Shared Connected and Autonomous Vehicles

Opportunities for West Yorkshire

September 2022

Introduction

Connected and autonomous vehicles (CAVs) use technology that enables the vehicle to assist with driving and allows communication with other vehicles on the road. CAVs could reduce traffic accidents, improve efficiency of transport systems while fundamentally changing travel behaviours.

- **Connected vehicle** – communicates with other vehicles nearby and/or pedestrians
- **Automated vehicle** – use technology for some (or all) driving task and operates in isolation from other vehicles using sensors onboard

The level of autonomy is on a spectrum, with no automation and driver assistance at one end, and full automation at the other as illustrated in the table below:

Level 0	**No Automation** The driver performs all driving task
Level 1	**Driver Assistance** Vehicle can assist with minor, singular tasks (e.g. cruise control)
Level 2	**Partial Automation** Vehicle can perform steering and acceleration.
Level 3	**Conditional Automation** Vehicle can perform most tasks, but driver intervention required
Level 4	**High Automation** Vehicle can perform all tasks, but driver intervention required in some circumstances
Level 5	**Full Automation** Vehicle can perform all tasks with no driver interaction required

Although CAV technology can be applied to both private and shared vehicles, this report considered the opportunities for shared CAVs in West Yorkshire only, which principally related to small to medium multiple occupancy vehicles. The use of CAV technology in these instances could have a number of potential benefits, including:

- The use of CAVs for public transport services could improve efficiency of transport systems through smart routing and driving efficiencies, reducing the cost of services and reduced environmental impact.
- The use of these technologies could improve road safety and reduce traffic accidents.
- CAVs are likely to have an impact on travel demand and congestion thanks to smarter route choices. It is anticipated that if properly managed, CAVs could reduce traffic flow and increase junction capacity.
- CAVs could contribute towards public health and environmental improvements due to reduced energy consumption / increased fuel efficiency, lowering emissions and supporting net zero ambitions.
- Some CAV services could offer lower deployment costs when compared with light rail alternatives, and lower operational costs when compared with classical buses, presenting possible alternatives suitable for deployment on routes where expected passenger volumes are too low to be economically viable.

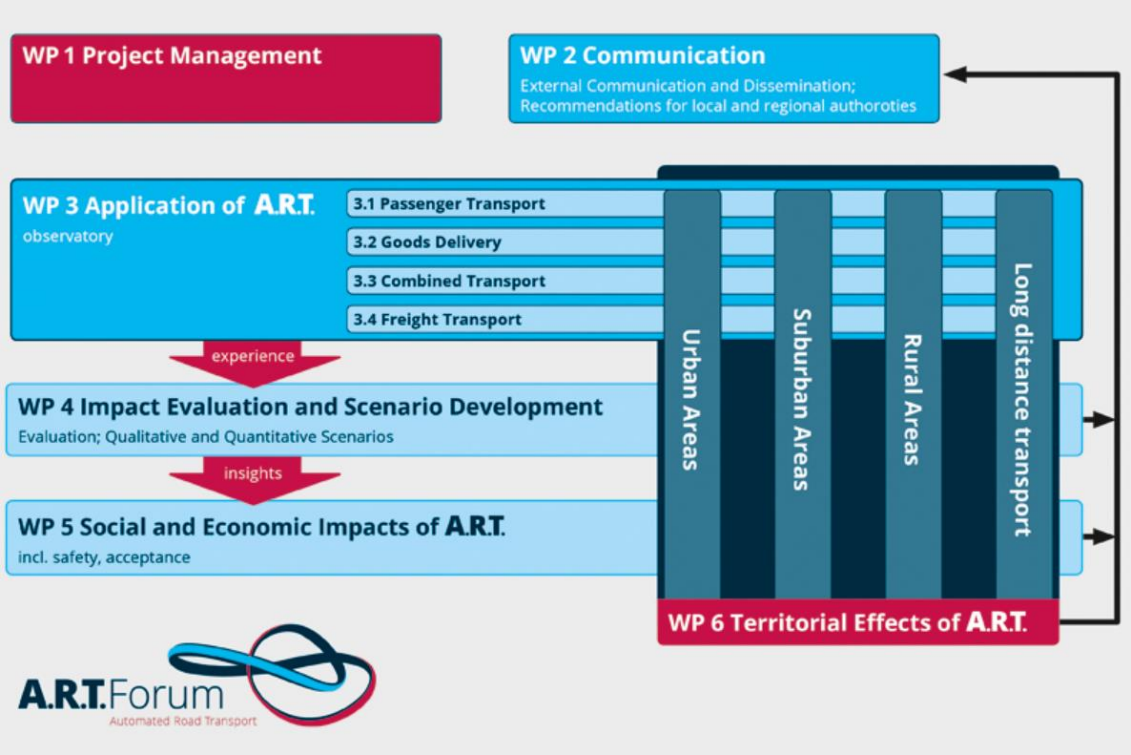
ART-Forum Interreg Project

ART-Forum (Automated Road Transport Forum) is an Interreg North Sea Region Project which considers the impact that automated transport could have on the entire road transport system and life in cities and regions. This is a three-year project between 2019 and 2022 with 14 partners from local authorities, technology and service providers, and academics from 5 different countries from the North Sea Region, namely Belgium, Denmark, Germany, Norway, and the UK.

Objectives include:

- Raise awareness and build capacity among stakeholders
- Develop policy recommendations that enable authorities to take advantage of opportunities to support strategic goals
- Support sustainable transport and territorial development goals as well as improve quality of life in communities
- Facilitate exchange between technological developers, academia and policy makers

The diagram below sets out the six work packages of the project:



West Yorkshire ART-Forum Project

West Yorkshire Combined Authority partnered with two universities to investigate the following research questions, design to align with our wider strategic priorities:

1. Can CAVs help to support inclusive growth, improve connectivity, and reduce carbon emissions?
2. Could autonomous public transport support accessibility and increase access to jobs?
3. Can these technologies increase public transport demand and deliver service improvements?
4. What is needed to deliver a service and what might the impact be on the road network?

Over the three years of the project, these questions were explored in the context of our wider work programmes, including bus service improvements, mass transit, and the Connectivity Strategy.

West Yorkshire Research

German Aerospace Centre (DLR)

Impact of CAV on-demand service using segregated bus lanes

Researchers at the Institute of Transportation Systems at DLR university worked with CA and Leeds City Council to model scenarios along the A65 in Leeds to analyse the impact of CAV on-demand services when using segregated bus lanes. The A65 was selected as an area with existing bus lane provision and existing traffic flow challenges.

The project considered the following question:

Can connected automated vehicles in an on-demand service improve traffic flow and provide quality of life benefits?

The research team used a simulation tool called Simulation of Urban Mobility (SUMO) to test five hypotheses set out below, with the summary findings described beneath each. The model used an on-demand service using six vehicles that picked up at bus stops and were able to pool rides.

1. **Increased vehicle occupancy by DRT should reduce congestion and travel time**

   The modelling found that increased vehicle occupancy resulted in shorter travel times by up to 15% during peak hours but minimal impact during off-peak hours.

2. **Accessibility can be improved compared to conventional public transport**

   Accessibility to public transport was improved using a DRT service as all bus stops could function as possible pick-up points, but accessibility varies depending on input parameters such as number of DRT vehicles, number of pick-up points, matching algorithm of services / ride pooling, detour factors, DRT vehicle size.

3. **CAV-based DRT will decrease vehicle kilometers and reduce emissions**

   Modelling found that decreased vehicle kilometers could be achieved with such services if ride pooling is used effectively – scenarios found that by using all 6 seats, total miles driven can be decreased by 58%.

4. **CAV will decrease the number of vehicles and save parking space**

   If CAV DRT services are maximized, modelling suggests a reduction of 289 vehicles, leading to approx. 3,323 m² that could be used for purposes other than car parking.

5. **Using existing bus lanes leads to further reduction of congestion and journey times**

   The model found no significant difference on congestion and journey time by enabling DRT vehicles to use bus lanes.

Conclusions

The research team found that automated road transport could offer new opportunities and benefits for transport networks, however most benefits were acquired by combining automated road transport with intelligent mobility concepts, e.g. demand-responsive public transport, smart journey planning / ride pooling. They also found that further exploration is needed with regards to the effects of reduced travel time and impact on behaviour change and modal split.

Robert Gordon University projects

Service Benefits and Route Optimisation of Autonomous Public Transport

Researchers from the School of Computing at Robert Gordon University undertook a study looking at potential service benefits and route optimisation considerations for autonomous public transport. In partnership with the CA and Leeds City Council, the project modelled the public transport network in Leeds to analyse the influence of introducing connected and autonomous vehicles into existing transport network.

The project considered two key questions:

1. **Can the introduction of CAV services linking residential areas to core bus routes and local hubs improve accessibility to promote a modal shift away from private car use?**

   Researchers developed a model to assess public transport accessibility in north-west Leeds to investigate this question in a live setting. The model considered the existing public transport network alongside scenarios introducing new CAV shuttle services linking residential areas to key public transport corridors. Scenarios for a new shuttle service reviewed various routes and vehicle numbers to assess the effect on journey times at peak times into Leeds City Centre. Bus route planners at the CA were tasked with the same challenge in isolation, with the results contrasted to explore the differences between human and automated routing algorithms. The automated approach showed some promise to provide bulk assessment of options prior to human refinement.

   Modelling highlighted notable public transport journey time improvements for residential areas away from core public transport corridors, which currently suffered from poorer public transport accessibility. The model used multi-objective optimisation to assess the number of vehicles required to deliver these benefits and found for services of this nature an optimum number of vehicles to maximise benefits (in this instance, eight vehicles).

2. **Can the introduction of CAV services improve accessibility to employment and education sites to promote a modal shift away from private car use?**

   Researchers developed a second model to test this question in an area of south Leeds between Stourton Park and Ride and Leeds rail station. The model assessed current journey times from the city centre to education and employment sites in this southern area of the city, alongside scenarios introducing new CAV shuttle services from Stourton Park and Ride as a transport hub. Both circular routes and targeted services were modelled, and the research found that the greatest journey times savings were achieved by introducing a series of targeted non-circular routes serving specific sites rather than the same number of vehicles on a circular route.

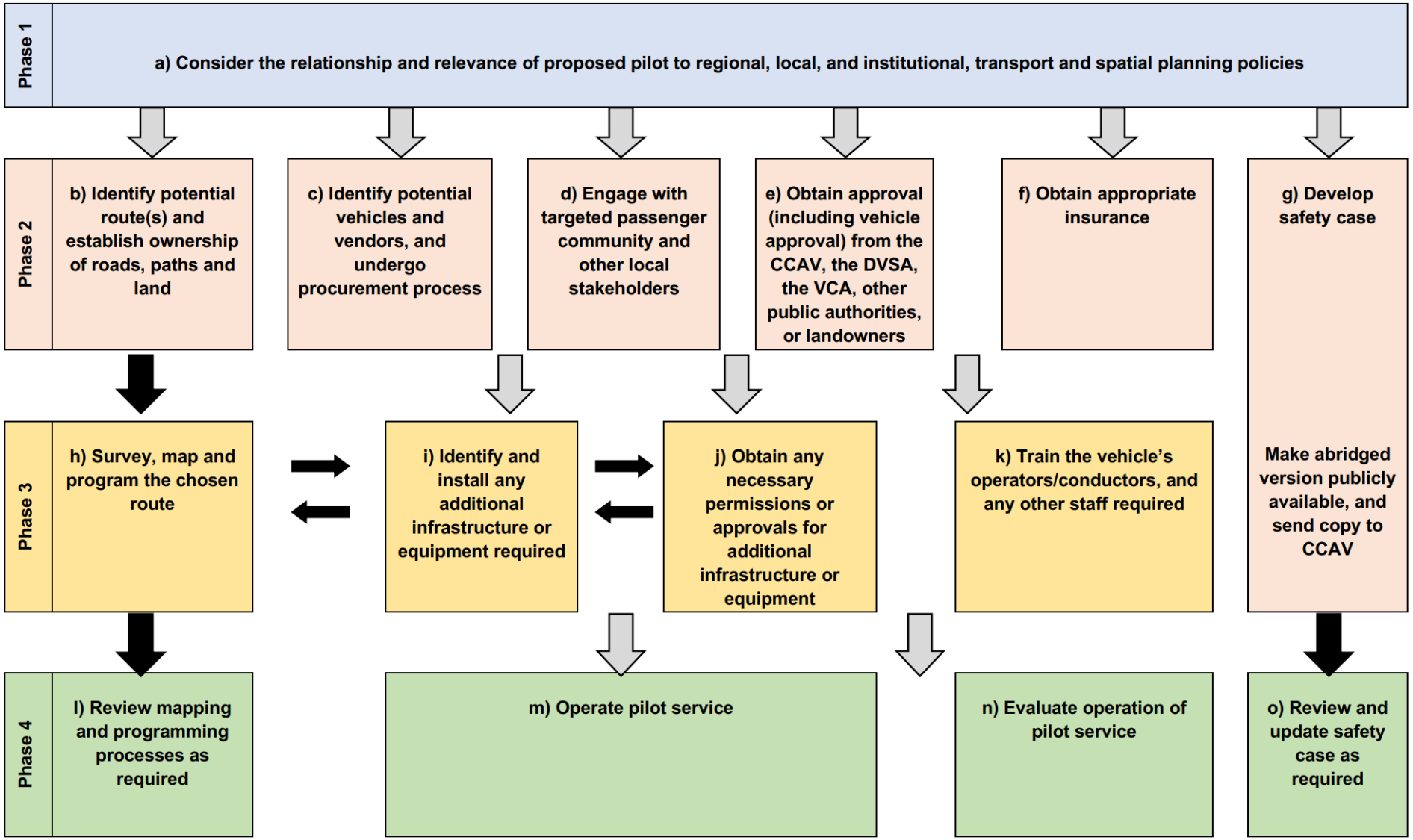
Roadmap: Introducing an autonomous bus service in West Yorkshire

Academics from the School of Creative and Cultural Business developed a roadmap for West Yorkshire on the steps needed to introduce an autonomous bus service in West Yorkshire, based on their research in the field and the work undertake to develop similar projects in Orkney, Scotland. The report discusses the laws, regulations, and land use and spatial planning issues to be considered, should the West Yorkshire Combined Authority wish to introduce autonomous bus services to the region. It is designed to complement the modelling work conducted by colleagues at the RGU School of Computing.

A flowchart has been developed for the introduction of autonomous buses, which presents a series of 15 interrelated steps 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’.

The work assumes that any 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. The report emphasizes that technology is advancing and that the document has been written at a time when there is considerable fluidity within the field of CAV planning, trialing, and regulation in the UK. Therefore, this roadmap is presented as the basis for design and delivery, to be amended to reflect latest law and policy positions and local funding requirements at the point a trial is being pursued.

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



West Yorkshire Combined Authority: Mass Transit

In 2019/20, the Combined Authority carried out a market testing exercise for advanced urban transit technologies which included information gathering on potential connected and autonomous solutions available and their potential for deployment in a West Yorkshire mass transit system. The exercise attracted strong interest within the industry, with around 120 organisations participating.

Key findings included:

- Transit technologies already exist for autonomous operations, but only in a fully segregated environment (for example, Docklands Light Railway) where there is no potential for conflicts / interactions with other types of vehicle or pedestrians. Current systems struggle to cope safely with mixed city traffic environments
- Respondents suggest that transit systems which require some interface with cars/pedestrians are likely to move towards greater autonomy (through provision of driver aids), but the vehicle will continue to require a driver over the next decade due to standards, safety and certification challenges. Legislation could change, but there remain challenges over acceptability.
- An area where autonomous operation was felt to offer practical benefits in tram-based systems was for depot-based movements, such as to maintenance / cleaning facilities and in stabling yards.
- Respondents also suggested that passengers value human interaction, so operators should consider having on-board staff, perhaps in a customer facing, non-safety critical role.
- Several technology and manufacturer contributors suggested that over the next decade, 5G technology offers an opportunity for the mass transit vehicle to be driven/controlled by a driver located in a control centre, rather than in the vehicle cab. This would potentially save on numbers of drivers required but there remain significant safety certification challenges which would need to be addressed.
- In autonomous vehicle systems, contributors advise that matters of cyber security will become prominent. Cyber-attacks and the use of social engineering is increasing, and these will need to be considered, especially in the design of safety critical systems.
- The increase in connected vehicles and Internet of Things devices will contribute to provide more data, more real-time data, and the increased ability to understand and manage transit systems in real time. In the context of these factors' contributors believe that it is vital that an urban transit scheme is planned for autonomous operation and importantly a wider connected transport network

West Yorkshire Combined Authority Workshops

To support research into opportunities for CAVs in West Yorkshire, several workshops have been held between 2019 and 2022.

Workshops 1 & 2: 2019/2020

Two workshops were held in December 2019 and February 2020 which were designed to inform the development of the West Yorkshire element of the ART-Forum project as well as the emerging Shared Transport Strategy. These sessions were used to workshop principles and policy recommendations for CAV locally, with the second session used to test and challenge policy and action recommendations. These workshops were attended by 28 attendees, with 10 representatives from 6 local authorities. Attendees at the sessions included representatives from all five West Yorkshire districts, transport consultants, car manufacturers, local universities and Department for Transport.

As a result of the workshops a series of recommended CAV actions were developed for consideration within shared transport strategy development. These actions are outlined in Table 1, together with the CA response to the ways in which these might be progressed.

Table 1 – Recommended actions and Combined Authority next steps

ID	Recommended action	CA next steps
Short Term: 0-2 years		
CAV1	Determine our goals and objectives for CAV within West Yorkshire and explore the potential for the technology to support our wider regional priorities to set our policy position.	Work to be progressed through the ART Forum Interreg project and in collaboration with district partners.
CAV2	Develop partnerships with academic institutions, manufacturers and bus operators to research and test policy objectives for CAVs, assess the potential impacts of technology and adoption scenarios on the transport network in the region and consider future infrastructure requirements to enable CAV development	Policy objectives for CAVs tested through the ART Forum project. Learning from the ART-Forum project will also help with understanding of future infrastructure needs to enable CAVs. Relationships with operators and manufacturers on CAVs still require some development.
CAV3	Explore opportunities for CAV technology to support the objectives the Connectivity Infrastructure Plan and advanced transit workstream	The Connectivity Infrastructure Plan and advanced transit workstreams are considering CAV technology.
Medium term: 2-5 years		
CAV4	Investigate opportunities for CAV trials in the region to test adoption scenarios, technology feasibility, and infrastructure and regulation requirements, with an emphasis on shared and public transport CAV technologies	Funding opportunities to enable CAV trials need to be identified. Opportunities and potential locations for trials will be explored through CAV working group with partner councils.
Long term: 5-10 years		
CAV5	Study impacts of growing private CAV adoption on transport network to inform future policy and investment decisions	The results of the ART Forum project will help to identify the impacts of CAV adoption on the transport network.
CAV6	Working with the regional and local planning agencies develop a regional CAVs and connected infrastructure plan	Engaging with regional and pan-northern partners to understand how a plan for CAV and connected infrastructure might be developed.

These recommendations were tested through a public consultation on the draft Future Mobility Strategy which was held August/September 2020. The feedback received from the public, industry, academics and our district partners has been used to refine and improve the recommended actions for CAV development in West Yorkshire.

Workshop 3: September 2022

A final workshop was held in September 2022 to present the findings of the Robert Gordon University and DLR University research projects and to discussion the implications of the work for transport policy development in West Yorkshire.

The workshop was attended by 18 attendees, including representatives from districts partners, our two university partners, and transport policy and transport services within the Combined Authority.

Based on the outcomes of the academic studies, four key areas were identified as areas of interest for further study:

- **Safety**: there was interest in the potential for connected and autonomous vehicle technologies to improve road safety in West Yorkshire, particularly in light of our Vision Zero ambitions. Measures such as speed controls were highlighted as areas of interest for the future.
- **Service efficiencies:** the potential efficiency benefits related to connected and smart technology for the bus fleet could help to reduce service costs, reduce prices and support emission reductions. Further model work in this area was highlighted as of interested.
- **Future proofing infrastructure:** the need to ensure new infrastructure meets the needs of advancing technology within the transport sector was highlighted as a priority, with a need for further work in this area to ensure projects we are delivering now do not become obsolete.
- **Public perceptions:** a greater understanding of public perceptions of shared CAVs and the impact on travel behaviour would be beneficial to understanding the potential longer-term benefits of the adoption of such technologies with the public transport offer.

West Yorkshire: Delivering against our goals

A review of interim work programme findings from ART-Forum project partners highlighted a range of possible benefits of CAV technology that could help to deliver about our goals in West Yorkshire:

- **Climate and Environment:** The use of connected and autonomous has the potential support our climate and environment goals by improving efficiency of transport systems through smart routing and driving efficiencies, reducing energy consumption and lowing emissions. The use of shared services could offer an attractive alternative to private car use, supporting modal shift to public transport, particularly if utilised as demand responsive services in areas of lower passenger volume. Trials through ART-Forum have focused on urban environments and further exploration into the environmental benefits of these services as well as rural services would be advantageous.
- **Inclusive Growth:** Introducing new shared CAV services could help to bolster our public transport network, improving connectivity and accessibility of employment, education and services. When used flexibly as demand responsive, services could provide lower operational cost alternatives to conventional bus services, supporting service efficiency benefits that allow greater coverage of services. It is anticipated that CAV services, if effectively managed, could reduce traffic flow and increase junction capacity, increasing journey times for all modes. Modelling work through ART-Forum has begun to explore these themes and several areas for further investigation.
- **Tackling Inequalities and Supporting Diversity:** Shared CAV services could contribute towards public health through smart routing, driving efficiencies, and customer appeal (modal shift), lowing emissions and helping to improve air quality. Shared CAV services could offer lower deployment costs when compared with light rail alternatives, and lower operational costs when compared with classical buses, presenting possible alternatives suitable for deployment on routes where expected passenger volumes are too low to be

economically viable. Technology costs, however, currently result in higher deployment costs but these are expected to reduce over time as technology developments. Trials of small shuttle services by other ART-Forum partners have highlighted possible use cases for older residents and those with mobility issues as a means of increased accessibility and reducing social isolation.

Policy Recommendations

The ART-Forum research in West Yorkshire and stakeholder engagement has been used to develop a series of policy recommendations for shared connected and autonomous vehicle technology in West Yorkshire and beyond. These have been explored with district partners through the workshops held and will look to be incorporated in policy and strategy development and work programmes going forward, as well as be made available to other local and combined authorities to support decision making on shared CAV services.

- **Safety benefits:** the improvements to road safety that connected and autonomous technologies could offer is of significant interest, particularly in light of Vision Zero ambitions. Measures such as speed controls, collision reduction mechanisms and vulnerable road user protection are all areas with potential significant benefit and would benefit from further study. However, there is a recognition that shared CAV services must not be introduced to the detriment to walking and cycling, particularly when considered in the context of limited road space availability and the need to prioritise active travel modes.
- **Improved connectivity:** research in West Yorkshire has highlighted potential benefits of utilising demand responsive shared CAV services to complement the existing public transport network. Such services can provide feeder services from areas with lower public transport access to core network, improving public transport journey times to employment, education and services, helping to reduce transport related social exclusion and support modal shift away from private car use. However, there is still some way to go until the technology and legislation (in the UK) allows these services to become commonplace. In the interim, exploring intelligent, connected demand response solutions may help to bridge the gap and offer many of the benefits of shared CAV services.
- **Service efficiencies:** research has suggested that potential efficiency benefits related to connected and smart technology for the bus fleet could help to reduce service costs, reduce prices and support emission reductions. Reducing the costs of operating public transport offers opportunities to improve provision and deliver new services for the benefit of residents and businesses. However, further modelling work in this area particularly in real world environments is required to fully understand the potential efficiencies that could be delivered.
- **Future proofing infrastructure:** the need to ensure new infrastructure meets the needs of advancing technology within the transport sector was highlighted as a priority in the West Yorkshire research. As CAV technology advances for both shared and private vehicles, there is great uncertainty as to the implications for the highway network and how these technologies may change travel practices with implications for the wider transport network. This includes questions as to the future need for 5G infrastructure, highway design, parking demand, and bus service models. There is a need for further work in this area to ensure infrastructure projects we are delivering now do not become obsolete as technology advances, and the possible negative ramifications of CAV use (e.g. increase of private car use, loss of active travel priority) are legislated against.
- **Travel behavior & public perceptions:** early user preference work has highlighted customer interest in shared CAV services, but such work is early in development and more exploration is needed into the impact that shared and private CAVs could have on travel behavior. A greater understanding of public perceptions of shared CAVs and the impact on travel behaviour would be beneficial to understanding the potential longer-term benefits of the adoption of such technologies with the public transport offer and help policy makers and transport planners design schemes going forward.

Find out more

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All information correct at time of writing