Automated Road Transport Forum for the North Sea Region (ART-Forum)

Roadmap: Laws, regulations and planning issues to be considered if introducing an autonomous bus service in West Yorkshire

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Executive Summary

Introduction

This report discusses the laws, regulations, and land use and spatial planning issues to be considered, should the West Yorkshire Combined Authority (WYCA) wish to introduce autonomous bus services to the region. It is designed to complement the modelling work currently being conducted by colleagues at the RGU School of Computing.

It is based on two assumptions: 1) that the WYCA will initially wish to become involved in autonomous passenger vehicle trials; and 2) that these trials (and any subsequent permanent services) will be based upon the use of vehicles that have a larger passenger capacity and/or are capable of faster speeds than the small autonomous shuttle bus vehicles used in most UK and European trials to date.

It consists largely of a flow chart (see page 10) and accompanying explanatory text, and presents a series of 15 interrelated steps (labelled ‘a’ to ‘o’) that should be followed, when planning and implementing an autonomous bus trial. The 15 steps do not follow a precise chronological order, as many of them require to be conducted simultaneously, and in collaboration with other stakeholders. They may also require revision as a pilot project progresses. They are, however, presented here in four broad chronological groupings or ‘phases’.

Phase 1

a) Consider the relationship and relevance of the proposed pilot to regional, local, and institutional, transport and spatial planning policies.

Phase 1 consists of only one step, in which a proposed autonomous trial is considered in relation to regional, local and organisational priorities and policies. Particular attention has been paid to north and north-west Leeds, the area on which RGU’s modelling work has so far focused. While transport and planning policy documents have rarely made explicit reference to *autonomous* transport, they do highlight a need for better-connected and more sustainable public transport options across north Leeds. It might be argued, then, that the introduction of autonomous bus services would be closely aligned with regional and local strategies.

Phase 2

Phase 2 consists of six preparatory steps that are more administrative in nature.

b) Identify potential route(s) and establish ownership of roads and land

An important early stage in the process is identifying potential routes for the autonomous bus service, and establishing the ownership of the roads and land on which these routes would operate. On establishing ownership, the trialling organisation will then be in a position to seek any permissions required to conduct the pilot. In considering the associated modelling work being conducted by the RGU School of Computing, it has been assumed that most, if not all, of the roads included in the modelling process are public highways that have been adopted by Leeds City Council.

c) Identify potential vehicles and vendors, and undergo procurement process
A prerequisite for an autonomous bus trial will, of course, be the acquisition of a suitable vehicle. This report focuses on two vehicles: the 10-seat Aurrigo Shuttle, which has been used in trials in Cambridge and Birmingham-Solihull; and the 36-passenger Alexander Dennis Enviro200 bus, currently being used in the CAVForth trials between Edinburgh and Fife. This report argues that the more conventional specifications of these vehicles align more readily with current regulatory requirements.

d) Engage with targeted passenger community and other local stakeholders
Observers generally agree that the trialling organisation should undertake initial engagement with potential users of the service and with other stakeholders, such as local businesses, who may be affected by the service. In considering any proposed autonomous bus services in north and north-west Leeds, the WYCA and Leeds City Council might wish to engage with: local parish and town councils and other community groups, such as Horsforth Town Council and the Adel Neighbourhood Forum; the student and staff bodies of Leeds Trinity University in Horsforth, and Leeds Beckett University's Headingley campus; large local businesses and enterprises, such as Leeds Bradford Airport; and representatives of business support groups, such as the West & North Yorkshire Chamber of Commerce or the Federation of Small Businesses in West Yorkshire.

e) Obtain approval (including vehicle approval) from the CCAV, the DVSA, the VCA, other public authorities, or landowners
Should the WYCA decide to conduct autonomous bus trials, they should engage with the following organisations at the earliest opportunity: the UK Government's Centre for Connected and Autonomous Vehicles (CCAV); the appropriate highways authorities (most probably Leeds City Council and National Highways, the latter only if any major 'A' roads form part of the proposed bus route); local authorities (again, most probably Leeds City Council); the Traffic Commissioners for Great Britain (the North east of England office, in Leeds); and West Yorkshire Police.

Approval to use the trial vehicles on public roads is typically sought by the vehicle manufacturer or vendor. This will require engagement with the Driver & Vehicle Standards Agency (DVSA) and/or the Vehicle Certification Agency (VCA).

f) Obtain appropriate insurance
It will be necessary to obtain appropriate insurance for any vehicle(s) used in the trial. While some problems have been encountered in obtaining cover for small, pod-like, autonomous shuttle vehicles, no such problems have been reported (at least publicly) in the trials involving the Aurrigo Shuttle and Alexander Dennis Enviro200 vehicles.

g) Prepare safety case
Two key documents have emerged relating to the need for a site-specific, operational safety case, which demonstrates that a trial can be conducted safely, and provides details of how any adverse incidents will be managed. These are: the British Standard Institution's PAS 1881: 2022; and Zenzic's 2021 *Safety Case Framework*. The former advises that a safety case be structured in 14 distinct sections. Zenzic argues that trials involving the carriage of passengers (as would be the case in any West Yorkshire trials) should be regarded as "high complexity", and should therefore contain the most robust supporting evidence. When complete, an abridged version of the safety case should be made publicly available, and a copy also sent to the CCAV.

Phase 3
Phase 3 consists of four, more practical, preparatory steps.

h) Survey, map and program the chosen route
A more thorough examination of the chosen route will be required. This should establish the route's more detailed topography, and should identify any fixed, physical hazards (e.g., junctions with other roads/paths, tight bends, street furniture, etc.), and any dynamic, moving hazards (i.e. other vehicles, pedestrians, cyclists, pushchairs, dog walkers, etc.) that the autonomous vehicle is likely to encounter along the route.

The projects reported in the literature (usually involving small shuttle vehicles) have typically used simultaneous localisation and mapping (SLAM), where the vehicle navigates along its prescribed route by using its cameras and 3D sensors to create a digital map of its surrounding environment, comparing this with an existing, pre-programmed map of the route. To create this pre-programmed 3D map, the vehicle is driven, manually and at a very slow speed, along the proposed shuttle bus route, perhaps a number of times. This is done in collaboration with the vehicle vendor.

As any West Yorkshire project is likely to operate on public highways, with mixed traffic, such an approach may not be practicable. Perhaps of more relevance, then, are the processes adopted by the CAVForth project, where the vehicles are to operate on part of Scotland's trunk road network at speeds of up to 50mph. Here, the route survey consisted of a number of higher-speed drive-throughs, with route data being captured in the form of LIDAR (Light Detection and Ranging) scans and dash cam recordings. A digital twin of the CAVForth route was also created, to allow simulated journeys and hazardous scenario testing.

i) Identify and install any additional infrastructure or equipment required
The mapping processes will assist in identifying any infrastructural modifications, or any additional equipment, that may be required on the chosen route(s). These might include new or repaired road surfaces and lane markings; bus stops and shelters; new signage (perhaps including 'localisation signs'); smart traffic lights and other warning lights; traffic-calming measures for other vehicles; parking restrictions on the route; the installation of additional communications equipment; the creation of a 'control room', to monitor the vehicles remotely; and/or the creation of a garage or depot for bus storage, charging and maintenance. Much will depend here on the length and complexity of the chosen route, anticipated levels of passenger demand, and the likely permanence of the bus service.

j) Obtain any necessary permissions or approvals for additional infrastructure or equipment
Should a need be identified for additional parking or waiting restrictions, a revised speed limit, or new road markings and signage, then permissions and approvals would have be sought from the local highways authority (most probably Leeds City Council).

If additional communications equipment is found to be necessary, then permission may be required from the local planning authority (again, Leeds City Council). Similarly, planning permission will probably have to be sought if additional, temporary accommodation for the autonomous vehicles is required for the duration of the trials.

k) Train the vehicle's operators/conductors, and any other staff required

The CCAV's 2022 *Code of Practice: Automated Vehicle Trialling* states that any AV trial in the UK must have a driver or operator, in or out of the vehicle, who is ready, able, and willing to resume control of the vehicle. For trials on public roads, the driver/operator must hold an appropriate driving licence; and for trials not conducted on the public road, it is *strongly recommended* that a licence be held.

The CCAV further recommends that trialling organisations should develop robust procedures to ensure the competency of safety drivers/operators; and that they undergo continuous development and training. With this in mind, the driver(s)/operator(s) on any West Yorkshire trial services should undertake a training programme that covers the processes involved in driving the vehicle, both in manual mode and automated mode, and in transitioning between the two modes. This training should also cover the potentially hazardous situations that might be encountered throughout a trial, and what actions they should take when resuming manual control of the vehicle. Such training is usually provided by the vehicle manufacturer or vendor.

Phase 4

The final phase, Phase 4, is the day-to-day operational phase of the autonomous bus trial and will consist of four steps.

l) Review mapping and programming processes as required

Should there be any significant physical changes to the route during the course of the pilot project (e.g., roadworks, or the erection of new building or other structures), then the vehicle's existing map will have to be updated and potentially re-programmed. Although, ideally, the identification of any planned infrastructural changes would have formed part of the initial route identification process, so that these can be taken into account in advance, or an alternative route found.

m) Operate pilot service

This step effectively consists of the day-to-day operation of the autonomous vehicle(s) on the prescribed route, which hopefully will run safely whilst adhering to any proposed timetable. However, the literature reports a number of factors (both human and environmental) that might impede an autonomous bus's progress along its route.

In terms of weather conditions, for example, heavy rain, sleet, snow, or fog might interfere with the vehicle's navigation; as might bright sun reflecting off of street furniture, and any roadside detritus blown up during windy conditions. Damp weather and extreme temperatures (both high and low) might test the vehicle's heating, ventilation, and air conditioning systems, and have a knock-on effect on its operational capacity, before it needs to be recharged. Falling leaves and low-hanging branches can force a vehicle to stop, as can birds and animals passing in front of its sensors.

In terms of human behaviour, the bus's journey may be interrupted by the (sometimes deliberate) actions of any nearby pedestrians. This might take the form of people 'testing' the vehicle's capacity to stop by running or jumping in front of the vehicle. Or, in the longer term, people who know that the vehicle will stop, simply walking in front of it without giving any consideration to the passengers' journey time and onboard experience.

n) Evaluate operation of pilot service

An important part of the overall process will be the *ex post* evaluation of the pilot project. As a minimum, this evaluation should consider the overall performance of the vehicle and its automated driving system (ADS); and also the passengers' perceptions of the trial service, in terms of its speed, comfort, reliability, safety, and overall usefulness.

More extensive evaluation might look at the perceptions and behaviour of other road users. Any WYCA project team might also want to consider conducting cost-benefit analyses, that explore the potential for autonomous bus trials in north and north-West Leeds to become long-term, financially sustainable services.

o) Review and update safety case as required

The safety case should remain a live document throughout the duration of the trial. As such, it should reflect any amendments that are made following, for example: a change of route; changes to the vehicle's hardware or software; incidents or near misses; or any other lessons learned during the trial. These edits should be logged systematically, ensuring that an audit trail is maintained.

Potential processes when introducing permanent, post-trial, autonomous bus services in West Yorkshire

In addition to discussing the numerous issues that need to be considered before an autonomous bus trial can be undertaken 'on the ground' in West Yorkshire, this report exploresd the longer-term regulatory requirements for the introduction of post-trial autonomous bus services in the region. Here, the report has drawn primarily on the Law Commissions' (2022) recommendations to the UK, Scottish and Welsh Governments.

A key factor will be whether or not the autonomous buses have a user-in-charge onboard throughout the journey. If a user-in-charge is onboard, the Law Commissions believe that no fundamental changes to existing bus legislation will be required. However, for No User-in-Charge (NUIC) services, a new licensing system is proposed. Until more is known about how passenger services will operate in the absence of a driver, the Law Commissions have recommended that an interim passenger permit scheme be introduced in the UK.

Automated Road Transport Forum for the North Sea Region (ART-Forum)

Laws, regulations and planning issues to be considered if introducing an autonomous bus service in West Yorkshire

1. Introduction and background

This document makes an initial effort at mapping the laws, regulations, and land use and spatial planning issues to be considered, should the West Yorkshire Combined Authority (WYCA) wish to introduce autonomous bus services to the region. It is designed to complement the modelling work currently being conducted by colleagues at the Robert Gordon University (RGU) School of Computing.

The work here is based on two broad assumptions. Firstly, that the WYCA will initially wish to become involved in autonomous vehicle trials. In this regard, the WYCA's 2020 *Future Mobility Strategy* indicated a desire to "investigate opportunities" for connected and autonomous vehicle (CAV) trials in the region in the medium-term (i.e. within 2-5 years), with a focus on shared and public transport CAV technologies (WYCA, 2020a, p.14).

The second assumption is that these trials (and any subsequent permanent services) will be based upon the use of vehicles that have a larger passenger capacity and/or are capable of faster speeds than the small autonomous shuttle bus vehicles that have been used in most UK and European trials to date (including by ART-Forum partner, Aalborg Kommune). The RGU School of Computing's modelling work so far has been based on vehicles travelling at an average speed of 32 km/h (20 mph). And while some shuttle bus vehicles are capable of such speeds, Hagenzieker *et al.* (2020, p.13) report that pilot schemes have typically operated at less than 21 km/h (13mph). Furthermore, these small 'pod-like' vehicles usually lack conventional controls and features (e.g., steering wheel, pedals, wing mirrors), and therefore do not meet current regulatory requirements for use on UK public roads (Talbot *et al.*, 2020; Urban Transport Group, 2020, p.12).[1] Section 3c of this present report further considers the choice of autonomous vehicles for passenger-carrying trials.

It should be emphasised that this document has been written at a time when there is considerable fluidity within the field of CAV planning, trialling, and regulation in the UK. Most importantly, the Law Commission (of England and Wales) and the Scottish Law Commission (hereafter referred to jointly as the Law Commissions) have recently completed a three-year review of the UK's regulatory framework for CAVs.[2] The Law Commissions' final report, published in January 2022, contained 75 recommendations for the UK, Scottish and Welsh Governments. And while the three governments have yet to decide whether these recommendations should be accepted, and what legislation should be introduced to bring them into effect, the work of the Law Commissions has been very influential in preparing this present document.

The Zenzic *Safety Case Framework* (Zenzic, 2021a & 2021b), which has been adopted by the UK's CAV testbed 'ecosystem', CAM Testbed UK[3]; and the revised PAS (Publicly Available Specification) 1881, now entitled *Assuring the Operational Safety of Automated Vehicles - Specification*, published in April 2022 (British Standards Institution, 2022) have also been significant. Both documents are integral to the *Code of Practice: Automated Vehicle Trialling*, produced by the UK Government's Centre for Connected and Autonomous Vehicles (CCAV) and updated most recently in January 2022.

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[1] Plus personal correspondence with the Centre for Connected and Autonomous Vehicles (CCAV), 25 September 2020
[2] See https://www.lawcom.gov.uk/project/automated-vehicles/
[3] See https://zenzic.io/testbed-uk/

It should also be borne in mind that the technologies used in CAVs are dynamic and constantly evolving (Law Commissions, 2020, p.131); and the time frames for their maturation are “unclear, and their impacts highly uncertain” (Government Office for Science, 2019, p.88). Future technological developments may well render some of the contents of this present report less relevant and/or out of date. As the Urban Transport Group (2020, p.5) argues:

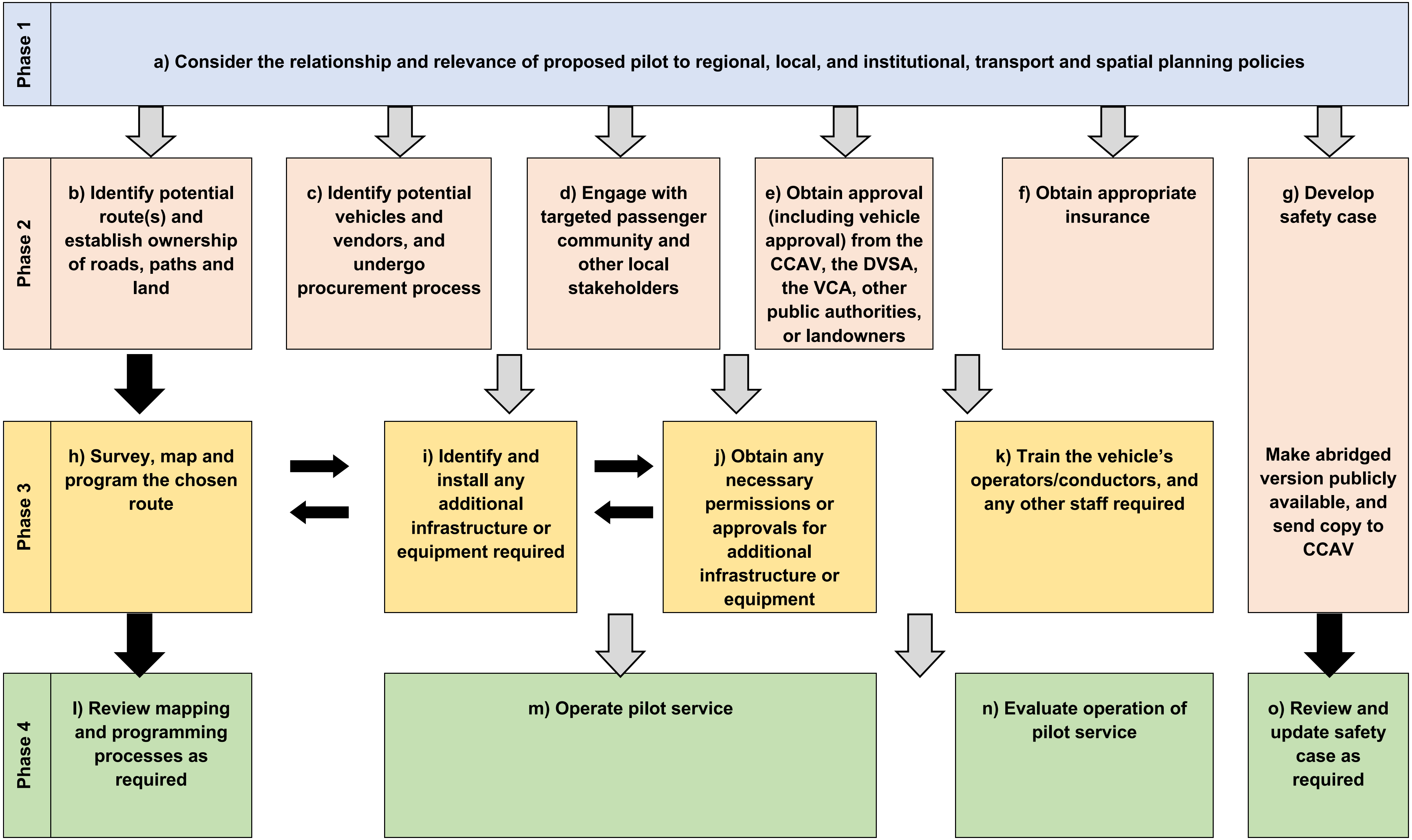
> “...CAVs are, and will continue to be, a moving target with live implications at every twist and turn rather than a single leap to a pre-determined end state on which all thinking and policy making should focus on accommodating.”

With these points in mind, this document should be regarded only as a ‘snapshot’ of the regulatory situation facing WYCA, as of May 2022. It has been compiled following an extensive literature search and review, together with interviews and personal correspondence with individuals currently involved with CAV trials across the UK. The rest of the document is structured as follows:

Section 2, on page 10, consists of a flow chart which represents the steps and processes that will be involved in implementing an autonomous bus service pilot in West Yorkshire; while Section 3 provides accompanying explanatory text that discusses each step in further detail.

Section 4 provides some initial observations on the processes that are likely to be involved in the introduction of any permanent *post-trial* autonomous bus services in West Yorkshire. As the regulatory framework for such services does not yet exist, these observations are very much based on the Law Commissions’ recommendations in their final report (2022). Finally, Section 5 presents some brief conclusions.

2. Flowchart: steps in introducing an autonomous bus pilot project in West Yorkshire



3. Steps in introducing an autonomous bus pilot project in West Yorkshire

In viewing and interpreting the flow chart on the previous page, a number of points should be borne in mind. First, the overall procedure will not be a strictly linear one: many of the processes will require to be conducted simultaneously, and may also need ‘revisiting’ as any trial project progresses.

Second, each of the boxes (representing steps) in the flow chart has an associated letter, i.e., a, b, c, etc. These letters should not be regarded as representing precise chronological stages in the overall process: rather, they act only as ‘signposts’ to the relevant sections of the accompanying text below. However, the steps *have* been arranged, and colour-coded, in four broad chronological groupings or ‘phases’: **Step a, in blue**, represents the first, overarching **Phase 1** of the process, when a proposed pilot project is considered in relation to regional, local, and organisational priorities and policies; **Steps b to g, in pink**, represent the more administrative preparatory stages of **Phase 2**, where stakeholders are consulted and permission to conduct the pilot is sought; **Steps h to k, in yellow**, represent the more practical preparatory stages of **Phase 3**, where the route, vehicle, and operational staff are made ready, in advance of the pilot; while **Steps l to o, in green**, represent the final (and ongoing) phase, **Phase 4**, which occurs when the pilot project is operational.

With regard to the arrows linking the boxes on the flow chart, these largely represent movement between the four broad phases, rather than direct, sequential linkages between specific steps in the process. Where direct, sequential links between steps *are* identified, these are connected with solid black arrows (e.g., with Steps b, h and l).

Finally, the existing literature on autonomous passenger vehicle trials (see, for example, Alessandrini, 2018; Müür *et al.*, 2020) emphasises that the overall procedure should be very much a *collaborative* effort between the trialling organisation and other stakeholders and interested parties. As will be discussed in the text that follows, a number of the steps will rely, in particular, on close collaboration between the trialling organisation and the vehicle’s manufacturer/vendor.

a) Consider the relationship and relevance of the proposed pilot to regional, local, and institutional, transport and spatial planning policies

As part of CityMobil2 — a European Commission-funded research project that trialled autonomous shuttle buses in seven European cities — Stam *et al.* (2015) and McDonald *et al.* (2018) advised that “step zero” of the implementation process should consist of a preliminary “site diagnosis”, where an analysis is made of the political and planning context of the city or area in which the trial is to be conducted. Here, they suggested, local and regional policies and strategies should be scrutinised, in order to establish how a CAV trial might contribute towards meeting local objectives.

With regard to West Yorkshire, the WYCA’s current transport strategy, to 2040, notes that:

> “Connected and autonomous/driverless vehicles have the potential to transform transport provision and usage, with the ability to make better use of highway capacity as well as encouraging new models of car sharing. We will develop our approach to the deployment of autonomous vehicles on our roads, as the technology is tested through pilot projects in the UK ensuring that this new form of travel becomes well integrated with other modes.” (WYCA, 2017a, p.48)

And, of course, it has already been observed that the WYCA's 2020 *Future Mobility Strategy* has indicated a desire to explore opportunities for CAV trials in the region, with a particular focus on shared and public transport CAV technologies. With specific reference to bus services, WYCA has also produced a *Bus Strategy* (WYCA, 2017b) and a *Bus Service Improvement Plan* (2021a). And while neither document explicitly mentions the use of autonomous vehicles, both express a wish to see a modern, integrated and innovative bus system across the region. Meanwhile, West Yorkshire's *Mass Transit Vision 2040* (WYCA, 2021b) indicates that the region may introduce tram, light rail, tram-train, and/or advanced bus rapid transport technologies between, and within, its metropolitan areas, which will be integrated with an improved, existing public transport system. Again, though, the potential use of autonomous vehicles is not discussed.

At the more local level, the West Yorkshire *Connectivity Infrastructure Plan* (WYCA, 2021c) is described as an extension of the Transport Strategy 2040 and sets out a long-term transport infrastructure investment programme for the next 20 years. This plan was informed by a process in which West Yorkshire was divided into ten "corridors" (see Figure 1), each being the subject of a "case for change" study by Mott MacDonald.

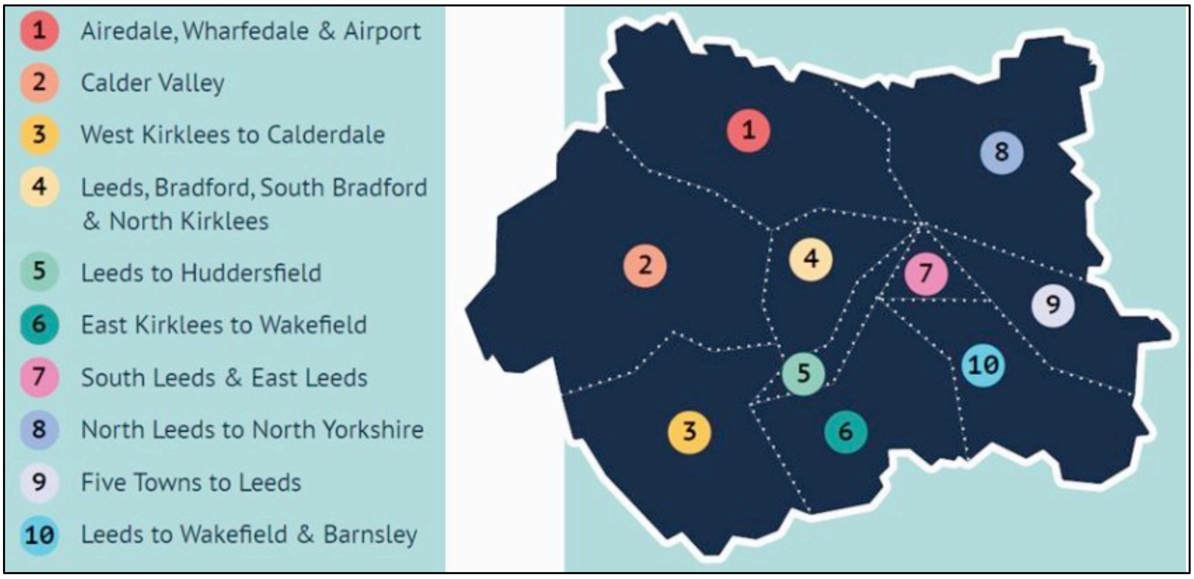


Figure 1: West Yorkshire Connectivity Plan: Reporting Map (Mott MacDonald, 2020a, p.3)

In this present report, these corridors have been considered in relation to the work being carried out by colleagues at RGU's School of Computing. As Figure 2 illustrates, the modelling work to date has focused on potential bi-directional and circular routes within an area of north and north-west Leeds, with each route incorporating a stop at Horsforth Station. Located around 5 miles north-west of Leeds city centre, Horsforth appears to the bottom left (i.e. in the south-west) of each of the maps in Figure 2. This area, then, encompasses the south-east part of Corridor 1 ("Airedale, Wharfedale & Airport") and the south-west part of Corridor 8 ("North Leeds to North Yorkshire"). In the respective "case for change" reports, Mott MacDonald (2020a, p.33; 2020b, p.36) highlights the communities within these areas that require better connectivity.

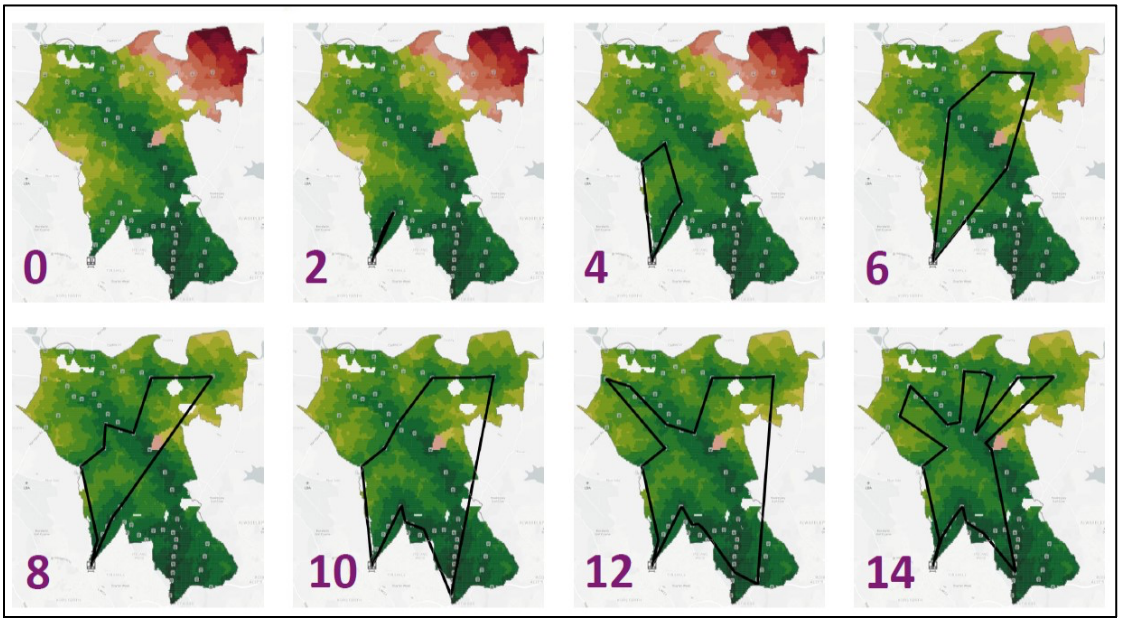


Figure 2: Area of north-west Leeds on which RGU's CAV-based route modelling has been focused (Han *et al.*, 2022)

Also worthy of further mention is West Yorkshire's *Mass Transit Vision 2040*, which adopts a different corridor-based categorisation of the region. Here, the area on which RGU's computer modelling has focused borders the eastern edge of the "Bradford and North West Leeds" corridor, and incorporates part of the "North Leeds" corridor (see Figure 3). The vision document identifies opportunities for the introduction of, and/or better connections to, mass transit developments in these two corridors.

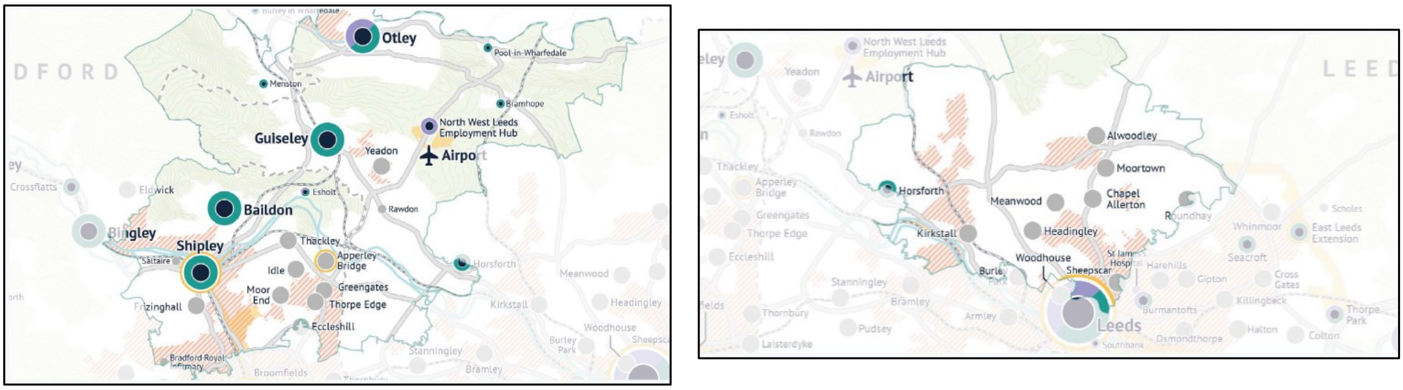


Figure 3: The Bradford and North West Leeds corridor (left) and the North Leeds corridor (right), from West Yorkshire's Mass Transit Vision 2040 (WYCA, 2021b, pp.40-43)

Leeds City Council has its own transport strategy (*Connecting Leeds*), and an associated action plan to 2024 (Leeds City Council, 2021a & 2021b). Here, while a need is expressed to have "a bus network that connects everyone and everything" (2021a, p.37), autonomous vehicles are discussed only at the broadest level:

"The technology for autonomous vehicles is advancing across the world. Making this technology work safely in a densely populated urban environment, however, is still a huge challenge. We need to be able to adapt to this technology as it develops within the framework of the strategy, ensuring solutions are inclusive, healthy, low carbon and an efficient use of roadspace." (2021a, p.41)

With regard to spatial planning in West Yorkshire, this is the responsibility of the individual local authorities that constitute the region; although, as agreed in a *Statement of Common Ground* (WYCA, 2020b), these should be complementary and should collectively reflect shared economic, environmental and social priorities.[4] Again using the area modelled by RGU's School of Computing as a reference, the *Leeds Local Plan* (Leeds City Council, 2019a) is of most relevance here.[5] Interestingly, the *Leeds Local Plan* highlights the need for "a co-ordinated and comprehensive relationship between development and transport to facilitate sustainable communities and ensure Leeds' continued economic success" (p.50).

For local planning purposes, Leeds is divided into a number of "Housing Market Characteristic Areas", with the RGU modelling area forming part of "North Leeds" (see Figure 4). The *Leeds Local Plan* identifies North Leeds as one of the areas in the city where opportunities for development of previously developed land and regeneration are greatest; while also observing that they provide sustainable locations in terms of public transport connections (p.42). A more detailed report (Leeds City Council, 2019b) identifies sites, across North Leeds, that could be allocated for housing, with a target of 6,000 residential units having been set (p.210). It also identifies communities where there may be scope for additional retail developments (pp.208-9).

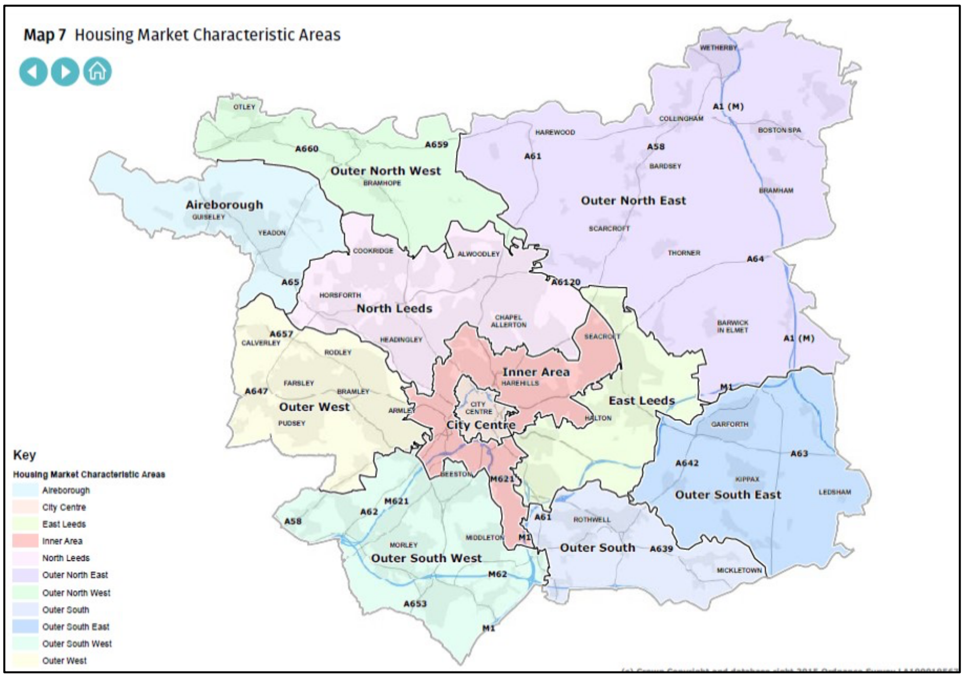


Figure 4: Leeds Housing Market Characteristic Areas (Leeds City Council, 2019a, p.43)

[4] See also https://www.westyorks-ca.gov.uk/growing-the-economy/strategic-economic-framework/policies-and-strategies/spatial-planning/
[5] See also https://www.leeds.gov.uk/planning/planning-policy/adopted-local-plan

At an even more localised level, the town of Horsforth, for example, has its own *Neighbourhood Plan* (Horsforth Town Council, 2019), which envisages that, by 2028, housing growth will have taken place, but in the knowledge that "complementary and essential infrastructure, facilities and services have kept pace with that housing growth" (p.9). It also foresees that:

> "A more integrated and improved road, rail and bus network will have developed to serve this larger Horsforth, with a greater emphasis on walking, cycling and equestrian provision, improved car parking provision and more public transport, with less reliance on cars." (p.9)

The suburb of Adel also has a *Neighbourhood Plan* (Adel Neighbourhood Forum, 2016), which seeks to attain better public transport links in the area, including to Holt Park, Horsforth, and Leeds (p.67).

Overall, then, in terms of a preliminary "site diagnosis", while transport and planning policy documents rarely make explicit reference to *autonomous* transport, they do highlight a need for better-connected and more sustainable public transport options across north and north-west Leeds. With this in mind, it might be argued that the introduction of autonomous bus services would be closely aligned with regional and local strategies.

b) Identify potential route(s) and establish ownership of roads and land

Unsurprisingly, an important early stage in the process will be to identify potential routes for the autonomous bus service(s) and establish the ownership of the roads and land on which these routes would operate (Fordham *et al.*, 2018). On establishing ownership, the trialling organisation will then be in a position to seek any permissions necessary to conduct the pilot (of which more is discussed in **Step e**). However, in providing guidance on establishing an autonomous passenger service, some authors have suggested that other factors should also be considered when identifying potential routes. They argue that the chosen route and service should have a clear purpose, and should complement, or add value to, existing mobility options in the vicinity; rather than being viewed only as an opportunity to demonstrate autonomous technologies (e.g., Müür *et al.*, 2020).

There is also an argument that the choice of route(s) for an autonomous bus service should attempt to strike a balance between the known capabilities and limitations of the vehicles that are currently available (see **Step c**), and the learning opportunities that the pilot will provide for the trialling organisation, for example in measuring the interactions between the vehicle, its surrounding environment, and other road users (University of Michigan, 2018; Müür *et al.*, 2020).

In discussing road ownership, the definition of a 'public road' should be considered. The *Highways Act 1980* defines a public road in England and Wales as a "highway maintainable at the public expense", which a local highway authority (i.e. a council) has a duty to maintain (Section 36). Furthermore, the Act requires each council to maintain a list of the roads within their area which are maintainable at the public expense (i.e. "adopted highways"). For the area in north and north-west Leeds discussed here, the highway authority is, of course, Leeds City Council, whose most recent publicly available list of adopted highways is dated November 2018.[6] As was seen in Figure 4, RGU's School of Computing has modelled a range of potential routes across the area. It is perhaps safe to assume that most, if not all, of the roads included in the modelling process are public highways that have been adopted by Leeds City Council.

[6] Available, in CSV format, at https://data.gov.uk/dataset/2a9f3074-e40d-4ffa-8d9a-3033563bdb3f/leeds-city-council-adopted-highways

c) Identify potential vehicles and vendors, and undergo procurement process

A prerequisite for an autonomous bus trial will, of course, be the acquisition of a suitable vehicle. As was noted earlier in **Step b**, the choice of vehicle will be closely intertwined with the choice of route (Müür *et al.*, 2020). The selection of a route may be dictated by the dimensions, passenger capacity and technical capabilities of a preferred vehicle type. Or the choice of vehicle may be dictated by the dimensions and gradients of the existing highways on a preferred route.

It was also noted earlier that most passenger-carrying autonomous vehicle trials conducted so far in the UK and in Europe have used small shuttle bus vehicles that have low passenger capacities and travel at very low speeds. These have included the PodZero and Westfield POD vehicles, both of which have four seats; and the slightly larger EazyMile EZ10 and Navya Autonom vehicles, which can each theoretically carry up to 15 passengers (i.e. with some passengers standing). Furthermore, these types of vehicle typically lack conventional controls and features (e.g., steering wheel, pedals, wing mirrors), and therefore do not meet the current regulatory requirements (see also **Step e**) for use on UK public roads (Talbot *et al.*, 2020). As a result, most UK trials of these small shuttle vehicles have taken place on private roads or land, such as parks or university campuses.

With these points in mind, this present report focuses on two other vehicles that are currently being used in UK trials, the Aurrigo Shuttle and the Alexander Dennis Enviro200 bus (see Figure 5). In common with the smaller shuttles, these vehicles are equipped with Global Navigation Satellite Systems (GNSS) and a complex network of cameras and sensors, with which they scan and understand their surroundings and identify and react to obstacles and hazards. In trials, they have also had a safety operator on board, who has been ready to intervene if the vehicle behaves unexpectedly, encounters any unusual obstacles, or displays any fault warnings. The key difference, however, is that these two vehicles combine autonomous technologies with conventional controls.

Figure 5: Aurrigo Shuttle (left) and Alexander Dennis Enviro200 bus[7]

[7] Images from https://futuretransport-news.com/ and https://www.cavforth.com/

The Aurrigo Shuttle vehicle was initially developed for the Smart Cambridge T-CABS (Trumpington to Cambridge Autonomous Busway Service) project, with plans for it to operate on an existing segregated, guided busway, between Trumpington Park and Ride and Cambridge Station, via the Cambridge Biomedical Campus. Following Covid-19 disruptions, the focus of the T-CABS project moved away from the segregated busway towards a two-mile mixed-traffic route that connected the Madingley Road Park and Ride with the University of Cambridge's West Cambridge and Madingley Rise campuses. Although the project was again interrupted by Covid-19, three Aurrigo Shuttle vehicles made over 100 journeys during the trials, carrying just over 300 passengers (Aurrigo, 2021; Garner, 2021). During this period, in August 2020, the Aurrigo Shuttle was also used at the Wales Open golf tournament, at the Celtic Manor Resort, to transfer the golfers and caddies from the club house to the first tee (Willis, 2020). Following the Cambridge trials, Solihull Council in 2021 became the first UK local authority to purchase an Aurrigo Shuttle vehicle (UK Central Solihull, 2021). Initial trials at the National Exhibition Centre (NEC) have been followed recently by tests on a longer and more complex route at Birmingham Airport (BBC News, 2022a; Solihull Council, 2022). There have also been some suggestions that Solihull's Aurrigo vehicle may be used during the Commonwealth Games, which are to be held in Birmingham in July-August 2022 (e.g., Attwood, 2021).

The Aurrigo Shuttle (L 5.80m, W 2.28m, H 2.54m) is a 10-seat electric vehicle, with a range of 124 miles, and can travel at speeds of up to 30mph (although this has been limited to 20mph in the Birmingham Airport trials). As such, Aurrigo market the vehicle as being "set to transform the way people transport around towns and cities", and helping to "provide transport for city centres, shopping and care facilities, airports and heritage sites" (Aurrigo, 2022). And while it is noted in the literature (e.g., Hopkins and Schwanen, 2018; Talbot *et al.*, 2020) that autonomous vehicle vendors, and pilot project managers, are often reluctant to share technical and financial details, for reasons of commercial sensitivity and intellectual property protection, the purchase of the Aurrigo Shuttle vehicle, and the trialling process, appears to have cost Solihull Council around £250,000 (BBC News, 2022a; Solihull Council, 2022). With these points in mind, the extent to which the Aurrigo Shuttle vehicle will be of interest to the WYCA will very much depend on the extent and purpose of any potential autonomous bus service(s), and, of course, anticipated passenger numbers.

The Alexander Dennis Enviro200 bus, meanwhile, is being used in the part-CCAV-funded CAVForth project.[8] This is the first (and so far only) UK project to use a 'full-size' vehicle (L 11.50m, W 2.47m, H 2.86m). Here, Alexander Dennis have built five bespoke Enviro200 buses, each capable of carrying up to 36 passengers, that will operate on a 28-mile round-trip route on the trunk road network, from the Ferrytoll Park and Ride facility in Fife, across the Forth Road Bridge Public Transport Corridor, to the Edinburgh Park transport hub. The service, to be operated by Stagecoach, is expected to carry up to 10,000 fare-paying passengers per week, at speeds of up to 50mph. The buses are powered by a regular diesel internal combustion engine, although autonomous driving is expected to yield up to a 20% fuel saving, over a manually driven version. Each bus is equipped with a sensor and control system (CAVstar) developed by the project lead, Fusion Processing (see Fusion Processing, 2020a). Demonstrations of this vehicle have been held at Stagecoach depots (Fusion Processing, 2019a), and in conference and exhibition centre car parks (Fusion Processing, 2019b & 2020b); but the Covid-19 pandemic resulted in live road testing (initially without passengers) being delayed until April 2022 (BBC News, 2022b). The passenger service is expected to go live in late summer 2022 (Stagecoach, 2022). Again, precise financial details are lacking, but the overall costs of the CAVForth project are estimated to be around £6.1m (Fusion Processing, 2020a). While the CAVForth trials are the closest to a 'conventional' bus passenger service to be found amongst current UK CAV trials, the WYCA would clearly have to consider the size and capacity of the Enviro200 buses, in deciding whether these would be appropriate for operating on any route(s) earmarked for potential autonomous bus services in the region.

[8] See https://www.cavforth.com

On this last note, a further CCAV-funded project is worthy of mention here. Led by First Group, the MultiCAV project had initially proposed to trial a small fleet of 8-seat autonomous shuttles in and around the Milton Park business and science hub near Didcot, Oxfordshire, connecting with existing transport hubs including Didcot Parkway Station (First Group, 2018). However, the procurement of such vehicles appears to have proved difficult, with Birtwistle (2019) noting that they would have required "too many derogations from regulations to permit passenger carriage". As an alternative, the MultiCAV project has turned to Fusion Processing, who are to instal their CAVStar system in a 15-seater electric minibus. It is also suggested that a full-size (12m, 36-seat) electric driverless bus, manufactured by project partner Arrival[9], is to be introduced as part of the project (Coach & Bus Week, 2021; Oxfordshire County Council, 2021; Searles, 2021). At the time of writing, no evidence can be found that trials of the 15-seater autonomous minibus have begun, but it perhaps illustrates that the WYCA may well have a wider range of passenger vehicles from which to choose in the near future.

d) Engage with targeted passenger community and other local stakeholders[10]

Amongst those authors who offer guidance on establishing an autonomous bus pilot, there is general agreement that the project team should undertake initial engagement with potential users of the service and with other stakeholders, such as local businesses, who may be affected by the service (e.g., University of Michigan, 2018; Müür *et al.*, 2020; Turnbull, *et al.*, 2020).

The extent and the nature of the engagement undertaken here will depend on the motivations for establishing the pilot. If, for example, they are what Cregger *et al.* (2018, p.12) describe as "short-term motivations" — perhaps in generating interest in autonomous technologies more generally — then the engagement may consist only of publicity and awareness-raising activities. If, however, the project team has "long-term motivations" (Cregger *et al.*, 2018, pp.12-13), in perhaps seeking a solution to an existing transportation problem, then more substantive engagement will be required. This was a key element of the CityMobil2 project, where extensive *ex ante* research was conducted, which explored local residents' attitudes towards the potential introduction of autonomous shuttle services in their city (McDonald *et al.*, 2018).

In the UK, too, the need for preliminary engagement with potential users has been recognised. As Squires, discussing the CCAV-funded Capri project, puts it:

> "In order for a CAV solution to be successful, it will need to respond to user requirements and provide a positive experience. These requirements are likely to vary depending on the context and environment in which the CAV is deployed. It is therefore recommended that user research is undertaken to inform the decision to invest in a CAV application and to develop a quality service offering." (Squires, 2020, p.11)

Indeed, the Capri project, in conducting its own user research, highlighted the need for a *co-design* approach, where potential users' aspirations for, and expectations of, a bus service are explored from an early stage (Shergold *et al.*, 2020). The CAVForth project has also adopted a co-design approach, having consulted around 500 potential users of the proposed service, using a combination of surveys, workshops,

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[9] Arrival started proving ground trials of its electric bus in late-2021, and public road trials are expected in 2022. See https://arrival.com/us/en/news/arrival-begins-proving-ground-trials-of-its-electric-bus

[10] Here, in using the term 'stakeholders', I do not include local landowners and other regulatory bodies from which permission to conduct the pilot would be sought, as these are discussed in **Step e**.

and a full-day “design jam”.[11] It is also interesting to note that the Law Commissions’ second consultation paper, which focused on the introduction of what was then termed Highly Automated Road Passenger Services (HARPS), discussed the importance of the co-design of such services, particularly in terms of their accessibility to older and/or disabled people (Law Commissions, 2019, pp.108-111).

In considering any proposed autonomous bus service(s) in north and north-west Leeds, then, the WYCA and Leeds City Council might wish to engage, to varying degrees, with: local parish and town councils and other community groups, such as the aforementioned Horsforth Town Council and Adel Neighbourhood Forum; the student and staff bodies of Leeds Trinity University in Horsforth, and Leeds Beckett University’s Headingley campus; large local businesses and enterprises, such as Leeds Bradford Airport; and representatives of business support groups, such as the West & North Yorkshire Chamber of Commerce or the Federation of Small Businesses in West Yorkshire.

e) Obtain approval (including vehicle approval) from the CCAV, the DVSA, the VCA, other public authorities, or landowners

In addition to engaging with those in the local community that might be most affected by any autonomous vehicle trials, the CCAV (2022) advises that the trialling organisation should, at the earliest opportunity, engage with a range of relevant public bodies, namely:

- **The CCAV**
- **Highways authorities** (Should the West Yorkshire trial route be located in north and north-west Leeds, the highway authority will be Leeds City Council; but if any major ‘A’ roads form part of the route, National Highways must also be consulted)
- **Transport authorities and local authorities** (Ordinarily, the transport authority would be the WYCA, although they may also be the trialling organisation in this case. Should any spatial planning issues arise, Leeds City Council, as the relevant planning authority, should also be consulted.)
- **Traffic Commissioners for Great Britain** (Here, West Yorkshire is covered by the North east of England office, which is actually based in Leeds)
- **Police** (West Yorkshire Police)[12]

The CCAV notes that the purpose of this initial engagement is to obtain information, advice and guidance on, for example: the proposed route of the trial; any planned roadworks or road closures on the proposed route; any relevant local policies that might apply; any operating licences required; and the procedures to be followed in the event of a reportable incident (see **Step g**).

In terms of obtaining broad approval to conduct a trial, the CCAV’s Code of Practice (2022) notes that:

> “Trialling any level of automated vehicle technology is possible on any UK road if carried out in line with UK law. Trialling organisations do not need to obtain permits or pay surety bonds when conducting trials in the UK. As part of complying with the law, they will need to ensure that they have:
>
> > • A driver or operator, in or out of the vehicle, who is ready, able, and willing to resume control of the vehicle;

[11] Personal communication with Stagecoach, 8 October 2020.
[12] Although the CCAV note that the police have established a central point of contact to provide guidance and clarity to trialling organisations: CAVTrials.PoliceLiaison@dft.gsi.gov.uk

• A roadworthy vehicle; and

• Appropriate insurance in place.” (see **Step f**)

With regard to the presence of a driver or operator, ready to resume control of the autonomous vehicle, this remains a key regulatory requirement for UK trials. And while the Law Commissions' final report considers the future for what they now term “No User-in-Charge” (NUIC) passenger services (of which more is discussed later), they observe that:

> “…there is much that is not known about how passenger services will operate in the absence of a driver. The immediate need is to collect more evidence and gain more experience…” (2022, p.193).

With this in mind, it seems likely that the requirement for an onboard driver/operator in autonomous passenger vehicle trials will remain in place for the foreseeable future. Certainly, the CAVForth trials, and the Cambridge and Birmingham-Solihull trials involving the Aurrigo Shuttle, have all involved a driver/operator remaining ‘at the wheel’ throughout the journey.[13] Furthermore, when live passenger trials of the CAVForth project commence in the late summer of 2022, each vehicle will also have a human ‘Captain’ on board, to offer information, assistance and reassurance to passengers.[14]

Vehicle Approval

With regard to a vehicle's roadworthiness, the regulatory challenges associated with operating small or mid-size autonomous passenger vehicles on public roads have been discussed, in considerable technical detail, by Talbot *et al.* (2020), as part of the Capri project. They highlight the key UK road vehicle regulations with which an autonomous vehicle must align to obtain vehicle approval, particularly: the *Road Traffic Act 1988*; the *Road Vehicles (Approval) Regulations 2009* (since revoked by the *Road Vehicles (Approval) Regulations 2020*); and the *Road Vehicles Construction and Use Regulations 1986*.

In the UK, most vehicle manufacturers/vendors currently seek approval for the road use of their vehicles from the Vehicle Certification Agency (VCA). Vehicles designed and constructed primarily for the carriage of passengers are considered under ‘Category M’, which is further divided into three subcategories:

> **M_1**: Vehicles comprising not more than eight seating positions, in addition to the driver's seat.
>
> **M_2**: Vehicles comprising more than eight seating positions, in addition to the driver's seat; the vehicle's maximum mass must not exceed five tonnes; and it may have space for standing passengers.
>
> **M_3**: Vehicles comprising more than eight seating positions, in addition to the driver's seat; the vehicle's maximum mass is greater than five tonnes; and it may have space for standing passengers.

Talbot *et al.* (2020, p.7) noted that the Westfield POD (the vehicle used in the Capri project), was most closely related to the M_1 category, and they focused on how closely it complied with the legislation, in terms of its braking and steering systems, lighting, passenger restraints, impact performance, etc. They concluded that Westfield PODs, and other similar vehicles, “do not easily fit into an existing regulatory structure” (p.56). This, then, further explains why this present report focuses more on the Aurrigo Shuttle

[13] Videos of these trials, demonstrating the continued presence of a ‘driver/operator’, can be found at https://www.youtube.com/watch?v=bw150j8zve8&t=157s, https://www.youtube.com/watch?v=dwL2VVXshaw&t=273s and https://www.youtube.com/watch?v=Sr3HfOKJhb8.

[14] See https://www.youtube.com/watch?v=1T9MsP2LMAU

and Alexander Dennis Enviro200 vehicles, as their more conventional specifications align more readily with current regulatory requirements.

Vehicle approval can currently take one of three forms:

> **(Provisional) GB Type Approval.** Since 1 January 2021, following the UK's exit from the EU, Great Britain has operated a Provisional GB Type Approval scheme, which has replaced EU 'whole vehicle type' approval. This provisional scheme is expected to be replaced by a Full GB Type Approval Scheme in July 2023.[15] This type of approval is for manufacturers producing and selling larger volumes of vehicles, aimed at mass markets, and is unlikely to be used for autonomous buses.

> **National Small Series Type Approval (NSSTA).** This type of approval is aimed at manufacturers producing and selling more modest numbers of vehicles. While it is similar to GB Type Approval, its technical and administrative requirements are designed for smaller production runs. Here, manufacturers are limited in the number of vehicles they can produce in a given calendar year. For M_1 passenger vehicles, this figure would appear to be a maximum of 1,500 vehicles per year.[16] For M_2 and M_3 passenger vehicles, the maximum would appear to be 1,000 vehicles per year.[17] The CCAV (2022) suggests that the Small Series Type Approval option is also unlikely to be suitable for autonomous bus trials. It does note, however, that if a trial involves a *modified* production vehicle, which has already been approved via the GB Type or the NSSTA scheme, then its original approval is likely to form part of the required evidence when seeking vehicle approval for a trial.

> **Individual Vehicle Approval (IVA).** Where approval is given only to a single vehicle, or to a very small number of vehicles. Physical inspection and other tests of the vehicle are required before approval is given. This scheme is administered by the Driver & Vehicle Standards Agency (DVSA).[18] The CCAV (2020) implies that the IVA scheme is the most appropriate approval route for autonomous vehicle trials. But while the DVSA publishes an inspection manual for M_2 and M_3 passenger vehicles, to be used during the IVA process, this does not yet address any aspects relating to autonomous driving (DVSA, 2020).

Once the vehicle has been approved, it should then be registered with the Driver and Vehicle Licensing Agency (DVLA), as per the *Road Vehicles (Registration and Licensing) Regulations 2002*.

Overall, then, obtaining (vehicle) approval for an autonomous bus to be used in trials on public roads is perhaps the biggest challenge facing the WYCA (or any other prospective trialling organisation). With this in mind, should the WYCA wish to progress autonomous bus trials in the region, it is advised that contact be made with the CCAV at the earliest possible opportunity, to discuss vehicle use and approval options.

When vehicle approval has been granted, insurance has been obtained, and the presence of an onboard driver/operator has been guaranteed, then there should be relatively few other barriers to gaining overall trial approval from the CCAV. And if it is assumed that most, if not all, of the roads on any proposed routes will be public highways that have been adopted by Leeds City Council (or any of the other constituent councils in West Yorkshire), then there should be little need to consult, or seek permission from, any other landowners.

[15] See https://www.vehicle-certification-agency.gov.uk/provisional-gb-type-approval-scheme-frequently-asked-questions/
[16] See https://www.vehicle-certification-agency.gov.uk/vehicle-type-approval/national-type-approval-in-the-uk/
[17] See *Road Vehicles (Approval) Regulations 2020*, Section 31.
[18] See https://www.gov.uk/vehicle-approval/individual-vehicle-approval

f) Obtain appropriate insurance

In the UK, as has already been indicated, the CCAV's 2022 *Code of Practice: Automated Vehicle Trialling* insists that "appropriate insurance" be in place for any autonomous vehicles being used in a trial, in compliance with Section 143 of the *Road Traffic Act 1988* and the *Automated and Electric Vehicles Act 2018.*[19] In discussing trials of small pod-like passenger vehicles, some authors (particularly in North America) have suggested that insurance providers in the "over-the-counter" market might be unwilling to underwrite such vehicles (Cregger *et al.*, 2018, p.24; University of Michigan, 2018, p.12). In the UK, this was certainly the case at the University of Salford, where considerable difficulties were encountered when attempting to insure their Navya Autonom vehicle (Brown, 2020). Salford's experience is in contrast to that of most of the other shuttle trials that have taken place in the UK. Although this can perhaps be explained by the fact that insurance providers have been key, collaborative partners in these projects. AXA has been a partner in the UK Autodrive, FLOURISH, and Capri projects (see AXA, 2020), while RSA collaborated in the GATEway project. In the latter case, both insurer (Kemp, 2018) and insured (Fordham *et al.*, 2018), were keen to emphasise that the insurance cover was underpinned by a comprehensive safety case (of which more will be discussed in the next step, **Step g**).

The insurance situation with the CAVForth trials, and with the Aurrigo Shuttle's Cambridge and Birmingham-Solihull trials, is unclear. Certainly, any problems encountered in obtaining insurance cover have not been reported publicly. It might be assumed, therefore, that if the WYCA decide to undertake any autonomous bus trials in the future, then insurance cover should be acquired fairly readily.

g) Prepare safety case

In large, pan-Europe autonomous shuttle bus trial projects, such as CityMobil2 and SOHJOA Baltic, a constant theme has been that of the design and approval of a site-specific, operational "safety case" or "safety plan", which demonstrates that a trial can be conducted safely, and provides details of how any adverse incidents will be managed (e.g., Csepinszky *et al.*, 2015; Alessandrini, 2018; Bellone *et al.*, 2020).

In the UK, the original Code of Practice on trialling autonomous vehicles (Department for Transport, 2015) did not really touch upon safety cases; but subsequent guidance, including that provided by Transport Systems Catapult (2018, Section 3), Jenkins (2019), and a revised Code of Practice (CCAV, 2019, p.9), did suggest some broad content. In 2020, however, two key (and related) documents emerged, to provide more comprehensive guidance on preparing a safety case. Zenzic's *Safety Case Framework Report 2.0* built upon the CCAV's 2019 Code of Practice, but also informed the more detailed British Standard Institution's PAS 1881: 2020, *Assuring the Safety of Automated Vehicle Trials and Testing*. Both documents have since been revised, the former being divided into two sets of guidance, one for trialling organisations creating safety cases, the other for reviewers of safety cases (British Standard Institution, 2022; Zenzic, 2021a & 2021b).

The British Standard Institution's PAS 1881: 2022 advises that a safety case should be structured in 14 sections[20] as follows:

[19] The *Automated and Electric Vehicles Act 2018* set out new insurance provisions, where the driver's liability and the automated vehicle's liability must be insured under the same policy (see Law Commissions, 2022, Chapter 13).
[20] Zenzic is not so prescriptive, noting that the information contained within a safety case will vary significantly depending upon the nature and complexity of a trial; and that some trialling organisations may choose to present the safety case in a single document, while others may choose to prepare multiple documents (Zenzic, 2021a, p.18).

1. Purpose and scope of the safety case. Here, the document should identify the organisation that has developed the safety case, and the trialling organisation that 'owns' the safety case. It should also outline any consortium partners and their roles. It should provide: an overview of the testing or service being conducted; high-level methodological details; and information on any *phases* of testing or service being conducted (where applicable). Any notable exclusions, outside the scope of the safety case, should also be explained here. And it should indicate when the safety case will be updated, and under what circumstances.

2. Safety case introduction. The safety case introduction should include an overview of the methodology for the trial, including: the location of the trials (e.g., testbeds, public highways, private land); the type and number of vehicles being trialled; details of how these trials are to be progressed or advanced over time; and details of the service or intended service, such as the number of passengers in each vehicle and the duration of the trial journeys. It should also include a high-level description of the vehicle being tested, including a summary of the hardware and software being used, and what human control will be required.

***3. Vehicle and automated driving system (ADS)*. ** In which details are provided on the trial vehicle's build and/or modifications, its livery and conspicuity, and its compliance with, or demonstrable exemption from, relevant vehicle and design standards. It should also include high-level overviews of, for example: the vehicle's sensors and cameras; its navigational capabilities; its human-machine interface; data storage and accessibility; and security of the system, both cyber and physical.

4. Operational Design Domain (ODD). Here, the safety case will specify the operating conditions in which the vehicle is designed to operate safely, such as: on particular road type(s); within particular traffic flow levels; at particular speeds; or in particular environmental conditions (including weather, lighting and visibility). Details of the specific route(s) on which the trial will operate should be provided, and identified using map images and/or latitude and longitude coordinates. Evidence should be provided of the ADS's capabilities, in safely operating within this ODD, and how the ADS verifies that it is operating within the defined ODD. This section should also include details of what mitigating actions the system takes when scenarios cannot be negotiated or managed safely.

5. Objectives. The objectives of the tests being conducted or the service being operated should also be documented in the safety case. For an automated mobility service this should include a description of the service (e.g., information on vehicle movements, travel speed, passenger numbers, role of the safety operator), evidence to demonstrate that the service can operate safely within the defined area, and how safety during operation is being monitored and evaluated.

6. Assurance of system safety and security. An overview of systems safety assessments conducted should be included, to provide assurance that the system is safe and secure for the defined operating environment. This should provide details of when the assessment(s) took place, assurance that the system can always be overridden by the safety operator in the event of incidents or failures, and details of the operational controls required to maintain systems safety and security.

***7. Operational risk assessment*.** The trialling organisation should conduct an appropriate operational risk assessment and include this within the safety case. This should provide an overview of the methodology used to identify potential hazards, and to assess and evaluate the risks foreseeable during testing. It should assess the risks posed to all affected parties, including the passengers, the vehicle's safety operator, other road users, road workers, and any other third parties. It should also assess the risks associated with: the vehicle's hardware and software; vehicle monitoring and control; external dependencies, including communications; the test procedures taking place; and the trial's route and infrastructure. All risks should be reduced as low as reasonably practicable (ALARP), and to an acceptable level. The controls that will be implemented to manage the level of risk, and the decisions regarding the tolerability of risks, should also be documented in this section of the case study.

8. Operational guidance. Here, the safety case should document the safe working practices to be followed to assure safety and security throughout the lifecycle of the trial. This section should also contain details of the trial's emergency response plan, which should be developed in consultation with the local emergency services and other key stakeholders (e.g., highway authorities, landowners, insurers). The emergency response plan should include, for example: details of any vehicle-specific hazards that could impact upon emergency services' intervention or safety; information on how to disable the autonomous vehicle's motion; and details of the key roles and responsibilities of those involved in the emergency plan.

9. Operational domain selection and assessment. The safety case should identify the area(s) where the vehicle(s) will operate autonomously. For trials taking place within a public domain, or on private land with public access, a safety assessment should be conducted on the operating area(s), and the methodology and results included within the safety case to demonstrate that the proposed operating area is suitable for the vehicle type, the defined ODD, and the operation of the vehicle. The safety case should also provide details of any changes required to infrastructure or street furniture, and any control measures (e.g. traffic management) required to minimize the level of risk posed by the trial. The assessment should record, for example: the route length; the carriageway type; speed limits; traffic flows; the density of pedestrians and other vulnerable road users; available historical collision data; and any existing or potential hazards or barriers to performing the trial.

10. Safe operation and control. Here, the safety case should identify how the automated vehicle is controlled in operation and how safety and security (including cybersecurity) are maintained in the event of a fault or failure. It should identify the process (or minimal risk manoeuvres) for defaulting to a minimal risk condition, given a hazardous situation or abort condition, and how the minimal risk condition is achieved. It should document the minimal risk manoeuvres and include a justification that the minimal risk conditions and manoeuvres are acceptably safe and appropriate for the operating environment. Where a safety operator is required to take over control of a vehicle whilst in motion, the safety case should identify how the safety operator is alerted when action is required. It should include evidence to demonstrate that the safety operator will have time to diagnose and safely respond to anomalies. It should also provide details of the safety operators' responsibilities, skills, experience, fitness to drive, and training received; and how their performance during the trial operations will be monitored. The safety case should also include the criteria (e.g., narrow road sections, poor lane markings, restricted visibility) that might restrict or compromise the safe operation of the vehicle, and the related risk avoidance or reduction strategies. For passenger services, it should also document how passenger welfare will be maintained in normal and emergency situations, and what measures have been put in place to support accessibility and the safety of passengers with additional needs.

11. Monitoring, reporting and continuous improvement. Here, the safety case should include a description of the monitoring being conducted during trials to enable the continued safety performance of the vehicle and to validate the risk decisions and assumptions made in the safety case. It should identify the persons/roles responsible for data capture processes and maintaining compliance with the safety case. It should provide details of what safety data is collected and analysed, how and how frequently it is collected, who will have access to this data, how the data is downloaded/transferred and stored, and the period of time for which the data will be retained. The processes for the reporting and analysis of incidents and near misses should also be detailed here. As should the process for learning lessons throughout the trial, and the ways in which the safety case will be reviewed, updated and communicated to reflect this learning.

12. Change control. The safety case should remain a live and up-to-date document throughout the trial, and this section should provide an overview of the change control process. It should, for example, contain details of: the process for monitoring and capturing any changes made; the process involved in assessing the level of risk posed by these changes; who is responsible for approving changes; the process for validating (post-change) system performance before continuing trials in the public domain; how changes will be communicated and implemented; and the method for monitoring the subsequent effects of any changes made.

13. Stakeholder consultation and engagement. This section of the safety case should include a comprehensive list of relevant stakeholders, and should provide details of the nature and extent of the communication and consultation undertaken with those identified. This should include details of any public education and awareness-raising campaigns launched that could foreseeably influence, or have been launched to influence, the safety of the trial; plus details of any relevant safety feedback received. It should also provide evidence of appropriate approvals and permissions having been obtained, from landowners, local authorities, highway authorities, licensing agencies, etc. Where trials are taking place in the public domain, and might impact upon participants or members of the wider public (as would be the case in any West Yorkshire trials), an ethics impact assessment should be undertaken, in order to establish that the ethics oversight of the trial is proportionate to the level of risk posed. And when trials are intended for public domains a publicly available and accessible version of the safety case (in the form of a high-level summary) should also be published.

14. Insurance. The safety case should include details of who is insuring the trial, vehicles and safety operators, and any specific equipment being tested. Insurance certification should be included in the safety case. Where organizations self-insure their operations, suitable evidence of this should be provided.

One other point relating to the safety case should be borne in mind. Zenzec (2021a, p.26) differentiates between "high complexity" and "low complexity" trials, arguing that trials involving the carriage of passengers (as would be the case in any West Yorkshire trials) should typically be regarded as "high complexity". They suggest that the assessment of trial complexity should guide the safety case creator in determining the level of detail required in the safety case and the necessary robustness of evidence or mitigations. In safety cases for passenger trials, they contend that:

> "Significant detail would need to be provided within the safety case, demonstrating evidence of operator control and risk mitigations in place for the operating environment." (p.27)

h) Survey, map and program the chosen route

While **Step b** involved identifying a preferred route for any autonomous bus service, and establishing the ownership of the relevant roads and land, **Step h** involves a more thorough examination of the route on which the service will operate. As Rehrl and Zank (2018, p.5) note:

> "Before a self-driving shuttle is able to drive autonomously from A to B on a pre-defined route, an extensive analysis and assessment of the driving environment and the driving lane have to be conducted."

This process — described variously as a "territorial study" (Christie *et al.*, 2016, p.33), a "detailed site assessment" (Fordham *et al.*, 2018, p.22), a "site survey" (Brown and Reed, 2020, p.19), or, more simply, "mapmaking" (Sherry *et al.*, 2020, p.6) or "mapping" (University of Michigan, 2018, p.19) — is designed to establish the more detailed topography of the route, and to identify any fixed, physical hazards (e.g., junctions with other roads/paths, tight bends, street furniture, planters, etc.), as well as any dynamic, moving hazards (i.e. other vehicles, pedestrians, cyclists, pushchairs, dog walkers, etc.) that the autonomous vehicle is likely to encounter along the route. The methods by which this survey is conducted might vary, but most authors are in agreement that this step of the implementation process must be carried out in close collaboration with the vehicle vendor.

In some cases, the surveys appear to have consisted initially of site visits and 'walk-throughs' of the proposed route by the project team, during which written and photographic evidence of infrastructural restrictions and pedestrian or cyclist behaviour has been collected. For example, Volvo (2019) describe the assessment of a proposed autonomous bus route, on an existing bus-only roadway in Gothenburg, Sweden. Here, the project team (including the proposed safety operator of the vehicle) walked along the trial route, armed with a copy of the Gothenburg Municipality's *Road Equipment Map*, which provided rich detail of traffic lights, street furniture, and other infrastructure. Photographs and written descriptions of the road surface conditions, traffic flows, and the behaviour of other vehicles, cyclists and pedestrians were then gathered as the walk-though progressed. In the UK, meanwhile, the Capri team conducted pre-trial site visits to both the Queen Elizabeth Olympic Park in London (where shuttle trials took place on paths shared with pedestrians and cyclists), and the Cribbs Causeway shopping mall near Bristol (where trials took place in the mall's car park), observing cyclist/pedestrian flows and behaviour (particularly that of children), and identifying any 'blind spots' and other hazards on the proposed routes. At Cribbs Causeway, for example, they identified that various raised planters and hedges bordering the car parks could obscure pushchairs and pedestrians from an approaching shuttle bus (Brown and Reed, 2020, p.20).

Many of the autonomous shuttle bus projects reported in the literature have used simultaneous localisation and mapping (SLAM). Here, the vehicle navigates along its prescribed route by using its cameras and 3D sensors to create a digital map of its surrounding environment, comparing this with an existing, pre-programmed map of the route (see Bellone *et al.*, 2020, or Iclodean *et al.*, 2020, for a more detailed, technical explanation of SLAM). In order to create this pre-programmed 3D map, the vehicle has to be driven, manually and at a very slow speed, along the proposed shuttle bus route, perhaps a number of times. Rehrl and Zankl (2018, p.5) suggest that these manual drive-throughs should be at a speed of 1 metre per second (i.e. around 2.2 mph). The University of Michigan, meanwhile, noted that it conducted its mapping (of a campus-based route) in the evenings and at nights, to minimize traffic disruption (2018, p.19), with law enforcement officials from the Department of Public Safety & Security providing an escort to the autonomous shuttle. When this initial 3D mapping has been completed, the data then has to be manually edited, to remove any dynamic objects (e.g., pedestrians, cyclists, or other vehicles) that have been scanned; and any necessary driving rules (e.g., vehicle speed, priorities, or stops) have also to be added to the program (Rehrl and Zankl, 2018, p.5). Rehrl and Zankl then advise that a number of test drives be conducted, with the vehicle in autonomous mode, until the project team is satisfied that a safe and comfortable autonomous journey can be completed.

As has already been noted, UK autonomous shuttle bus projects have largely operated on private roads, or on paths located on private land, where walk-throughs or low-speed drive-throughs of the proposed route will be relatively straightforward. However, with any West Yorkshire project, where the autonomous vehicle will be travelling on public highways, and mixing with other road vehicles, such processes may not be practicable. Perhaps of more relevance, then, are the processes adopted by the CAVForth project, where the vehicles will operate on part of Scotland's trunk road network at speeds of up to 50mph. Here, the route survey consisted of a number of higher-speed drive-throughs, with route data being captured in the form of LIDAR (Light Detection and Ranging) scans and dash cam recordings. A digital twin of the CAVForth route was also created by Bristol Robotics Lab Processing (see Figure 6), to allow simulated journeys and hazardous scenario testing. The CAVForth survey also consisted of an analysis of CCTV visibility, to identify parts of the route where any additional coverage might be required.[21]

Figure 6: Digital twin of CAVForth project route[22]

i) Identify and install any additional infrastructure or equipment required

The mapping processes discussed in **Step h** will assist in identifying any infrastructural modifications, or any additional equipment, that may be required. Much will depend here on the length and complexity of the route, anticipated levels of passenger demand, and the likely permanence of the autonomous bus service. The paragraphs that follow provide some examples, from the literature, of infrastructural additions and modifications that have been required during autonomous bus projects. It is realised, of course, that only some of these are likely to be necessary, or even worthy of consideration, in any proposed West Yorkshire pilot.

Dedicated lane for bus operation. In a number of projects in Continental Europe a dedicated or segregated lane, on an existing roadway, has been created for the vehicle(s). For example, in the CityMobil2 pilot in Trikala, Greece, a dedicated, 2.5m-wide lane was constructed using a combination of line-painting, reflective road studs (i.e. 'cats eyes'), and other, on-road, painted signage (see Figure 7). In any future West Yorkshire projects, this may not be practicable; much will depend on the route selected. Should a larger vehicle, such as the Aurrigo Shuttle be deployed, any such dedicated lanes will probably have to be wider than those in the Trikala example. In this regard, it is worth noting that the CAVForth service will operate partly in bus priority lanes, and will cross the Firth of Forth using the original Forth Road Bridge, which is now a designated Public Transport Corridor, accessible to buses, taxis and motorcycles only.

[21] Personal communication with Transport Scotland, 6 October 2020.
[22] See https://www.cavforth.com/simulation/

Figure 7: CityMobil2 project: dedicated shuttle bus lane in Trikala, Greece
(Sources: McDonald *et al.*, 2018; Stam *et al.*, 2015)

In some other projects, all or part of the bus route has been physically segregated from other traffic (and from cyclists and pedestrians) by the erection of temporary fencing or crush/crowd control barriers; for example in the CityMobil2 project in Kivistö, Finland; and in the SOHJOA pilot at Helsinki-Vantaa Airport, also in Finland (see Figure 8).

Figure 8: Segregated shuttle bus lanes in Kivistö and Helsinki-Vantaa Airport, Finland
(Sources: McDonald *et al.*, 2018; Rutanen and Arffman, 2017)

New or repaired road and pavement surfaces, etc. A small number of autonomous bus projects have reported the need to repair, upgrade, or introduce new road or footpath surfaces, on or adjacent to the bus route. For example, the aforementioned CityMobil2 pilot in Oristano took place on a tree-lined, beachfront boulevard, where parts of the asphalt surface, damaged by tree roots, had to be repaired before the shuttles could operate effectively (McDonald *et al.*, 2018, p.165). The CityMobil2 pilot in Vantaa (which connected Kivistö railway station with a new housing development) required the construction of a new, paved area at the housing development end of the route (see Figure 9); and, indeed, a new set of stairs at the railway station end, which allowed passengers to move from street level down to the bus stop (McDonald *et al.*, 2018, p.178). In a SOHJOA pilot, which operated on the Herventa campus of the Tampere University of Technology, in Finland, a number of temporary kerb ramps were created, to both “smoothen the ride of the bus” and to accommodate cyclists who were being diverted from the bus route on to adjacent walkways (Rutanen and Arffman, 2017, p.22).

Improved lane markings. In a number of the pilots reported in the literature, the autonomous vehicle's suite of sensors and cameras has included a lane detection facility (e.g., University of Michigan, 2018; Sherry *et al.*, 2020; Bellone *et al.*, 2020). With this in mind, additional or improved lane markings on the bus route may be required (Cregger *et al.*, 2018). Certainly, following the CAVForth project site surveys, Transport Scotland reviewed the condition and clarity of the lane markings along the Edinburgh Park to Ferrytoll Park and Ride route.[23] It should also be noted, however, that the visibility and recognition of lane markings may be affected by lighting levels (both natural and artificial), and by weather conditions (Ainsalu *et al.*, 2018; Bellone *et al.*, 2020). Zankl and Rehrl (2018) also highlight the limitations of lane detection features in rural areas, where lane markings may not always be present. This last point should be borne in mind if any autonomous bus projects are considered for the more rural parts of West Yorkshire. Indeed, this was an issue recognised in the Law Commissions' second consultation paper (Law Commissions, 2019, p.37) where they note the challenges posed to CAVs by rural roads, "such as: fewer road markings; the negotiations required to back-up on single lane roads[24]; and dealing with livestock on the road".

Bus stops and 'stations'. In addition to their start and end points, some of the autonomous bus pilot routes described in the literature have been lengthy enough to allow for a small number of scheduled stops along the way. The infrastructure associated with these stops can vary in its level of sophistication. In many cases, the bus stops will simply have a 'shuttle stop' sign, perhaps supplemented by a timetable or information board, or by other painted signage on the pathway. In La Rochelle in France, and in Aalborg in Denmark, ramped platforms were constructed at all stops, allowing easier accessibility to the vehicle. The Aalborg route also saw bus shelters installed at two stops. The newly-paved area at the housing development end of the Vantaa pilot in Finland provided passenger seating and a shelter with information boards (see Figure 9). In Oristano, near the centre point of the waterfront route, a temporary kiosk was erected at the bus stop, for passenger registration and information (this can just be made out at the top far right of Figure 15).

[23] Personal communication with Transport Scotland, 6 October 2020.
[24] Although the single-track road is more commonly found in the Scottish Highlands and Islands than in rural England.

Figure 9: Autonomous shuttle bus stops at (clockwise from top left): the University of Michigan (2018); *Sophia Antipolis, France* (Shladover *et al.*, 2018); *Koppl, Austria* (Zankl and Rehrl, 2018); *Vantaa, Finland* (McDonald *et al.*, 2018); *La Rochelle, France* (Merat *et al.*, 2018); *and Aalborg, Denmark* (SmartBus, 2021)

Other signage. In addition to ‘shuttle stop’ signs, timetables, and information boards, other new signage may be required along a trial route. The literature would suggest that these typically consist of two types: warning signs, to indicate that autonomous vehicles are operating or are being tested in the area; and signs indicating that new speed limits have been introduced on the bus route, or on roads that join or intersect the bus route (see Figure 10).

Figure 10: Autonomous shuttle trial warning signs used at (top, left to right) the University of Michigan (2018); *in Appelscha, in the Netherlands* (Boersma *et al.*, 2018); *and in the SOHJOA pilots in Finland* (Rutanen and Arffman, 2017); *and (bottom) in the Smart Cambridge project* (Gardner, 2021)

'Localisation signs' and other reference points. Another form of 'signage' that has been required by some autonomous bus pilots is the 'localisation sign'. As Bellone *et al.* (2020) explain, the SLAM process can be hindered by a lack of relatively large, static structures (such as buildings) along a route, as the bus uses these as localisation points for its navigation. Indeed, they recommend that a fixed structure be present at least every 50m along a route. Large trees are not suitable as reference points, because they will 'move' in the wind, and will 'change shape' when they drop their leaves in the autumn (Rutanen and Arffman, 2017, p.32). And while some vehicles may be able to navigate only with enhanced satellite connections (i.e. Differential Global Navigation Satellite System – DGNSS), the presence of tall buildings and trees next to the route may interfere with these satellite signals. With these points in mind, the installation of some (temporary) fixed structures along the route may be required. Bellone *et al.* (2020, p.16) suggest that these might be large, three-dimensional signs, in the shape of a triangle or square. Cregger *et al.* (2018, p.21) suggest that large boulders might be a useful alternative. The use of three-dimensional signs was adopted in the SOHJOA project in Finland, as can be seen in Figure 11; although it should be noted that the use of localisation signs on a route on the heavily-wooded island of Mustikkamaa, Helsinki, was unsuccessful, and that the pilot there had to be abandoned (Rutanen and Arffman, 2017, p.32).

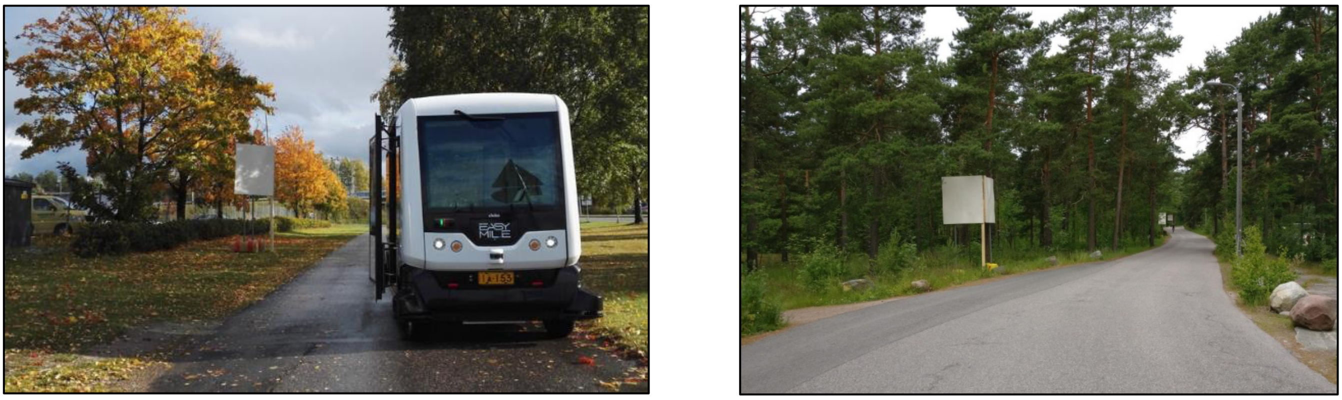

Figure 11: Localisation signs used in the SOHJOA pilots at Helsinki-Vantaa Airport, and at Mustikkamaa, Helsinki (Rutanen and Arffman, 2017)

Smart traffic lights and other warning lights. Where autonomous bus routes have joined, or intersected with, other roads, the installation of temporary traffic lights, giving priority to the autonomous vehicle, has sometimes been necessary. In some cases these have been 'smart' traffic lights, that have automatically communicated with the shuttle bus as it approached the junction; for example, in Trikala (McDonald *et al.*, 2018, p.126). In other cases, the traffic lights have been operated remotely, by the onboard safety operator (e.g., Rutanen *et al.*, 2016, p.18). In one of the Finnish SOHJOA pilots, in Otaniemi, blinking yellow traffic lights were employed, to act as a warning to other road users (Rutanen and Arffman, 2017, p.26).

Traffic-calming measures for other vehicles and cyclists. In addition to warning signs and lights, some projects have installed other traffic-calming infrastructure, where the shuttle bus route joins with or intersects other roads or cycle paths. These have included barriers and bollards (McDonald *et al.*, 2018), temporary kerbs (Shladover, *et al.*, 2018, p.299), and speed bumps, such as that introduced in Hernesaari, Helsinki (see Figure 12).

Figure 12: Speed bump installed as part of SOHJOA trial in Hernesaari, Helsinki (Rutanen *et al.*, 2016)

Parking restrictions on shuttle bus route. With the co-operation of local public authorities, several projects have arranged for parking restrictions to be introduced on the autonomous bus route for the duration of their trials. This has happened, for example, in the CityMobil2 pilots in La Rochelle, Trikala, and in San Sebastian in Spain (McDonald *et al.*, 2018); and in two of the SOHJOA project routes in Finland (Rutanen *et al.*, 2016). Although, when these restrictions are ignored, as in the Trikala example illustrated in Figure 13, the onboard safety operator may have to take control of the shuttle bus, to negotiate any illegally parked vehicles.

Figure 13: Illegally parked car on Trikala shuttle bus lane (Papadima *et al.*, 2020)

Installation of additional communications equipment. As was noted earlier, autonomous shuttle bus vehicles typically navigate along their prescribed route using a combination of SLAM and GNSS technologies. For GNSS data, and the more precise GNSS-correction data, the bus route will require to have good satellite and mobile data coverage (see Ainsalu *et al.*, 2018, or Iclodean *et al.*, 2020, for more detailed, technical explanations). In some of the pilots reported in the literature, however, this coverage has been inadequate, and has required the installation of additional fibre optic cable, fixed antennae (McDonald *et al.*, 2018), or what are known as GNSS “base stations” (Zank and Rehrl, 2018) or “reference stations” (Rutanen and Arffman, 2017) along, or very near to, the shuttle’s route. In this respect, it is also worthwhile mentioning again the tree-lined boulevard used as the route in the CityMobil2 Oristana trials; because there the project team had to arrange for some of the trees to be pruned, to reduce interference with the vehicles’ satellite navigation system (McDonald *et al.*, 2018, p.165).

Control room. A number of the shuttle bus projects in Continental Europe have included a “control room” or “control centre”, from which the progress of the vehicles has been monitored remotely; and where the individual manning the control room is in a position to intervene, in the case of an emergency (e.g., Correia, 2016; Piao *et al.*, 2016; McDonald *et al.*, 2018; Madigan *et al.*, 2019). Typically, these have been employed when small fleets of two or more shuttles are being operated. For example, the control rooms in the CityMobil2 pilots in La Rochelle, Lausanne, and Trikala (see Figure 14), were each monitoring six vehicles simultaneously. In the UK autonomous bus trials conducted to date, no evidence can be found of a control room having been utilised; although it should be noted that when the CAVForth passenger trials begin in late summer 2022, the vehicles will be monitored remotely on CCTV, by the Traffic Scotland National Control Centre in South Queensferry (Fusion Processing, 2020a). It should also be noted that the Law Commissions (2022, Chapter 9) anticipate that the vast majority of NUIC passenger services will eventually be monitored by remote operation centres, and have recommended that these be run by licensed NUIC operators who can ensure that staff provide remote assistance safely (see also Section 4 of this present report).

Figure 14: Control room in Trikala (Alessandrini, 2018, p.289)

Garage or 'depot' for bus storage, charging and maintenance. For electonic autonomous vehicles, a key requirement will be a garage or 'depot' in which they can be stored securely and recharged, and where any required maintenance can be carried out. Ideally, the depot should be located near to the operational route of the vehicle. Indeed, Müür *et al.* (2020, p.35) suggest that this distance should be a maximum of 500m, to prevent the vehicles having to travel on unsuitable roads, or having to be regularly transported to and from the route on a trailer. The type and precise location of those depots reported in the literature have varied widely (see Figure 15). For example, in the GATEway trials in Greenwich, the vehicles were secured in a "safe storage cage" at the InterContinental Hotel O2, located on the Greenwich Peninsula (Fernández-Medina *et al.*, 2018, p.5; Fordham *et al.*, 2018, p.20); a similar arrangement was in place in Aalborg, with the 'garages' being decorated by young local artists. In the Digibus project in Koppl, Austria (Zankl and Rehrl, 2018), garage facilities were provided by the local municipality; and in the Smart Cambridge project, a temporary "base camp" was established, presumably on the University of Cambridge campus.

In the CityMobil2 trials, the La Rochelle vehicles were stored and recharged at the vehicle depot of one of the project partners (McDonald *et al.*, 2018, p.116); the Lausanne shuttles were secured in an underground garage at the university campus (of the Ecole Polytechnique Fédérale de Lausanne) on which the trials were taking place (Christie *et al.*, 2016, p.32); while the Trikala vehicles' depot consisted of a tent (see Figure 15) surrounded by a temporary fence (McDonald et al, 2018, p.166), located mid-way along the beachfront route. A tent was also used as a depot in the SOHJOA Baltic pilot in Tallinn, where it was erected in the car park of the Estonian Art Museum. Here, however, low winter temperatures adversely affected the recharging of the vehicles, and additional radiators had to be installed in the tent to maintain an optimum minimum temperature of 5 degrees Celsius (Soe and Müür, 2020, p.15). This was an issue encountered throughout the Baltic countries involved in the SOHJOA trials, where Müür *et al.* (2020, p.36) advise that a temperature of at least +0˚C is required for effective recharging.

Figure 15: Autonomous bus 'depots' in (clockwise from top-left) Koppl, Austria (Zankl and Rehrl, 2018); *Oristano, Italy* (McDonald, *et al.*, 2018); *Aalborg, Denmark* (EV Cartel, 2021); *and Cambridge* (Garner, 2021)

j) Obtain any necessary permissions or approvals for additional infrastructure or equipment

Should any of the infrastructural interventions discussed in **Step i** be deemed necessary for any future West Yorkshire autonomous bus pilots, and should the trials be taking place in the aforementioned area of north and north-west Leeds, permissions and approvals would largely have to be sought from Leeds City Council, as both the local highways authority and the local planning authority. For example, if it was felt that additional parking or waiting restrictions, or a revised speed limit, should be introduced on the proposed trial route, then the project team would seek to apply for a Traffic Regulation Order (most likely a temporary one), as per the *Road Traffic Regulation Act 1984*. If the trial team sought to make any *physical* alterations to the highways on the route, by means of fences, bollards, or speed bumps, then these would have to meet the requirements of the *Highways Act 1980.* And if any new road markings, signage, traffic lights, or any other warning lights (temporary or otherwise) were to be introduced, then these would have to be approved by Leeds City Council, as per the *Traffic Signs Regulations and General Directions 2016.*

If additional communications equipment, such as antennae or a GNSS base station, is found to be necessary, then planning permission is likely to be required. Similarly, planning permission will probably have to be sought if additional, temporary accommodation for the autonomous vehicles is required for the duration of any trials.

k) Train the vehicle's operators/conductors, and any additional staff required

As has been noted throughout this report, the CCAV's Code of Practice indicates that any AV trial in the UK must have a "driver or operator, in or out of the vehicle, who is ready, able, and willing to resume control of the vehicle" (CCAV, 2022). For trials on public highways, the safety driver/operator must hold the appropriate category of driving licence for the vehicle under trial; and for trials not conducted on the public road, it is "strongly recommended" that an appropriate category of licence be held. The Code of Practice goes on to indicate that:

> "Safety drivers and safety operators supervising public road trials should understand the capabilities and potential limitations of the technologies under trial as completely as possible. They should be familiar with the characteristics of the vehicle, preferably through extensive experience of trials conducted on closed roads or test tracks."

The Code recommends that trialling organisations "develop robust procedures to ensure the competency of safety drivers and operators"; and that safety drivers/operators undergo "continuous development and training". This training should cover potentially hazardous situations that may be encountered throughout a trial, and what actions the driver/operator should take when resuming manual control of the vehicle. The Code also highlights the importance of the drivers/operators receiving training in the process of transitioning between conventional manual control and the automated mode.

With regard to autonomous shuttle buses, driver/operator training has usually been provided by the vehicle manufacturer or vendor (Müür *et al.*, 2020, p.42). The duration of this training has not always been reported in the literature, but two weeks would appear to be typical (e.g., Alessandrini *et al.*, 2015, p.158; University of Michigan, 2018, p.26; Müür *et al.*, 2020, p.42; Soe and Müür, 2020, p.7). It is also generally advised that some initial off-route training, in a closed-off area, be undertaken, prior to deploying the vehicle on the proposed route. This was certainly the case in the GATEway project, where initial training took place in part of the car park of the InterContinental Hotel O2 on the Greenwich Peninsula (see Figure 16).

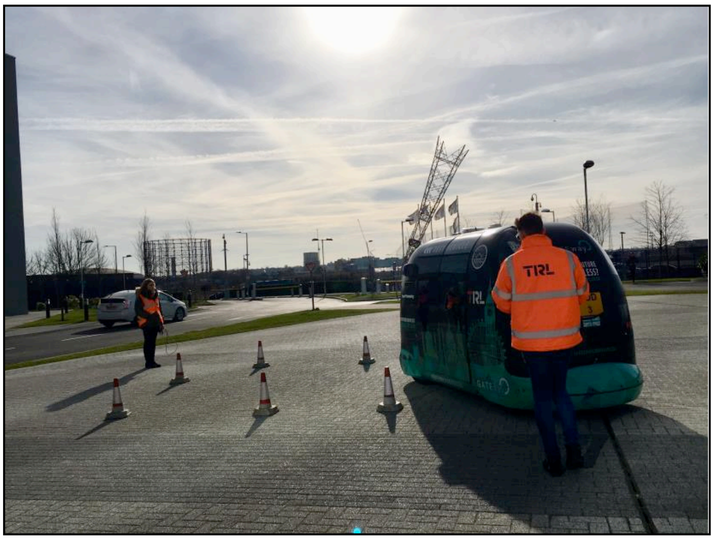

Figure 16: GATEway Project: initial manual operator training at InterContinental Hotel O2 (GATEway, 2018)

The University of Michigan (2018, pp.25-26) provides a list of the procedures covered in its shuttle "conductor" training programme, which consists of three distinct phases: operating the vehicle in manual mode; operating it in automated, driverless mode; and "on-the route" training (see Table 1).

Table 1: Procedures covered in the University of Michigan's shuttle bus conductor training programme (adapted from University of Michigan, 2018, pp.25-26)	
Manual Use • Getting around obstacles • Positioning vehicle on route • Safely stopping the shuttle • Parallel parking • Turning the shuttle	**Driverless Use** • Startup and shutdown procedures for the shuttle • Charging the shuttle • Getting on the path and starting the shuttle route • Detailed process to resolve any system errors • When and how to use the emergency stop button • Safety for pedestrians and other vulnerable road users
On-the-Route Training • Access to the shuttle garage • Signing in and out of shifts • Obtaining keys for the vehicle • Vehicle startup checklist • Positioning the shuttle on the route • Running a daily test route prior to allowing passengers • Passenger safety procedures • Ridership rules g	 • Passenger interaction guidelines • How and when to use the radio • Common issues • When to use manual mode • Emergency procedures • Returning the vehicle into the bay • Shutdown and charging procedures • Post-shift documentation

In addition to the list of training skills identified by the University of Michigan, Soe and Müür (2020, p.7) suggest that the shuttle's safety operator(s) receive training on cleaning the vehicle, upgrading the software, and sending data reports to the manufacturer/vendor.

In an interesting development, Stagecoach (2022) recently announced that over 20 specially trained 'Autonomous Bus Professionals' are to be recruited from within its East Scotland business, who will be responsible for the onboard monitoring of the CAVForth autonomous system when the passenger service goes live in late summer 2022. They will work alongside the previously mentioned 'Captains'.

Training may also be required for any other staff involved in the trials. For example, in the CityMobil2 Oristano trials, the control centre staff (who were monitoring the six vehicles' progress remotely) underwent separate training, with each having to complete at least 40 operational hours before being certified (McDonald, *et al.*, 2018, p.129). In UK trials where shuttle vehicles have operated on shared-use paths with pedestrians and cyclists (e.g., GATEway and Capri), additional "marshals" have been employed along the route, to ensure public safety and provide passenger support (Fordham *et al.*, 2018; Mbakada, 2020). The GATEway project also had: a "roving marshal", who rode along the trial route on a bicycle, providing support to the vehicle operators and pod stop marshals; a "trials manager", who oversaw the trial operations "on the ground"; "vehicle support", who provided support in relation to any vehicle malfunctions or queries; and “ACS/systems support”, who provided support related to the vehicles’ autonomous control system (ACS) and fleet management system. On each of the trial days, the GATEway project team consisted of at least 10 members of staff fulfilling these various roles. Each member of staff underwent specialised training for the specific roles they were to perform during the trial. This involved a day of classroom-based training, which included an overview of the project and the trial’s objectives, roles and responsibilities, the emergency response plan, vehicle design, and the DfT’s (2015) Code of Practice (GATEway, 2018).

l) Review mapping and programming processes as required

Step h of this report outlined the surveying, mapping and programming processes that are required, so that an autonomous passenger vehicle can ‘recognise’ its prescribed route and its surrounding environment. Should there be any significant physical changes to the route during the course of the pilot project (e.g., roadworks, or the erection of a new building or other structure), then the vehicle’s existing map will have to be updated and potentially re-programmed (University of Michigan, 2018, p.19). Although, as Bellone *et al.* (2020, p.17) suggest, the identification of any planned infrastructural changes should form part of the initial route identification process (**Step b**), so that these can be taken into account in advance, or an alternative route found.

m) Operate pilot service

This step effectively consists of the day-to-day operation of the autonomous vehicle(s) on the prescribed route, which hopefully will run safely whilst adhering to any proposed timetable. As was noted earlier, there is an argument that the choice of route and service should strike a balance between the known capabilities and limitations of the shuttle vehicle, and the learning opportunities that the pilot will present for the service operator (University of Michigan, 2018; Müür *et al.*, 2020). But what lessons might the WYCA expect to learn from an autonomous bus pilot? Based on others’ previous experiences, it is perhaps fair to say that the trialling organisation should ‘expect the unexpected’. The literature reports a number of factors (both human and environmental) that have been found to impede an autonomous bus’s progress along its route.

In terms of meteorological conditions, for example, several projects have reported the problems caused by heavy rain, sleet, or snow, which the vehicles’ lasers and sensors have identified as obstacles, resulting in the vehicle stopping periodically (e.g., Rutanen and Arffman, 2017, p.18; Zankl and Rehrl, 2018, p.39; Bellone *et al.*, 2020, p.11; Brown, 2020; Soe and Müür, 2020, p.15). Snow that obscures lane markings (Ainsalu *et al.*, 2018, p.18), or which has been ‘banked’ at the roadside by a snow plough (Rutanen and Arffman, 2017, p.12) can also interfere with the vehicle’s navigation. Fog, too, can result in the images generated by a vehicle’s sensors being “low contrast and blurred” (Bellone *et al.*, 2020, p.11). In complete contrast, when the weather is sunny, reflections of light from street furniture have been known to interfere with a vehicle’s sensors (McDonald *et al.*, 2018, p.118). With electric vehicles, extreme temperatures (both high and low) can also impact upon a bus service, because the use of heating or air conditioning will increase the vehicle’s power consumption and reduce the vehicle’s daily operational hours (Soe and Müür, 2020, p.15). In damp weather, a small shuttle vehicle’s ventilation system may not be sufficient to prevent the windscreens steaming up on the inside, resulting in poor visibility for the safety operator (Zankl and Rehrl, 2018, p.39). Meanwhile, in windy conditions, vegetation, sand, dust, and other roadside detritus may be blown in front of the sensors, again affecting the vehicle’s performance (Rutanen and Arffman, 2017, p.11; Shladover *et al.*, 2018, p.302; Soe and Müür, 2020, p.15).

The natural world can provide other obstacles to shuttle vehicles. Falling autumnal leaves can interfere with a bus's navigation (Ainsalu *et al.*, 2018, p.20; Bellone *et al.*, 2020, p.16; Soe and Müür, 2020, p.15), as can overhanging tree branches (Mills & Reeve, 2019; Soe and Müür, 2020, p.15). Birds or animals (such as squirrels) passing in front of a shuttle can also bring the vehicle to a halt (Soe and Müür, 2020, p.11); while the University of Salford's vehicle has been impeded by a bird perching on its rooftop antenna (Urban Transport Group, 2020, p.9).

In terms of human behaviour, the progress of the vehicle may be interrupted by the (sometimes deliberate) actions of any nearby pedestrians. For example, in some of the CityMobil2 trials, there were instances of pedestrians (mostly older children and teenagers) "testing" the vehicle's capacity to stop by jumping in front of the shuttle; or, in the case of more hesitant individuals, "sticking a leg out" in front of the vehicle (Madigan *et al.*, 2019, p.207). However, such "low-risk stunts" were found to dissipate after the first few days of operation, as curiosity began to fade and the vehicles became accepted as part of the local environment (McDonald *et al.*, 2018, p.168). At the University of Salford, meanwhile, the many students moving around the campus created unforeseen problems for its Navya shuttle:

> "...students realised that if they walk in front of the AV it will stop, so they effectively pay little attention to the vehicle and cross directly in front of it to get where they're going. While frustrating, this has highlighted some of the behavioural psychology challenges facing CAVs as they are introduced to our roads." (Brown, 2020)

n) Evaluate operation of pilot service

An important part of the overall process will be the *ex post* evaluation of the pilot project (Turnbull *et al.*, 2020). In the publicly available literature, these evaluative exercises have tended to examine one or more of four broad aspects of autonomous bus trials:

Vehicle and system performance. In which metrics such as the number of miles travelled by the vehicle(s), the average speeds attained, the number of operational hours, and the number of obstacles, incidents and critical events identified by the vehicle's sensors are quantified and analysed. Much of this data will be recorded automatically by the ADS. However, additional, more qualitative data might also be collected by the onboard safety operator or by other trial staff. In the CityMobil2 trials, for example, the onboard "grooms" were equipped with tablets on which they recorded additional details of incidents that caused the vehicle to brake or stop, or events (such as door malfunctions) not recorded by the ADS. The CityMobil2 grooms also used these tablets to record the number of passengers using the trial services (McDonald *et al.*, 2018, pp.97-98).

User attitudes. The largest body of evaluative literature has grown around the study of passengers' experiences of travelling on autonomous buses. Typically, these studies have been based on post-journey surveys of, or interviews with, passengers (e.g., Christie *et al.*, 2016; Nordhoff *et al.*, 2019; Salonen and Haavisto, 2019; Hilgarter and Granig, 2020; Wicki and Bernauer, 2020). These surveys and interviews have explored, for example: the perceived speed, comfort, reliability, safety and usefulness of the journey they had just experienced; comparisons with other forms of transport; potential uses for autonomous buses within their local communities; their willingness to pay for such a service (journeys during trials have usually been free); and general attitudes towards driverless vehicles. In the UK, such user studies have formed part of both the GATEway (Fernández-Medina and Jenkins, 2017) and Capri (Paddeu *et al.*, 2020) projects. Occasionally, observational techniques have also been used, to study passengers' behaviour and activities when travelling on an autonomous vehicle (Eden *et al.*, 2017; McDonald *et al.*, 2018, p.98).

Other road users' behaviour. In some cases, the impact of shuttle bus trials on the behaviour and perceptions of other road users has also been explored. For example Merat *et al.* (2018) questioned pedestrians and cyclists in La Rochelle, Lausanne and Trikala, focussing on how safe they felt when sharing space with the CityMobil2 shuttles. While Madigan *et al.* (2019) analysed 3D video footage that was captured by cameras onboard some of the shuttles in La Rochelle and Trikala. Here, they explored how pedestrians, cyclists and motorists interacted with the autonomous vehicles in shared spaces.

Economic and financial implications. The evaluation framework for the CityMobil2 project also included an assessment of the economic and financial implications of the full-scale deployment of autonomous shuttle bus services, in the seven European cities in which trials were conducted. Each city conducted a cost-benefit analysis, based on one or more "practical scenarios" for autonomous bus deployment, and using a standardised set of indicators (McDonald *et al.*, 2018, p.92 & pp.105-6). However, details of these analyses are scarce. This can perhaps be explained by the comments of the project's advisory panel, who concluded:

> "It is unrealistic to expect to see measurable socio-economic impacts from demonstrations of the scale that were possible within the CityMobil2 schedule and budget, but... more could have been done to assess their likely scale. This remains an area where further work is needed." (Shladover *et al.*, 2018, p.305)

This is an aspect that has recently been looked at in some detail, as part of the CCAV-funded Capri project. Informed by stakeholder workshops (but not by Capri trial participants), AECOM conducted business case analyses of three potential shuttle bus deployment scenarios in the west of England: 1) transferring passengers between Bristol Airport's car parks and its main terminal; 2) shuttling students between Exeter University's Streatham Campus and Exeter St David's Railway Station; and 3) introducing a service that would operate in the Temple Quarter Enterprise Zone in Bristol city centre (Squires, 2020). Meanwhile, Connected Economics (2020) conducted an economic assessment of the opportunities to deploy autonomous buses in the west of England. They highlighted three locations that might offer viable business cases in the near-term: 1) Bristol Waterfront; 2) the University of Bristol's main campus at Clifton; and 3) the University of the West of England's main campus at Frenchay in South Gloucestershire. The Connected Economics report appears to have been compiled using desk-based research only: there is no obvious relationship between the economic assessments and the Capri trials held at the QEOP and the Cribbs Causeway shopping mall. Although, in their commentary on the Connected Economics report, the Capri consortium note that they "received substantial public interest and approval during pod trials, and almost no negative responses" (Connected Economics, 2020, p.4).

o) Review and update safety case as required

As was noted in **Step g**, the safety case should remain a live document throughout the duration of the trial. As such, it should reflect any amendments that are made following, for example: a change of route; changes to the vehicle's hardware or software; incidents or near misses; or any other lessons learned during the trial. These edits should be logged systematically, ensuring that an audit trail is maintained.

4. Potential processes when introducing permanent, post-trial, autonomous bus services in West Yorkshire

This report has so far discussed the regulatory and other processes involved in conducting autonomous bus service *trials* in West Yorkshire. If such trials were to be successful, then the WYCA and its constituent authorities may then wish to provide these services on a more permanent basis. This section of the report considers the *potential* processes that may be involved in introducing more permanent autonomous bus services in the region. It considers two broad aspects: 1) the approval and authorisation of the vehicle and its ADS; and 2) the licensing and the regulation of the passenger service operator.

As a UK regulatory framework for autonomous bus services does not yet exist, this section is very much based on the recommendations made by the Law Commissions in their final report (2022). As the UK, Scottish and Welsh Governments have yet to decide which of the Law Commissions' recommendations are to be accepted, and what legislation will be introduced to bring them into effect, the contents of this section should be treated with some caution.

Vehicle and ADS Approval and Authorisation

As is the case currently, the onus for seeking autonomous vehicle approval in the future is likely to be with the manufacturer/developer. Here, the Law Commissions (2022, Chapter 5) have proposed a new legal actor, the **Authorised Self-Driving Entity (ASDE)**. The ASDE will be the entity that puts a CAV forward for approval and authorisation. It may be the vehicle manufacturer, or a software designer, or a joint venture between the two. It must demonstrate that it was closely involved in assessing the safety of the vehicle, and it must also have sufficient funds to respond to any regulatory actions and to organise a recall. The ASDE will be responsible for vehicles that are driving themselves on GB roads, and must be able to assure the vehicle's continued safety and adherence to road rules throughout its lifetime.

The Law Commissions have proposed that the process be a two-stage one (see Figure 17). First, it must obtain whole vehicle approval, via the aforementioned Full GB Type Approval Scheme, expected in July 2023. However, the Law Commissions' have recommended that manufacturers who wish to include an ADS in their vehicles should have a choice: they could obtain *systems* type approval at the international (UNECE)[25] level; or they could apply under a proposed new Domestic AV Technical Approval Scheme. In either case, the whole vehicle will need to receive the GB Type Approval.

Before a vehicle can be regarded as self-driving, it will then undergo a separate 'authorisation' stage, where the authorisation authority (the Law Commissions envisage that the VCA will acquire this role) will assess each of the vehicle's ADS features, and state whether each feature is authorised for use with or without a 'user-in-charge' (see below).

[25] UNECE stands for the United Nations Economic Commission for Europe. It is a UN body which administers an international agreement governing the approval of motor vehicles in 56 countries. See https://unece.org/transport/vehicle-regulations

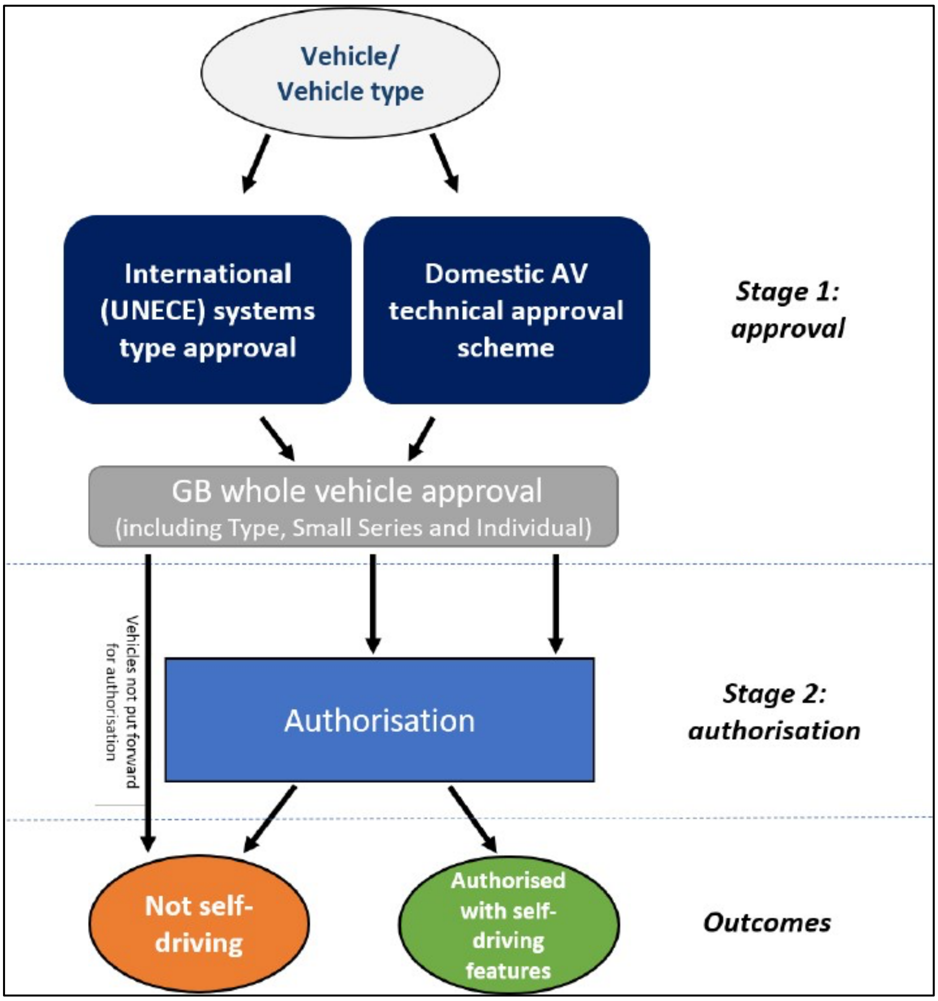

Figure 17: The Law Commissions' proposed two-stage approval and authorisation process
(Law Commissions, 2022, p.70)

Licensing and regulation of autonomous bus services
Before considering the potential regulatory situation for autonomous bus services in West Yorkshire, two other new legal actors, proposed by the Law Commissions, should be discussed: the User-in-Charge; and the No User-in-Charge (NUIC) Operator.

> **User-in-Charge.** The concept of a user-in-charge applies where a vehicle is authorised as having a self-driving ADS feature that requires a user-in-charge, who may be called upon to take over driving if the ADS issues a transition demand. The user-in-charge would be an individual 'human' (rather than an organisation), would be *onboard* the vehicle (not standing nearby or in a remote operations centre), and would be in a position to operate the driving controls if and when necessary (for current vehicle design, this would be in the driving seat). The user-in-charge will have to be qualified and fit to drive, and when responding to a transition demand would be subject to all of the ordinary responsibilities of a driver.

> **No User-in-Charge (NUIC) Operator.** In contrast, some ADS features will be authorised for use without a user-in-charge. Here, the Law Commissions have recommended that the vehicle is overseen by a licensed NUIC operator. This will be an organisation rather than an individual. The NUIC operator will be required to have "oversight" of the vehicle. This does not mean that they need to monitor the driving environment. Rather, they will be expected to respond to alerts from the

vehicle if it encounters a problem it cannot deal with, or if it breaks down or is involved in a collision. The Law Commissions anticipate that, in the great majority of cases, a NUIC operator will employ staff in a remote operations centre. To obtain a licence, a NUIC operator will need to show that it is of good repute, has appropriate financial standing, conducts its operation within Great Britain, and is professionally competent to run the service. It will then have to submit a safety case to show how it will operate vehicles safely without a user-in-charge or driver. The NUIC operator and the ASDE may be the same organisation, or completely separate entities. The Law Commissions anticipate that NUIC licences will be granted by the authorisation authority (i.e. the VCA), but that the legislation would be sufficiently flexible for another agency to take on the task.

In their second consultation paper, the Law Commissions (2019, Chapter 8) set out the current system of bus service regulation in England (outside London). This is illustrated at Figure 18. As can be seen, all prospective operators of a local bus service (excluding Section 19 and Section 22 permit holders[26]) must hold a Public Service Vehicle (PSV) operator's licence, which is issued by the Traffic Commissioners for Great Britain (see also Vehicle & Operator Services Agency, 2011). As has already been noted, West Yorkshire is administered by the Traffic Commissioners' North east of England office, based in Leeds.

To run a local bus service, operators must inform the relevant local authority 28 days before applying to the Traffic Commissioners; and must then apply to the Traffic Commissioners at least 42 days before the service starts. On receiving authorisation to proceed with the service, the operator must ensure that the vehicles are insured, and that any reasonable physical adjustments have been made to the vehicle, to meet the additional needs of passengers with a disability.

In considering future regulation and legislation, the Law Commissions (2022, p.164) argue that, because the current law is predicated on having a responsible person in the vehicle, "no fundamental shift" is required to accommodate autonomous passenger services that will have a user-in-charge. They contend that:

> "…the legislation continues to fulfil its purpose. There is still a person in the vehicle who is legally responsible for issues such as roadworthiness and insurance and who can move the vehicle if it comes to a halt inappropriately."

They suggest that any necessary legislative amendments could be made using general provisions, stating that a user-in-charge would be considered as a driver for the purposes of the passenger service legislation.

However, for future NUIC passenger services, where there will be no individual 'in charge', onboard the vehicle, the Law Commissions indicate that the applicability of current law is "uncertain" (2022, p.194). They argue that there is much that is not known about how to safeguard passengers from assaults, abuse, and harassment by others using the service; or how to provide accessible services for older and disabled passengers. They suggest that it is "premature" to establish a permanent regulatory scheme for NUIC passenger services, beyond what they describe as "Tier 1" safety obligations (e.g., insuring and maintaining vehicles, and installing safety-critical software updates).

[26] A Section 19 permit provides an exemption from PSV operator licensing to bodies that benefit the community, such as religious organisations, social welfare groups and non-profit making schools that operate buses for their pupils. Section 19 permits cannot be used to make a profit or to carry members of the general public. Section 22 permits can be granted to not-for-profit organisations, and are designed for community bus services carrying fare-paying members of the general public.

Operators require a PSV operator's licence from the Traffic Commissoners for GB, as per:-

- Public Passenger Vehicles Act 1981
- Transport Act 1985, and Transport Act 1985 (Amendment) Regulations 2019 (for Section 19 or Section 22 permit exemptions)

Operators must inform the relevant local authority that they are starting a service, 28 days before applying to the Traffic Commissioners, as per:-

- Bus Services Act 2017

Operators must then apply to the Traffic Commissioners at least 42 days before the service starts, as per:-

- Transport Act 1985
- Public Service Vehicles (Registration of Local Services) Regulations 1986, as amended by the Public Service Vehicles (Registration of Local Services) (Amendment) (England and Wales) Regulations 2004

All services must consider making "reasonable adjustments" for disabled users, as per:- Equality Act 2010

PSVs for >22 passengers must also consider accessibility, as per:- Public Service Vehicles Accessibility Regulations 2000

Vehicle and any ADS must be insured, as per:-

- Road Traffic Act 1988, part VI
- Automated and Electric Vehicles Act (2018)

Figure 18: Current steps in local bus service regulation in England, outside London
(Based on Law Commissions, 2019, Chapter 8)

They therefore recommend a new procedure, to issue **"interim passenger permits"**. This would allow initial passenger services to be provided in order to collect "real world" evidence about how best to meet these challenges, before designing a permanent regulatory scheme. Figure 19 provides an overview of the requirements for such a permit, as proposed by the Law Commissions. They recommend that the Secretary of State for Transport should have powers to grant interim permits to providers of NUIC passenger services in England. To ensure that accessibility is "entrenched" into NUIC passenger services, they have also recommended that a new statutory accessibility advisory panel be established. This panel would critically assess each permit application. Each year, the permit holder will be required to publish a report on the operation of the service, highlighting how it has safeguarded passengers and met the needs of older and disabled passengers (Law Commissions, 2022, p.200).

Furthermore, for a "bus-like service"[27] the Law Commissions recommend that the operator consult with the local transport authority, the relevant highway or road authorities, and the emergency services. In areas with a franchised bus network (this does not currently apply to West Yorkshire), the local transport authority would also need to give its consent to the issue of a permit. The Law Commissions recommend that an interim passenger permit be of a specified duration, suggesting a maximum of three years (p.199).

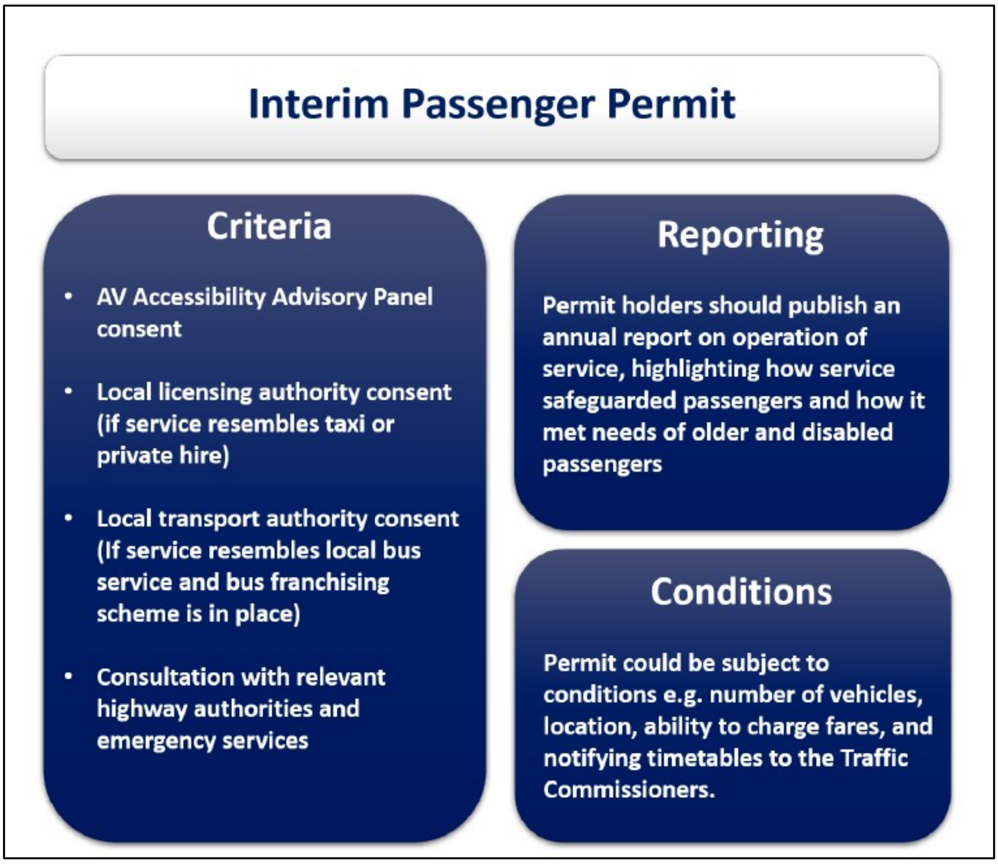

Figure 19: Overview of the Law Commissions' proposed requirements for an Interim Passenger Permit (Law Commissions, 2022, p.203)

Overall, then, it is likely that the future regulatory path for bus service provision will depend very much on whether the proposed service(s) will have an onboard user-in-charge, or will be monitored remotely.

[27] The Law Commissions (2022, p.202) define this as a service which "can transport more then eight passengers at a time; charges separate fares; allows passengers to alight within 15 miles; and which does not fall within an existing exemption".

5. Conclusions

This report has discussed the laws, regulations, and land use and spatial planning issues to be considered, should the West Yorkshire Combined Authority (WYCA) wish to introduce autonomous bus services to the region. It is designed to complement the modelling work currently being conducted by colleagues at the RGU School of Computing. It has been based on two assumptions: 1) that the WYCA will initially wish to become involved in autonomous passenger vehicle trials; and 2) that these trials (and any subsequent permanent services) will be based upon the use of vehicles that have a larger passenger capacity and/or are capable of faster speeds than the small autonomous shuttle bus vehicles used in most UK and European trials to date.

Based on an extensive literature review, as well as interviews and personal correspondence with individuals currently involved in AV trials in the UK, the report has discussed a series of 15 interrelated steps that should be followed, when planning and implementing an autonomous bus trial (see the flow chart on page 10). The 15 steps do not follow a precise chronological order, as many of them will require to be conducted simultaneously, and may require revision as the pilot project progresses. They have, however, been presented in four broad chronological groupings or phases.

In **Phase 1**, the potential introduction of autonomous bus services in West Yorkshire has been considered in relation to regional, local and organisational priorities and policies. Particular attention was paid to the area of north and north-west Leeds, on which RGU's modelling work has so far focused. While transport and planning policy documents have rarely made explicit reference to *autonomous* transport, they do highlight a need for better-connected and more sustainable public transport options across north Leeds. It might be argued, then, that the introduction of autonomous bus services would be closely aligned with regional and local strategies.

In **Phase 2**, the more administrative preparatory steps to be undertaken have been discussed. These include the need to: identify potential routes, and establish the ownership of the relevant roads and land; identify the type of vehicle that might be deployed; engage with the targeted passenger communities and any other relevant stakeholders; obtain permission or approval to conduct the trial from the CCAV and from other relevant public authorities and landowners; obtain appropriate insurance; and begin to develop the safety case for the trial. Here, it was argued that the more conventional specifications of vehicles such as the Aurrigo Shuttle and the Alexander Dennis Enviro200 bus align more readily with current regulatory requirements.

Phase 3 will consist of the more practical preparatory stages of the trial. In collaboration with the vehicle vendor, the prescribed route will have to be surveyed and mapped in detail, and the vehicle's ADS programmed to navigate its way along the route. Any additional infrastructure or equipment required (such as bus stops, temporary traffic lights, signage, or barriers and bollards) will have to be identified and acquired; and (where applicable) permission to install these will have to be sought from the relevant local authority (most probably Leeds City Council). A training programme for the onboard safety operator(s) and any other staff will also have to be delivered. And work on the safety case must continue, with an abridged version of the final safety case being sent to the CCAV *and* being made publicly available.

The final phase, **Phase 4**, will be the day-to-day operational phase of the autonomous bus trial. As has been discussed in this report, a range of human and environmental factors might affect the autonomous bus's progress along the prescribed route: from rain and snow, to falling leaves; and from bird and animal life, to mischievous teenagers. Should any major infrastructural changes occur along the route during the trial, then the vehicle's mapping and programming processes may have to be reviewed. The safety case may also require revision during the operational phase. Finally, the trial service should be evaluated. As a minimum, this evaluation should consider the overall performance of the vehicle and its ADS, and also passengers' perceptions of the service. More extensive evaluation might look at the perceptions and behaviour of other road users. The project team might also want to consider conducting cost-benefit analyses, that explore the potential for autonomous bus trials in north and north-West Leeds to become long-term, financially sustainable services.

In addition to discussing the numerous issues that need to be considered before an autonomous bus trial can be undertaken 'on the ground' in West Yorkshire, this report has explored the longer-term regulatory requirements for the introduction of post-trial autonomous bus services in the region. Here, the report has drawn primarily on the Law Commissions' (2022) recommendations to the UK, Scottish and Welsh Governments. A key factor will be whether or not the autonomous buses have a user-in-charge onboard throughout the journey. If a user-in-charge is onboard, the Law Commissions believe that no fundamental changes to existing bus legislation will be required. However, for No User-in-Charge (NUIC) services, a new licensing system has been proposed. Until more is known about how passenger services will operate in the absence of a driver, the Law Commissions have recommended that an interim passenger permit scheme be introduced in the UK.

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