service provider to enable rollout of the solution compared with an existing van. The highest score is awarded to the solution with the lowest capital costs.	low = 3pt medium = 2pt high = 1pt	3	3 to 9
		Revenue cost	Value of costs for maintenance of the system for the local authority. The highest score is awarded to the solution with the lowest revenue costs for the local authoririty e.g. very low maintenence costs or if the infrastructure will be maintained entirely by a private company.	low = 3pt medium = 2pt high = 1pt	3	3 to 9
		Operational cost (logistics company)	Considers the impact on the revenue cost of delivery for logistics companies including labour/fuel costs. The highest score is given to solutions which offer the lowest operational costs once the mode is established.	low = 3pt medium = 2pt high = 1pt	1	1 to 3
		Solution Subtotal				7 to 24
Benefits	Societal	Safety for other users	Considers the impact of using this mode on other users of the shared infrastructure (e.g. impact on all other road users in shared use lanes). The modes are scored on best infrastructure scenario such as segregated bike lanes where available. The highest score is awarded to solutions which cause the least risk to other road users.	lowest risk= 3pt low risk = 2pt lower risk = 1ptx no benefit = 0pt	3	0 to 9
	Economic	Improvements to road congestion	Considers the potential of the solution to reduce current congestion levels in the local last mile area. The highest score is awarded to solutions with the highest potential for a reduction in congestion.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
	Environmental	**Does this solution lead to a significant reduction environmental impacts?**	**Dealbreaker question to ensure new solutions aid sustainable transport targets.**	PASS/FAIL	NA	PASS/FAIL
		Reduction in CO2 tailpipe emissions	Considers the potential to reduce environmental impacts on global warming. This includes reducing tailpipe emissions directly through modal choice and reducing the number of km travelled. The highest score is awarded to the lowest emitters of carbon emissions or enablers of the greatest reduction in the km travelled by higher emitters.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
		Improvement in air quality (NOx and particulates)	Considers the potential to reduce the negative impacts of travel on air quality. This includes reducing emissions directly through modal choice and reducing the number of km travelled. The highest score is awarded to the solutions which are the lowest emitters of NOx and PM emissions per km travelled or enablers of the greatest reduction in km travelled by higher emitters.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	3	0 to 9
		Reduction in noise pollution	Considers the potential to reduce the negative impacts of travel on noise pollution. Potential for noise reduction in residential areas or during antisocial hours scores most highly. The highest score is awarded to solutions which emit the least noise pollution or reduce the need for noisier modes.	high = 3pt medium = 2pt low = 1pt no benefit = 0pt	1	0 to 3
		Benefits Subtotal (min 0, max 39)				0 to 39
Challenges	Enabling tech & infrastructure	New infrastructure requirements	Considers the cost and scale of any new infrastructure that is required or preferred for a successful deployment. The highest score is awarded to the solutions which require no new infrastructure.	no new infrastructure = 0pt low = -1pt medium = -2pt high = -3pt	3	-9 to 0
		Reliance on enabling tech	Considers whether the solution requires the implementation of enabling technologies for successful deployment. The highest score is awarded to solutions with no reliance on enabling technologies (e.g. GPS, connectivity, electrification).	no reliance = 0pt low reliance = -1pt medium reliance = -2pt significant reliance = -3pt	2	-6 to 0
	Enabling interventions	New legislative requirements	Considers the challenge of introducing new legislation to accompany the deployment or growth of the solution. The highest score is awarded solutions with precedence legislation in similar LAs or where there are insignificant infrastructure requirements to sign off.	no new legislation = 0pt small changes = -1pt medium changes = -2pt significant changes = -3pt	1	-3 to 0
	Culture	Use case versatility	Considers challenges regarding the size, weight and throughput of freight which can be moved via this mode (per vehicle/delivery) compared to the use case of a standard van. The highest score is awarded to the most versatile mode.	no challenge = 0pt good versatility = -1pt poor vesatility = -2pt very limited use case = -3pt	3	-9 to 0
			Considers whether the solution is likely to be supported politcially or whether it will garner	no challenge = 0pt		

Evaluation Criteria	Van	Electric van	Cargobike	Connected Autonomous Vehicle	Private ICE car	Drones	Motorcycle	Electric moped	Automated robots	Collectplus	Freight consolidation centre	Amazon lockers	Magway	Delivery to car	3D printing
	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)	Score (reviewed)
Technology Maturity	3	2	2	0	3	1	3	3	2	3	3	2	0	1	0
Capital cost	3	2	2	1	3	2	2	2	3	3	1	2	1	2	3
Revenue cost	1	1	2	1	1	2	1	1	2	3	2	3	3	3	3
Operational cost (logistics company)	1	2	3	2	1	3	2	2	3	2	1	3	2	2	2
Solution Subtotal	8	7	9	4	8	8	8	8	10	11	7	10	6	8	8
Safety for other users	0	0	2	2	0	2	0	0	3	1	1	1	2	1	2
Improvements to road congestion	0	0	2	0	0	3	1	1	2	1	2	1	2	1	2
Does this solution lead to a significant reduction environmental impacts?	fail	pass	pass	pass	fail	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass
Reduction in CO2 tailpipe emissions	0	3	3	3	0	3	2	3	3	1	2	1	3	1	2
Improvement in air quality (NOx and particulates)	0	2	3	2	0	3	1	2	3	1	2	1	3	1	2
Reduction in noise pollution	0	2	3	2	0	2	0	3	3	1	1	1	1	1	3
Benefits Subtotal (min 0, max 39)	0	7	13	9	0	13	4	9	14	5	8	5	22	5	11
New infrastructure requirements	0	-1	-2	-1	0	-1	0	0	-2	0	-3	-1	-3	0	0
Reliance on enabling tech	0	-1	0	-3	0	-3	0	-1	-2	0	0	0	-1	-2	-3
New legislative requirements	0	0	-1	-3	0	-3	0	0	2	0	1	0	-2	0	0
Use case versatility	0	0	-1	0	0	-2	-1	-1	-2	-1	0	-3	-2	-2	-3

Appendix D3 – Multi-criteria decision analysis

6

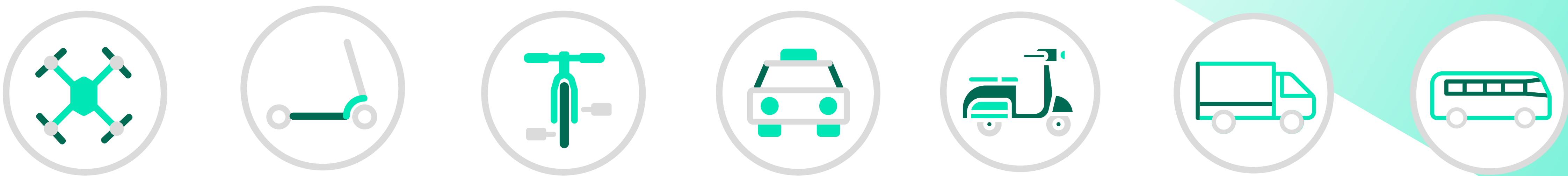
Appendix B

Table 14: Sensitivity analysis results for scenarios 4-9 for the movement of people

Category	MCDA Overview	xA + B + C			A + xB + C			A + B + xC			xA + xB + C			xA + B + xC			A + xB + xC			Scal factor
	Mode	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	
User-operated	Walking	73	1	0	93	1	0	58	1	0	102	1	0	67	1	0	87	1	0	1.5
User-operated	e-bicycle	54.5	2	0	74.5	2	0	39	2	0	81	2	0	45.5	2	0	65.5	2	0	
User-operated	Bicycle	52.5	3	0	71.5	3	0	37	3	0	78	3	0	43.5	3	0	62.5	3	0	
User-operated	e-scooter	5250	4	0	68.5	5	-1	35.5	5	-1	74.5	5	-1	41.5	5	-1	60	4	0	
User-operated	Docked shared bike scheme	49	5	0	69	4	1	32.5	6	-1	75	4	1	38.5	6	-1	58.5	5	0	
User-operated	Dockless shared bike scheme	48.5	6	0	67	6	0	31.5	7	-1	73.5	6	0	38	7	-1	56.5	6	0	
Service-based	Segregated CAV	41.5	8	-1	60	7	0	28	8	-1	64.5	7	0	32.5	8	-1	51	7	0	
Service-based	Taxi	42	7	1	48	10	-2	36	4		54	10	-2	42	4		48	8	0	
Service-based	Cable car	38	9	0	57	8	1	20.5	16	-7	62	8	1	25.5	16	-7	44.5	9	0	
Service-based	Green bus	38	9	0	52	9	0	25.5	10	-1	57	9	0	30.5	11	-2	44.5	9	0	
Service-based	Bus	37	11	0	47.5	11	0	27.5	9	2	52.5	11	0	32.5	8	3	43	11	0	
User-operated	Electric car club	36	12	0	47	12	0	25.5	10	2	52	12	0	30.5	11	1	41.5	12	0	
Service-based	On-demand ride hailing	34.5	13	0	41.5	16	-3	25.5	10	3	47	16	-3	31	10	3	38	14	-1	
User-operated	Electric car	34	14	-1	42.5	15	-2	25	13	0	47.5	15	-2	30	13	0	38.5	13	0	
Service-based	Connected Autonomous Vehicle	32	15	0	47	12	3	15.5	19	-4	52	12	3	20.5	19	-4	35.5	15	0	
User-operated	Car club	32	15	0	38	18	-3	24.5	14	1	43	19	-4	29.5	14	1	35.5	15	0	
Service-based	Water bus	30.5	18	-1	41.5	16	1	19	17	0	46	17	0	23.5	18	-1	34.5	17	0	
Service-based	Demand Responsive Transport	31.5	17	0	38	18	-1	21.5	15	2	43.5	18	-1	27	15	2	33.5	18	-1	
Service-based	Flying Taxi	26.5	20	-1	45.5	14	5	8.5	20	-1	49	14	5	12	20	-1	31	19	0	
User-operated	Motorcycle	28	19	1	31	20	0	18	18	2	37	20	0	24	17	3	27	20	0	
User-operated	Car	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	fail	

Table 15: Sensitivity analysis results for scenarios 4-9 for the movement of goods

Category	MCDA Overview	20xA + B + C			A + xB + C			A + B + xC			xA + xB + C			xA + B + xC			A + xB + xC			Scal factor
	Mode	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	Score	Rank	Change in rank	
Direct	Cargobike	46.5	1	0	54.5	1	0	32	1	0	63	2	-1	40.5	2	-1	48.5	1	0	1.5
Direct	Automated robots	46	2	0	54	2	0	26	3	-1	64	1	1	36	3	-1	44	2	0	
Indirect	Collectplus	44.5	3	0	39.5	5	-2	31.5	2	1	51	5	-2	43	1	2	38	3	0	
Indirect	3D printing	39	4	0	43.5	4	0	22.5	4	-1	52.5	4	0	31.5	4	0	36	4	0	
Direct	Drones	37	5	0	46.5	3	2	18	7	-2	54.5	3	2	26	7	-2	35.5	5	0	
Direct	Electric moped	33	6	0	36.5	7	-1	21.5	5	1	43.5	7	-1	28.5	5	1	32	6	0	
Indirect	Freight consolidation centre	31.5	7	0	36	8	-1	20	6	1	42.5	8	-1	26.5	6	1	31	7	0	
Indirect	Magway	30	9	-1	38	6	2	12.5	13	-5	45	6	2	19.5	13	-5	27.5	8	0	
Direct	Electric van	27.5	11	-2	29.5	9	0	16.5	8	1	36	11	-2	23	10	-1	25	9	0	
Indirect	Amazon lockers	31	8	1	27.5	11	-2	15	11	-2	37.5	9	0	25	8	1	21.5	11	-2	
Indirect	Delivery to car	30	9	0	27.5	11	-2	16	9	0	36.5	10	-1	25	8	1	21.5	10	-1	
Direct	Motorcycle	26	12	0	25	13	-1	15.5	10	2	32	13	-1	22.5	11	1	21.5	11	1	
Direct	Connected Autonomous Vehicle	21	14	-1	28.5	10	3	10	14	-1	32.5	12	1	14	15	-2	21.5	11	2	
Direct	Van	22	FAIL	FAIL	14	FAIL	FAIL	13	FAIL	FAIL	22	FAIL	FAIL	21	FAIL	FAIL	13	FAIL	FAIL	
Direct	Private car	20	FAIL	FAIL	12	FAIL	FAIL	10	FAIL	FAIL	20	FAIL	FAIL	18	FAIL	FAIL	10	FAIL	FAIL	



May 2021

Appendix D5

Technology Roadmap

ADEPT LIVELABS Transforming Local Places

Buckinghamshire Council

CATAPULT Connected Places

Executive Summary

Innovative last mile mobility solutions present an opportunity to transform Buckinghamshire's mobility landscape and offer sustainable options in line with strategic aspirations for improving air quality and reducing the over-reliance on private vehicles and delivery vans for short journeys.

Buckinghamshire is a county situated in England's Economic Heartland (EEH) region with significant planned investments over the next fifteen years. At the same time, technology is continuing to change the way we work, live and travel. This behaviour change has been accelerated due to COVID-19 and is likely to be even further impacted following the UK Government announcement that carbon emissions must be cut by 78% by 2035 compared to 1990 levels[1].

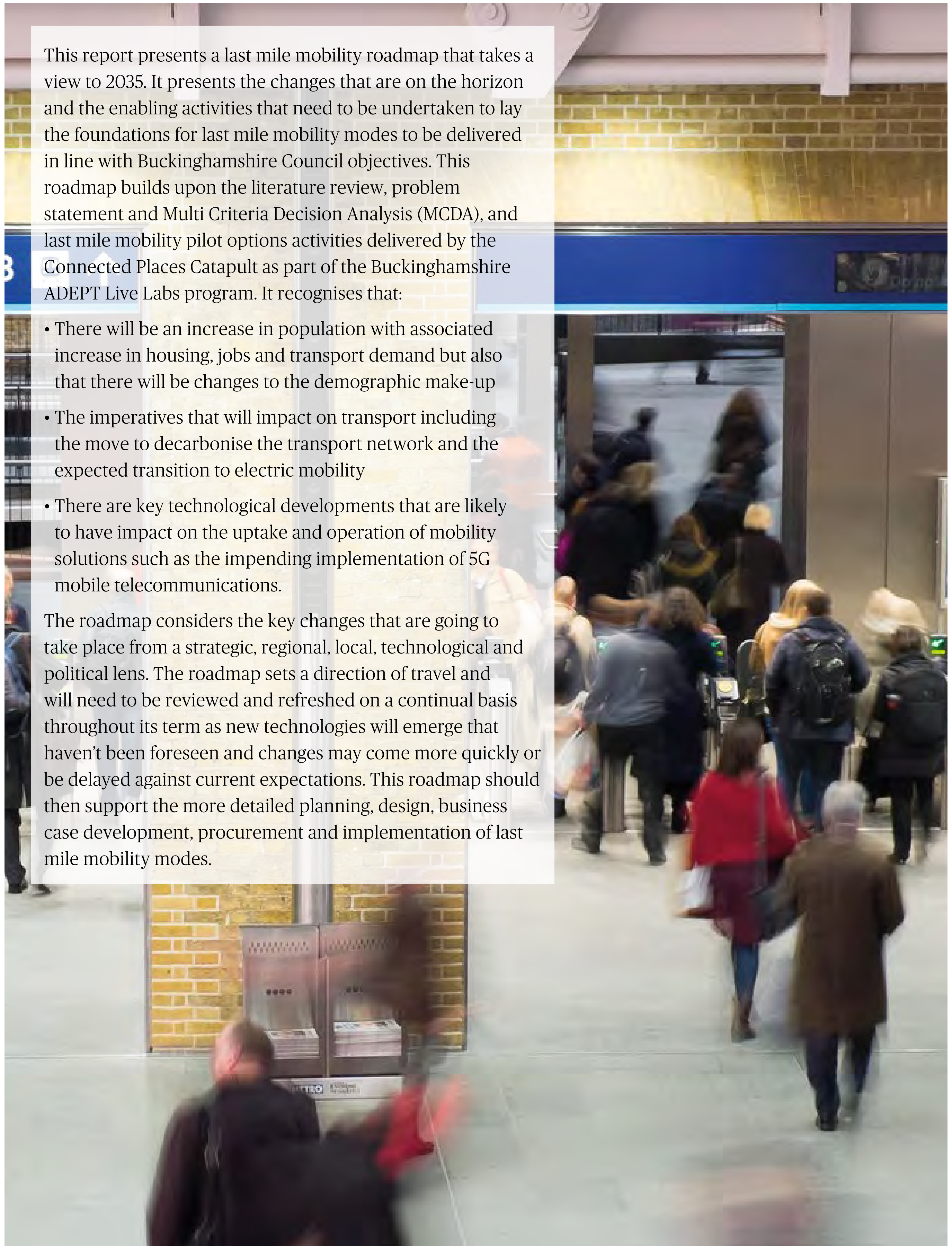
These changes link to and build upon Buckinghamshire's existing transport objectives of:

1. **Improve air quality** through reduced congestion
2. **Improve accessibility** through increased transport options
3. **Drive behaviour change** by making it easier and more attractive to use active and public transport modes
4. **Enable the ease of movement** in town centres and other urban areas through improved transport access
5. **Improve journey time** by balancing demand across transport modes
6. **Increase transport safety** by reducing the risk of death or injury on the network.

With this context in mind last mile mobility modes enable alternative solutions to car and van travel and options to meet sustainability targets whilst improving public health. Last mile mobility is defined in this report as:

> The,movement of goods or people over short distances to facilitate either;
> - end-to-end journeys between a precise origin and destination, or;
> - modal connections as part of a longer journey.

1 https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035



This report presents a last mile mobility roadmap that takes a view to 2035. It presents the changes that are on the horizon and the enabling activities that need to be undertaken to lay the foundations for last mile mobility modes to be delivered in line with Buckinghamshire Council objectives. This roadmap builds upon the literature review, problem statement and Multi Criteria Decision Analysis (MCDA), and last mile mobility pilot options activities delivered by the Connected Places Catapult as part of the Buckinghamshire ADEPT Live Labs program. It recognises that:

- There will be an increase in population with associated increase in housing, jobs and transport demand but also that there will be changes to the demographic make-up
- The imperatives that will impact on transport including the move to decarbonise the transport network and the expected transition to electric mobility
- There are key technological developments that are likely to have impact on the uptake and operation of mobility solutions such as the impending implementation of 5G mobile telecommunications.

The roadmap considers the key changes that are going to take place from a strategic, regional, local, technological and political lens. The roadmap sets a direction of travel and will need to be reviewed and refreshed on a continual basis throughout its term as new technologies will emerge that haven't been foreseen and changes may come more quickly or be delayed against current expectations. This roadmap should then support the more detailed planning, design, business case development, procurement and implementation of last mile mobility modes.

Contents

1 Introduction

1.1 Background and Motivation

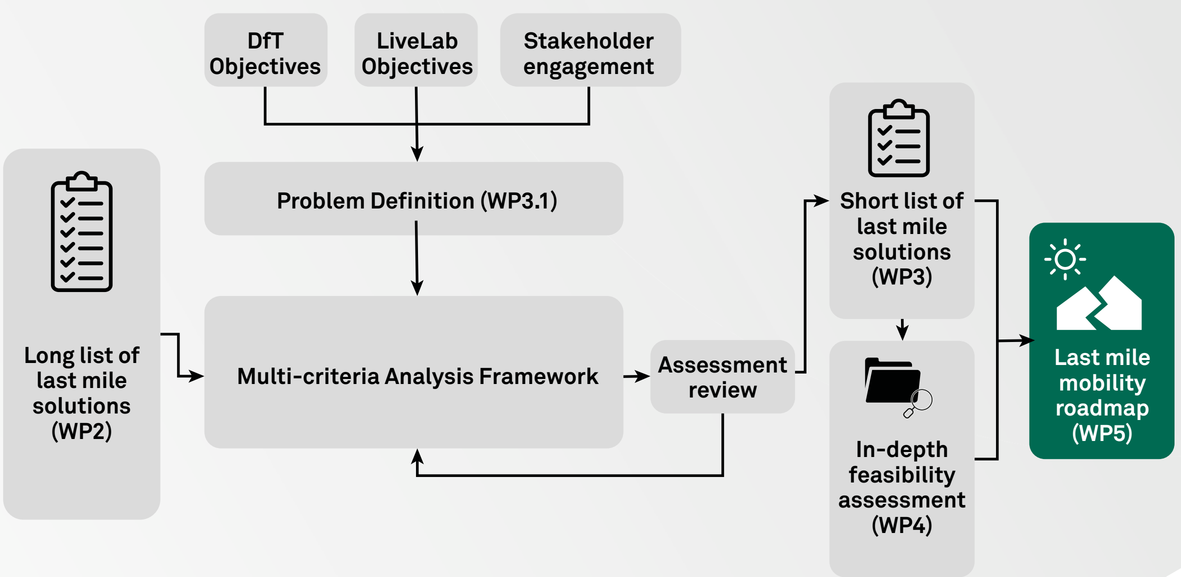
Buckinghamshire Council is leading the delivery of the £4.5m 'SMART Connected Community: Live Labs' project which is part of a £23m programme, funded by the Department for Transport (DfT), and led by the Association of Directors of Environment, Economy, Planning and Transport (ADEPT). The project is built around four themes: **Smart Materials, Smart Communication, Smart Energy, and Smart Mobility.** Within the Smart Mobility theme, the Connected Places Catapult (CPC) is delivering a feasibility study into last mile mobility solutions.

This roadmap provides a summary of the last mile mobility solutions that will be available to Buckinghamshire until 2035 and the enabling steps required to successfully implement the solutions.

1.2 Work Package Structure

The Last Mile Mobility Roadmap is a single work package in a much larger scope of works being conducted by Connected Places Catapult. It builds upon our previous work and considers the current landscape to provide a timelined view of possible last mile mobility solutions and enabling activities. ***Figure 1*** demonstrates that the roadmap builds upon the other outputs and helps shape and prioritise Buckinghamshires approach going forward.

Figure 1: Relationship between work packages



1.3 Overview

Buckinghamshire is a county situated in the vibrant and economically promising England Economic Heartland (EEH) region and is part of the Oxford-Cambridge arc with significant planned investments over the next 15 years. In 2019 the Buckinghamshire economy was worth £15.2 billion, further economic growth is expected with a requirement for 50,000 new homes by 2036[2]. Whilst such growth is great for the economy, Buckinghamshire is heavily reliant on private car use with almost 50% of the workforce employed outside Buckinghamshire. Therefore, this growth could result in long periods of disruption, significant increase in journeys and additional pressure on the local transport network.

Advances in sensing, communication, data processing and fuel technologies are paving the way for more intelligent approaches to managing transport demand and balancing the requirements of the highway network. This is leading to a rise in last mile mobility solutions. The definition of last mile mobility can vary depending on the context. For this report last mile mobility is defined as:

> **The movement of goods or people over short distances to facilitate either;**
>
> **a) end-to-end journeys between a precise origin and destination, or;**
>
> **b) modal connections as part of a longer journey.**

Last mile mobility solutions seek to meet the Government's focus on reducing carbon emission and increasing sustainable travel, whilst recognising the rapid increase in online shopping, which has only grown further following COVID-19.

Buckinghamshire Council is taking a proactive approach to deliver last mile mobility solutions which seek to address current challenges such as peak time traffic congestion, the over-reliance on private vehicles and NO2 levels in urban areas; as well as future challenges such as major road and rail schemes, economic growth, an ageing demographic and societal changes within the area. This proactive approach is demonstrated through last mile mobility initiatives such as the current e-scooter and Demand Responsive Transport (DRT) trials being undertaken.

This document identifies Buckinghamshire's strategic policies and objectives which last mile mobility will help to deliver and outlines a roadmap that sets out planned activities that build on current initiatives whilst taking into account the strategic social, economic, environmental and technological landscape. The roadmap will act as a tool to shape the development of future local relevant policies and identify and prioritise relevant activities and future investments by Buckinghamshire Council. The roadmap will need to be regularly updated to reflect changes in the strategic landscape and the associated activities that lead to realising the objectives.

2 https://www.buckinghamshire.gov.uk/your-council/corporate-plan/corporate-plan-2020-2023/buckinghamshire-numbers/

2 Strategic Landscape

The realisation of an effective and efficient transport system relies upon and also has an impact on, a range of political, social, economic, environmental, and technological factors. Therefore, it is prudent to consider such factors at the local, regional and national levels when developing the Buckinghamshire Last Mile Mobility Roadmap.

2.1 Local Context

The key transport-related characteristics of Buckinghamshire are:

- Almost 1 in 2 of the Bucks workforce are employed outside of the county[3]
- Car is the dominant mode of transport
- There is a mix of rural and urban areas with Aylesbury and High Wycombe the largest urban settlements
- Schools and Town Centres are the main sources of congestion with plenty of parking availability in town centres
- There is no significant Strategic Road Network (SRN) through Buckinghamshire
- Freight is routed through local roads and historic market towns due to limited SRN.

Figure 2: Buckinghamshire County

3 https://www.buckinghamshire.gov.uk/your-council/corporate-plan/corporate-plan-2020-2023/buckinghamshire-numbers/

2.2 Social, Political and Economic Aspects

2.2.1 Regional level

Buckinghamshire is located at the centre west of the England's Economic Heartland (EEH)[4] region and is part of the Oxford-Cambridge arc. In November 2017, the National Infrastructure Commission (NIC) published its findings on the Cambridge-Milton Keynes-Oxford Arc potential, highlighting that the region's economy could double or even triple in size[5].

EEH Transport Strategy

EEH has developed its 30 year transport strategy[6] with an ambition

> "to support sustainable growth and improve quality of life and wellbeing through a world-class, decarbonised transport system which harnesses the region's global expertise in technology and innovation to unlock new opportunities for residents and businesses, in a way that benefits the UK as a whole."

A crucial objective of the Transport Strategy is to realise a zero-carbon transport system by 2050.

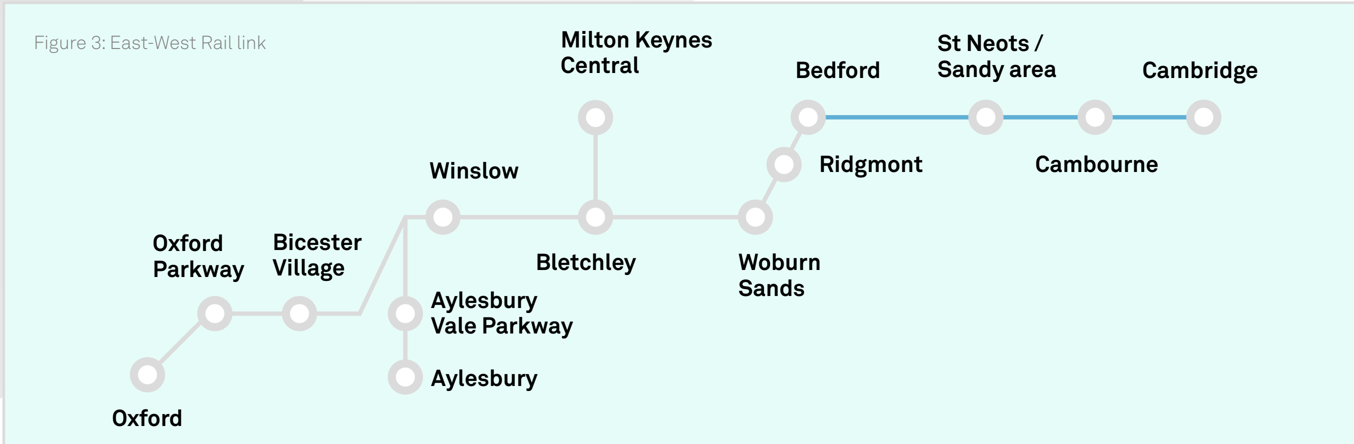
EEH's transport strategy contains the following key engagement outcomes relevant to last mile mobility[7]:

- Key factors influencing mode choice in the area are cost, convenience and journey time
- Journey time, reliability, environmental impact, cost and frequency were identified as the transport service key performance indicators
- Strong emphasis on travel behaviour and the need to influence through sticks and carrots
- Transforming infrastructure needs to be sustainable and not lead to more car journeys
- Urgent need to decarbonise transport through electrification and more use of public and active transport.

Oxford - Cambridge rail links

Buckinghamshire is part of the planned East-West Rail link between Oxford and Cambridge which has a delivery target of mid-2020's. The proposed route includes three stops in Buckinghamshire at Winslow, Aylesbury Vale Parkway and Aylesbury[8] (shown below).

Figure 3: East-West Rail link



4 EEH is strategic collaborative partnership with a shared commitment to realise the economic potential of the Oxford-Cambridge Arc and surrounding areas.
5 https://www.nic.org.uk/our-work/growth-arc/
6 https://eeh-prod-media.s3.amazonaws.com/documents/Connecting_People_Transforming_Journeys_av.pdf
7 https://eeh-prod-media.s3.amazonaws.com/documents/Outline_Transport_Strategy_engagement_report.pdf
8 https://eastwestrail.co.uk/the-project/bedford-to-cambridge

2.2.2 National level

The UK Government has set out their priorities for growth which include: levelling up the whole of the UK, supporting the transition to net zero and enabling the vision for Global Britain. To achieve this the Government has identified three core pillars in their strategy to Build Back Better[9], as follows:

- Infrastructure
- Skills
- Innovation

The strategy also references the Prime Minister's ten point plan for a green industrial revolution, based on the strengths of the UK:

1. Offshore wind
2. Hydrogen
3. Nuclear
4. Electric vehicles
5. Public transport, cycling and walking
6. Jet Zero and greener maritime
7. Homes and public buildings
8. Carbon capture
9. Nature
10. Innovation and finance

The importance of transport, mobility and logistics and the need to reduce carbon emissions is highlighted through the Build Back Better and ten point plans. Furthermore, the DfT has created a national bus strategy (Bus Back Better[10]) and is in the process of developing a Future of Freight Strategy. Both of these strategies feature challenges such as congestion and the shift towards zero emissions vehicles.

2.3 Environmental Aspects

The transport sector is a major source of CO_2 emissions, contributing to the global warming and climate change, and air pollution which has a direct impact on health. In 2017, Greenhouse gas (GHG) emissions from road transport made up around a fifth of the UK's total GHG emissions[11]. The impact of climate change is evident through the growing number of extreme weather events being witnessed over the past few years which is bringing disruptions to the transport network.

Road transport is a major source of air pollution and estimated to be responsible for up to 30% of particulate emissions (PM) in European cities and up to 50% of PM emissions in OECD countries[12]. According to Public Health England, air pollution is the biggest environmental threat to health in the UK, with between 28,000 and 36,000 deaths a year attributed to long-term exposure[13]. In 2018, DfT published its "Road to Zero" strategy with the ambition of having almost every car and van to be zero emission by 2050[14]. Furthermore, the UK Government announced that emissions will need to be cut by 78% by 2035 compared to 1990 levels[15], this is due to be enshrined in law.

Whilst air quality is generally acceptable in most areas there are some Air Quality Management Areas (AQMA) across Buckinghamshire due to exceedance in annual NO2 levels which is mainly derived from vehicle emissions[16].

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/968403/PfG_Final_Web_Accessible_Version.pdf
10 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/980227/DfT-Bus-Back-Better-national-bus-strategy-for-England.pdf
11 https://www.ons.gov.uk/economy/environmentalaccounts/articles/roadtransportandairemissions/2019-09-16
12 https://www.who.int/sustainable-development/transport/health-risks/air-pollution/en/
13 https://www.gov.uk/government/news/public-health-england-publishes-air-pollution-evidence-review
14 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf
15 https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
16 https://www.buckinghamshire.gov.uk/environment/air-and-water-quality/

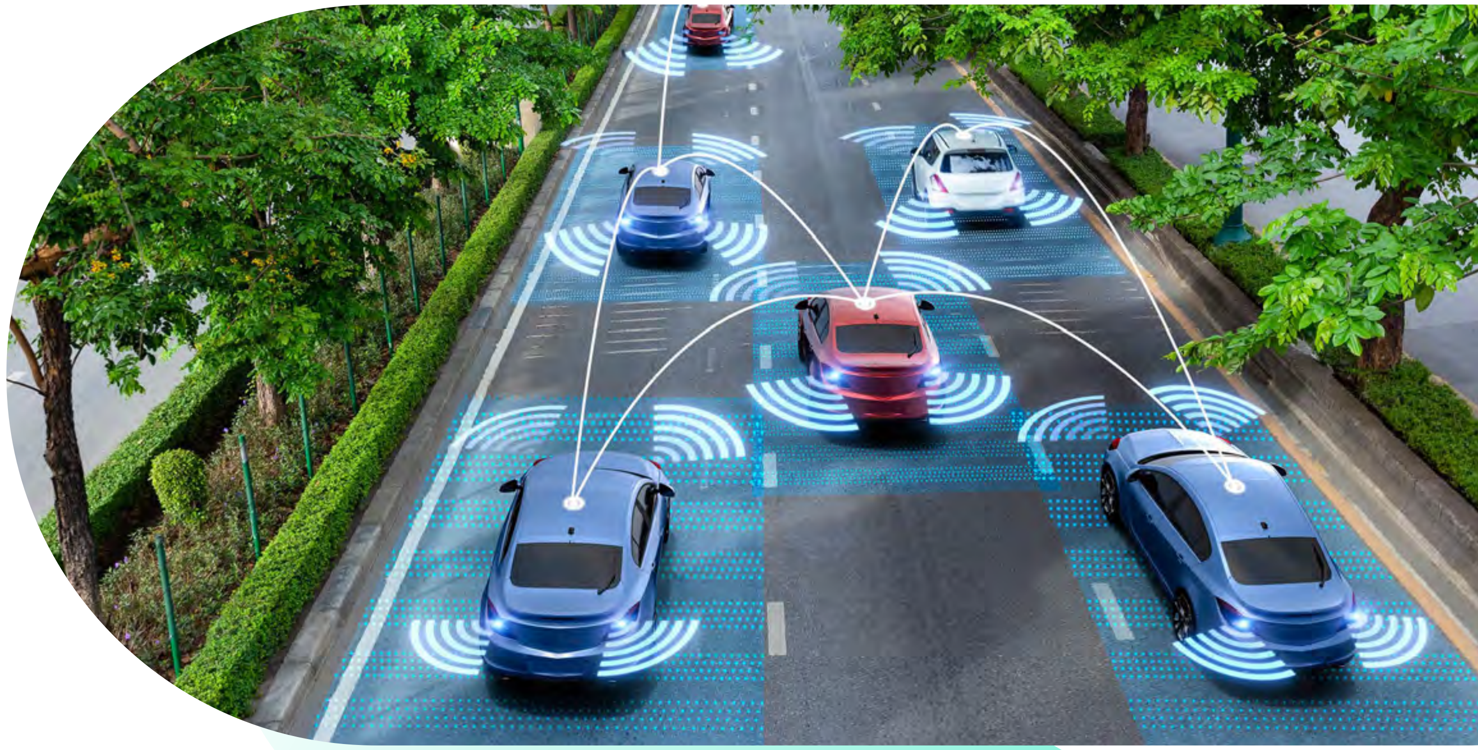
2.4 Technological Aspects

The past decade has witnessed significant technological advances in sensing, connectivity, computing, and data processing. The automotive industry is going through a transformative phase with advances in vehicle connectivity, electrification and automation. The proportion of Connected Vehicles (CV) on UK roads is increasing and it is forecasted that by 2026, all new registered vehicles will be connected[17]. CVs can provide a range of sensory data about traffic and road conditions which augment, and potentially replace, infrastructure sensors. Demand for Electric Vehicles (EV) has been rising in the UK with Electric and hybrid car sales reaching 10% of UK total car sales in November 2019[18]. Furthermore, it is anticipated that 100% of new registered vehicles in the UK have some level of autonomy (Levels 1-to-4[19]) by 2025[20].

Current technology advances are leading to the generation of significant amounts of data (Big Data) which, if accessed and utilised properly, can improve transport services and the operation of transport networks. For example, the opening of transport data by Transport for London (TfL) is generating annual economic benefits and savings of up to £130m for travellers, London and TfL itself[21].

The advent of Machine Learning and Artificial Intelligence (AI) is anticipated to bring many benefits to the transport sector including the support for autonomous driving, traffic management, and predictions of disruptions and journey times.

In order to exploit the range of last mile mobility solutions Buckinghamshire must continue to take steps to exploit advances in technology to improve the transport network.



17 https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-CONNECTED-REPORT-2019.pdf
18 https://www.ft.com/content/d57efdf6-ffad-11e9-be59-e49b2a136b8d
19 https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles
20 https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-CONNECTED-REPORT-2019.pdf
21 http://content.tfl.gov.uk/deloitte-report-tfl-open-data.pdf

3 Buckinghamshire's Aspirations for Last Mile Mobility

We took a top down view of a range of strategic policies and plans developed by central government, EEH and Buckinghamshire Council (see Appendix A for the range of documents reviewed) in order to derive the key objectives that Buckinghamshire are seeking from last mile mobility options and the policies that support these objectives.

By taking this approach we identified three key documents which align the last mile mobility outcomes that all the strategic documents are seeking to achieve.
These are:

- Local Transport Plan 4 (LTP 4)
- Aylesbury Transport Plan
- Buckingham Transport Plan

The Aylesbury and Buckingham Transport Plans identify six objectives which all transport related schemes should deliver and can be applied across Buckinghamshire, whilst LTP 4 sets out the strategic policies to support these objectives. Last mile mobility should be seen as an opportunity to support the delivery of these objectives as set out in the figure opposite:

Objectives:

1. **Improve air quality** through reduced congestion
2. **Improve accessibility** through increased transport options
3. **Drive behaviour change** by making it easier and more attracive to use active and public transport modes
4. **Enable the ease of movement** in town centres and other urban areas through improved transport access
5. **Improve journey time** by balancing demand across transport modes
6. **Increase transport safety** by reducing the risk of death or injury on the network

LTP 4 policies:

Policy 1: Efficient and effective transport provision
Policy 2: Travelling in Buckinghamshire and beyond; improving our connectivity
Policy 3: Managing the impact of new developments
Policy 7: Reliable road travel
Policy 10: Improving our environment
Policy 12: Encouraging walking for shorter journeys
Policy 13: Encouraging cycling
Policy 14: Car clubs, car sharing and taxis
Policy 15: Intelligent mobility and new technology
Policy 16: Total transport; the bus network Buckinghamshire needs
Policy 19: An effective approach to parking

Enabled through last mile mobility options

Figure 4: Last mile mobility objectives

Buckinghamshire comprises a number of small and medium market towns with large rural areas resulting in a range of transport needs, opportunities and challenges. By setting out the objectives we can see that Buckinghamshire are particularly seeking to enable journeys across this diverse environment that are:

Active	Through transport modes which promote health and wellbeing
Convenient	By providing a multitude of transport choices aligned to travellers needs
Door-2-Door	Enabled by an integrated (physical and digital) multimodal transport system
Efficient	Through a transport network that is planned and operated based on clear processes and demand-supply data-supported decisions
Inclusive	Enabling transport modes which do not discriminate and empower all types of users
Informed	Enabling users to make informed decisions about their journey's route, mode and travel time
Reliable	Through a reliable and resilient transport network that is efficiently maintained
Safe	Where the safety of users and operators of the transport network is embedded in every aspect of the network development and operation
Sustainable	Through environmentally and economically sustainable transport modes that support the clean growth and decarbonisation agenda

In order to deliver these objectives and provide the types of journeys set out above the developed roadmap focuses on last mile mobility modes, with each mode requiring a set of enabling activities to maximise the benefits of deployment. These modes and enabling activities are explored in further detail in the following section.

4

Last Mile Mobility Roadmap

The Buckinghamshire Last Mile Mobility Roadmap is developed to help shape the development of future policies, act as a tool to prioritise future investments and identify required actions that support these investments.

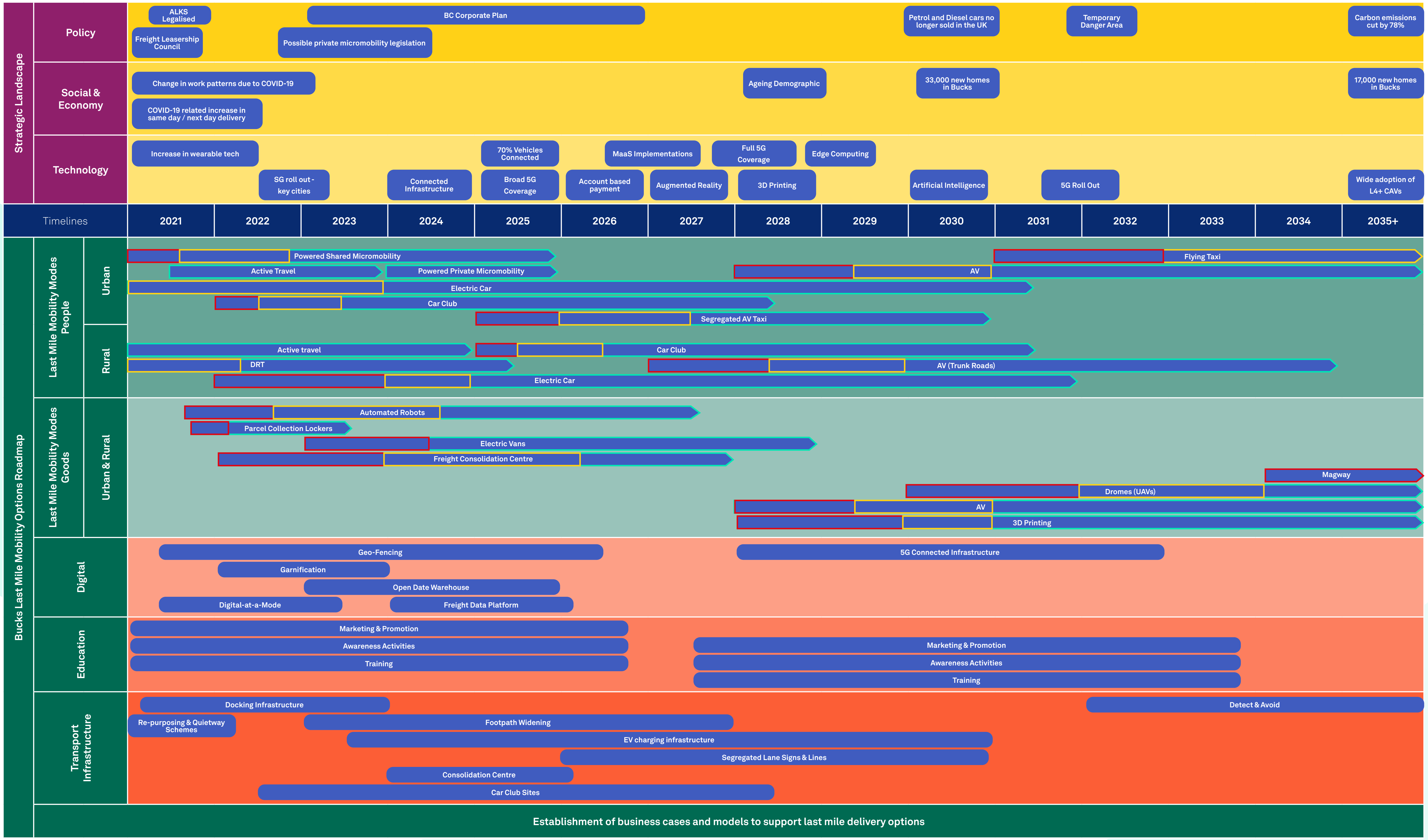
The roadmap covers the period 2021 - 2035. It identifies a range of last mile mobility modes which support the delivery of the six strategic objectives outlined in ***section 3*** and the key activities required to support these modes. These modes and activities can be grouped into six key categories:

- **Last mile mobility solutions (people):** a range of options for providing new and improved mobility modes for the movement of people to their destination or onward journey
- **Last mile mobility solutions (goods):** a range of options for providing new and improved mobility modes for the movement of goods to their destination or onward journey
- **Digital:** the supporting digital requirements for last mile mobility modes covering digital transformation, digital infrastructure, data processing and information extraction
- **Education:** covering headline activities needed for particular last mile mobility modes which require more intensive education and understanding beyond typical messaging
- **Transport infrastructure:** expansion, upgrade and creation of new infrastructure to support the last mile mobility modes
- **Commercial opportunity:** the creation of business cases and business models which are needed to support all last mile mobility modes.

Buckinghamshire need to carefully investigate the commercial opportunity for each last mile mobility solution which will vary depending on the characteristics of the solution but will be key to the successful long-term implementation. In addition, the roadmap recognises the wider political, social and technological landscape which has significantly changed over the past year as a result of COVID-19.

For each last mile mobility solution considered we referenced our earlier literature review (see Appendix B for reference sheet) and drew on expertise within the Connected Places Catapult to map approximate timescales for when solutions can realistically provide a viable option for Buckinghamshire. ***Figure 6*** presents the overall Buckinghamshire Last Mile Mobility Roadmap covering the six identified categories. Furthermore, for last mile mobility solutions people we have associated timelines based on geography (Rural or Urban) to highlight where the modes can most feasibly be deployed.

Most of the outlined activities in ***Figure 5*** consist of an underlying set of sub-activities which would: 1) assess the feasibility and benefits of the concept, technology or service in a Buckinghamshire context; 2) run a pilot to evaluate the outcomes and opportunity; 3) rollout of the service or technology over a defined time, geography and service level scale before transitioning to BAU.



Notes

- The development phases are shown as linear for clarity, however for some options there maybe overlap between the phases. For example, the powered shared micromobility option pilots may form part of the ongoing feasibility.
- The key to the right groups the development cycle into three board phases for the purposes of clarity with the roadmap. Should Bucks take forward any option there are likely to be a number of additional phases such as design.
- Powered micromobility includes a subset of options which follow a broadly similar implementation paths such as e-scooters and e-bikes.
- Active travel includes a subset of options which follow broadly similar implementation paths such as walking and cycling.

Key

Feasibility = feasibility of the option for Bucks or similar area (not when the option becomes a feasible solution in general i.e. the option may be feasible at an earlier state for testbeds and urban conurbations such as London)

Pilot = trial of the option and assessment of benefits before potential scaled rollout

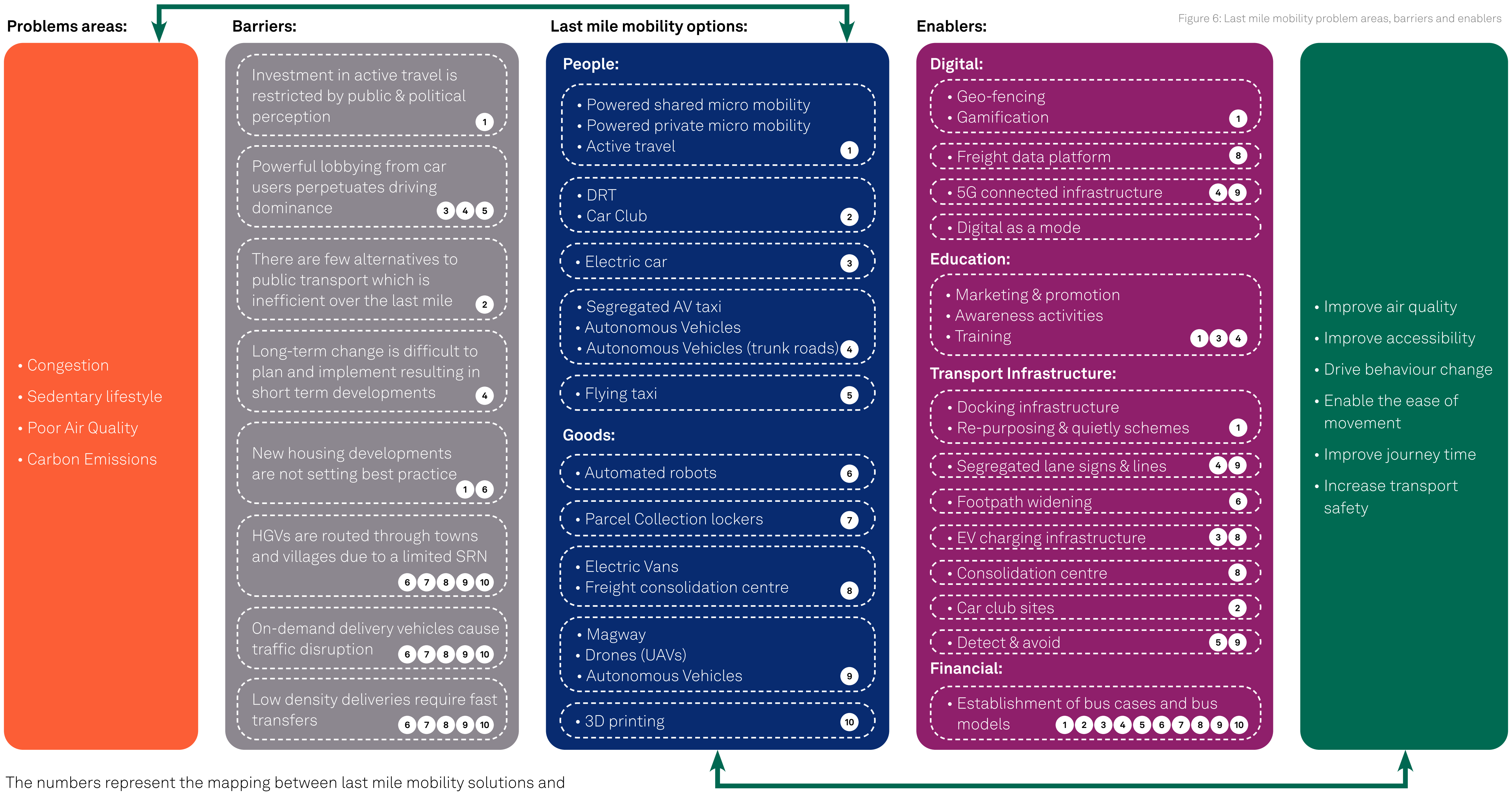
Rollout = scaled roll out of the option before embedment into BAU

Through our extensive engagement with Buckinghamshire Council employees we were able to thematically group the four problem areas and the key barriers for implementation of each last mile mobility mode. Furthermore, for each last mile mobility solution there are enabling activities which need to be delivered for successful implementation. These relationships are reflected in ***Figure 6***.

The Last Mile Mobility Roadmap offers Buckinghamshire with a view of a range of innovative and cutting-edge transport modes to address each of the four problem areas and meet the desired objectives. Whilst it provides a holistic view of multiple available modes it should not be seen as essential to deliver all of the last mile mobility solutions. Each solution will deliver incremental benefits and contribute towards delivery of the overall objectives and as such, Buckinghamshire should closely monitor and evaluate the success of any implementation.

Furthermore, the roadmap should be considered a live document that is regularly reviewed and updated to ensure it reflects technological, social and political changes and continues to align with Buckinghamshire's objectives.

Figure 6: Last mile mobility problem areas, barriers and enablers



The numbers represent the mapping between last mile mobility solutions and the relevant barrier, and enablers

5

Appendix A

Table of documents reviewed

Document name	Period covered
England's Economic Heartland Transport Strategy	2021 – 2040
Buckinghamshire Strategic Plan	2017 – 2020
Buckinghamshire Corporate Plan	2020 – 2023
Buckinghamshire Council TEE Business Unit Plan	2019 – 2023
Local Transport Plan 4	2016 – 2036
Aylesbury Transport Strategy	2016 – 2033
Buckingham Transport Strategy	2016 – 2033
Freight Strategy	2018 – 2036
Getting to School Strategy	2016 – 2036

Appendix D5 – Technology roadmap

6

Appendix B

Table of references for last mile mobility solutions

Last Mile Mobility Mode	Reference	Comments
Powered shared micromobility	E-scooter trials: guidance for users: https://www.gov.uk/guidance/e-scooter-trials-guidance-for-users Mobike, Bike-sharing and the City, April 2017, accessed from: https://mobike.com/global/public/Mobike%20-%20White%20Paper%202017_EN.pdf	Includes a number of mobility options such as e-scooters, e-bikes, docked and dockless all of which can be deployed / are being piloted in Bucks
Powered private micromobility	Guidance powered transporters: https://www.gov.uk/government/publications/powered-transporters/information-sheet-guidance-on-powered-transporters	Legislation does not currently allow for powered private micromobility on public highways
Active travel	Just Economics, The Pedestrian Pound: the business case for better streets and places, updated 2018, accessed from: https://www.livingstreets.org.uk/media/3890/pedestrian-pound-2018.pdf Six contenders for emergency active travel plan, accessed from: https://www.buckinghamshire.gov.uk/news/six-contenders-emergency-active-travel-plan/	COVID-19 has resulted in an increase in the requirement for active travel options which can be and are being rapidly deployed
Electric car	Aylesbury charging point locations, ZapMap: https://www.zap-map.com/locations/aylesbury-charging-points/	Limited number of EV charging sites deployed until funding supports a full scale rollout
Car club	Surrey County Council, Car clubs, accessed October 2020, accessed from: https://www.surreycc.gov.uk/roads-and-transport/sustainable-driving/car-clubs	Technically feasible - requires establishment of commercial model
Demand responsive transport	Council secures Government cash for new rural local transport schemes: https://www.buckinghamshire.gov.uk/news/new-rural-local-transport-schemes/	Funding secured for DRT services in Aylesbury and High Wycombe over the next four years
Segregated AV taxi	Michigan plans dedicated road lanes for autonomous vehicles: https://abcnews.go.com/Technology/wireStory/michigan-plans-dedicated-road-lanes-autonomous-vehicles-72352758	

Last Mile Mobility Mode	Reference	Comments
Autonomous vehicle (trunk roads)	SMMT Connected Report 2019: https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-CONNECTED-REPORT-2019.pdf	The UK autonomotive sectors view that AVs meeting requirements of SAE L4 from 2025 onwards
Flying taxi	Dubai to get its own sky lanes for flying taxis and drones: https://www.dubailad.com/dubai-to-get-its-own-sky-lanes-for-flying-taxis-and-drones/	Dubai are leading the way with this mode with commercial flights expected to be available in 2022. Significant legislative work needs to be undertaken in the UK to facilitate this mode as a long term option
Automated robots	Robots deliver food in Milton Keynes under coronavirus lockdown, 2020, accessed from: https://www.theguardian.com/uk-news/2020/apr/12/robots-deliver-food-milton-keynes-coronavirus-lockdown-starship-technologies	Starship robots currently deployed in Milton Keynes to undertake food deliveries
Amazon lockers	Warwick University, Amazon Lockers, accessed October 2020, accessed from: https://warwick.ac.uk/services/retail/shops/amazon	Deployed in multiple UK cities
Electric vans	DPD, DPD boosts electric fleet to 600 with UK's first MAN Truck & Bus 3.5t right-hand drive electric vans, accessed October 2020, accessed from: https://www.dpd.co.uk/content/about_dpd/press_centre/dpd-uk-boosts-electric-fleet-to-600-with-uks-first-MAN-electric-vans.jsp#:~:text=The%20parcel%20industry%20EV%20leader,to%20600%20vehicles%20in%20total	Requires take up from industry. DPD are taking steps to have the largest electric van fleet in the UK
Freight consolidation centre	Transport for London, The London Boroughs Consolidation Centre – a freight consolidation success story, accessed from: http://content.tfl.gov.uk/lbcc-case-study.pdf	The London boroughs consolidation centre has been successful. Requires significant infrastructure investment
Drones	Solent Transport, Drones will be used to transport medical supplies across the Solent to support the response to COVID-19, April 2020, accessed from: https://www.solent-transport.com/news/item/drones-will-be-used-to-transport-medical-supplies-across-the-solent-to-support-the-response-to-covid-19	Solent transport commenced trials of UAVs as part of the DfTs Future Transport Zones. Further work needs to be undertaken in relation to legislation and trials in an urban environment
3D printing	A. Mckinnon, The Possible Impact of 3D Printing and Drones on Last-Mile Logistics: An Exploratory Study, Built Environment, December 2016, Volume 42, Pages 617-629, DOI: 10.2148/benv.42.4.617	Currently, domestic 3D printing is not highly utilised due in part to high unit costs. May become a more viable product as unit cost and size reduce
Magway	J. Bates, Airport World, Going underground, September 2020, accessed from: https://airport-world.com/going-underground/	Technology will potentially be deployed in Heathrow. However, the commercial viability of implementing a similar technology in a local environment is unclear at this stage

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